Simple Charts for Modifying Crop Coefficients to Local Conditions

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Abstract. The d*efault crop coefficient values used in FAO-56 were developed for sub-humid climatic conditions with an average daily wind speed of 4 ½ mph (2 m/s) and an average daily minimum humidity of 45%. However, coefficient values can be modified with mathematical procedures to compensate for differing climatic conditions. Not modifying default values to local climatic conditions could cause over- or under-irrigation to occur. This paper presents a simplified method to modify crop coefficient values using look-up tables for approximately 180 locales in the USA and its possessions and Algiers City, Algeria. The tables are based on long-term climatic data available from the NOAA. The coefficient value that deviates the most from FAO-56 default values is the* ***K-c_ini*** *value, which sometimes needs to be increased 200%. This deviation occurs when high numbers of rainfall/irrigation events occur. Since rainfall on two or more consecutive days is considered one rainfall "event", a mathematical estimate was developed to convert total number of days with >0.01 inch or more rainfall per month to the number of non-contiguous rainfall events.*

Keywords. Crop coefficients, irrigation scheduling, FAO-56.

Introduction

This paper is based on procedures to adjust the default crop coefficient (K_c) values that are provided in *FAO-56, Crop evapotranspiration - Guidelines for computing crop water requirements - FAO Irrigation and drainage paper 56* (Allen et al., 1998). Adjustment of K_c values allows one to modify default FAO-56 K_c values to allow them to more accurately conform to local climatological conditions.

Crop coefficient value (K_c) is used in the following way to predict water use:

$$ET_c = ET_o \times K_c \qquad \text{Eq. 1}$$

Where, ET_c is the water use of the crop in question (inches or mm)
ET_o is reference evapotranspiration (inches or mm)

The FAO-56 procedure is very Spartan in concept and involves just three K_c values to describe conditions for the entire growing season; these points are: $\mathbf{K_{c\_ini}}$, $\mathbf{K_{c\text{-}mid}}$, and $\mathbf{K_{c\text{-}end}}$. However, based on local climate conditions, these default values can be increased or decreased (referred to as VERTICAL adjustment). A curve is then constructed through the three points to encompass the whole growing season and is known as the *crop coefficient curve*. The horizontal placement of the $\mathbf{K_{c\_ini}}$, $\mathbf{K_{c\text{-}mid}}$, and $\mathbf{K_{c\text{-}end}}$ values is based on the length in days of four crop development periods: *Initial*, *Crop development, Mid-season*, and *Late-season*.[1] Figure 1 shows the four-period, three-coefficient approach of building a crop coefficient curve.

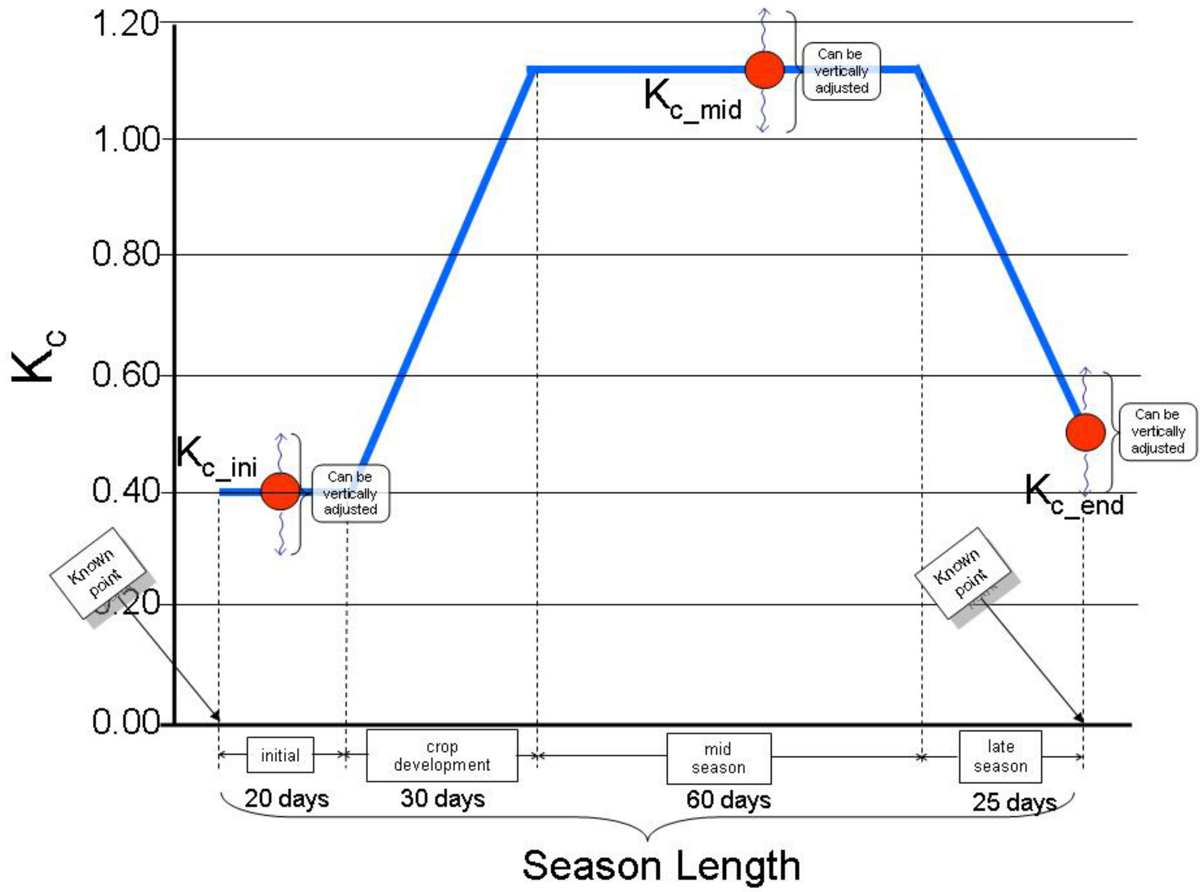


Figure 1 A constructed crop coefficient (Kc) curve for soybeans planted in central USA in May (after Allen et al., 1998). The three default Kc values can be modified to better meet local climatic conditions.

Crop Coefficients

The crop coefficient is the keystone to accurately predict crop water use from weather data. Crop water use, ET_c, is determined by adjusting the known value of ET_o with the proper crop coefficient value (K_c). Sometimes, $ET_c > ET_o$, which indicates that the crop in question uses

[1] Adjusting the amount of time for any of these periods results in HORIZONTAL adjustment, but is not the topic of this paper. However, it is an important consideration. For example, the Initial period goes from planting to 10% ground cover. It is obvious that soybeans planted in 38-inch rows in April and those drilled in rows 7 ½ wide in mid-June will reach 10% cover at greatly divergent times.

more water than does the reference crop, thus the crop coefficient >1.0. When $ET_c < ET_o$, the crop coefficient value < 1.0.

In consumptive use research the studied crop's rate of water use, ET_c, is empirically determined (through lysimeters, Bowen ratio equipment, neutron probes, etc.), after which crop coefficient values are then developed by rearranging Eq. 1 to the form of Eq. 2, which is valid for periods that have not received rainfall or irrigation.

$$K_c = ET_c \div ET_o \qquad \text{Eq. 2}$$

Over the growing season, crop coefficient values for a season start out low, increase as the canopy fills in, and then plateaus out until they begin to decline with the unsought of crop senescence. When plotted over the season, the changing crop coefficient values have the shape of an upside-down sauce pan. K_c values plotted over time are referred to as a crop coefficient curve or Kc curve. The actual day-to-day K_c values along the K_c curve exhibit much bounce as seen in Figure 2 (after Howell, 1998).

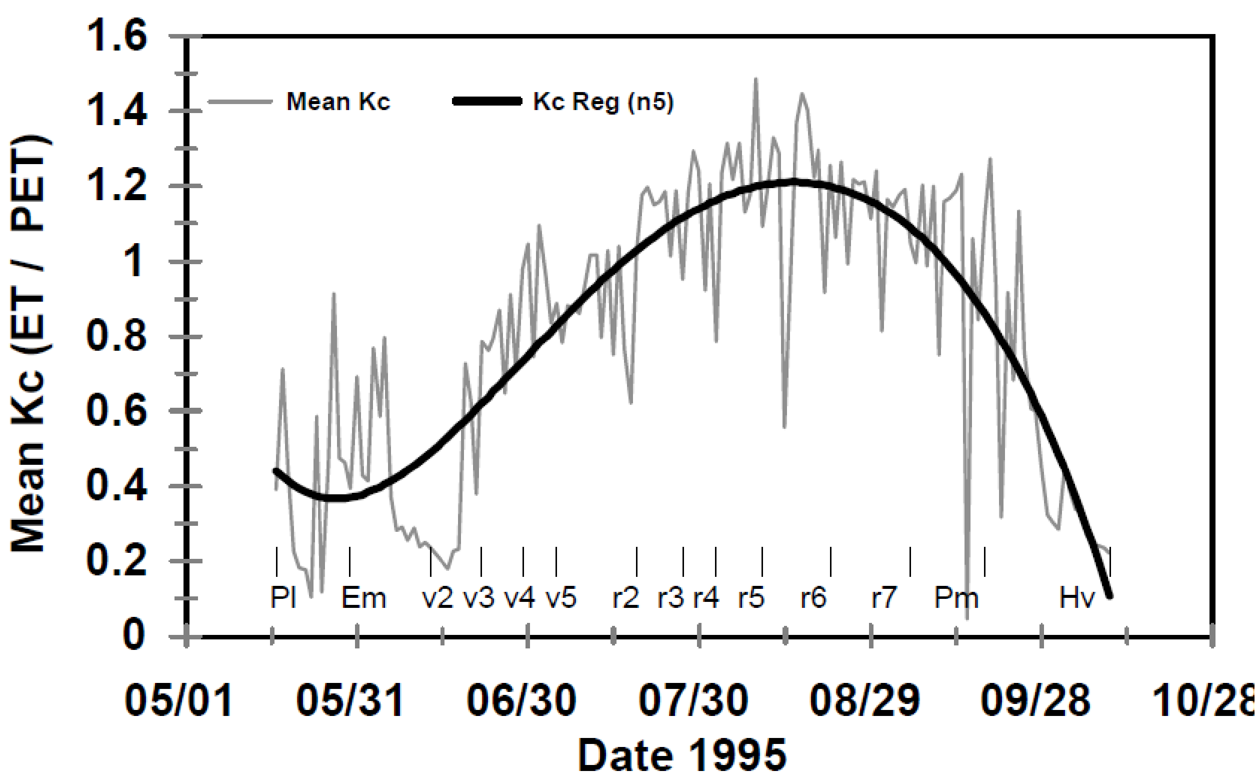


Figure 2 Actual crop coefficient values determined by a weighing lysimeters for soybeans and the best fit curve (i.e., crop coefficient curve) for the same data (after Howell, 1998).

Crop coefficients are of two types. The most commonly used one is the *single crop coefficient* (K_c). This coefficient is used when crop transpiration (T) and soil evaporation (E) are combined jointly. The *dual crop coefficient* (K_{cb} +K_e) is used when T and E are calculated separately; it is also referred to as the *basal crop coefficient*. The single crop coefficient value will be higher since it has to account for water loss through both T and E. The normal range of K_c values is from 0.30 to 1.20, whereas, the normal range of K_{cb} values is from 0.15 to 1.15.[2]

Modifying Default Crop Coefficient Values

Suggested values for both types of coefficients are provided in FAO-56. The mid- and end-season coefficient values (K_{c_mid} and K_{c_end}) were derived from locations having an average daily minimum Relative Humidity value of 45% and an average daily wind speed of 4 ½ mph (2 m/s). Additionally, crop height also influences values.

The initial crop coefficient value (K_{c_ini}) is influenced by ET_o, frequency between wetting events, and soil type/depth of wetting event. The initial crop coefficient values appear to be based on locales having an average early season daily ET_o of 0.15 inches (4 mm) per day and about a 10-day frequency between wetting events. Table 1 shows the various factors that influence adjustment for the three cardinal coefficient values for both types of crop coefficients.

Table 1. Factors used in adjusting crop coefficient values.

Type of coefficient	Period Coefficient		
	Kc_ini	Kc_mid	Kc_end
Single crop coefficient (K_c)	~ ETo ~ frequency of wetting ~ wetting depth ~ soil type	~ crop height ~ min. RH ~ wind ~ freq. of wetting (only if K_{c_mid} <1.0)	~ crop height ~ min. RH ~ wind ~ desired harvest conditions ~ don't adjust if K_{c_end} <0.45
Dual crop coefficient (K_{cb})	Does not require adjustment	~ crop height ~ min. RH ~ wind	~ crop height ~ min. RH ~ wind ~ desired harvest conditions

Modifying the Mid- and End-Season Crop Coefficient Values

Locales having weather parameters that differ from those used in FAO-56 can have their mid- and end-coefficient values adjusted using an equation from FAO-56 (Allen, et al., 1998):

$$K_{c\_Adj} = K_{c\_FAO-56} + \left[0.04(u_2 - 2) - 0.004(RH_{\min} - 45)\right]\left(\frac{h}{3}\right)^{0.3} \qquad \text{Eq. 3}$$

Where:

K_{c_Adj} is the adjusted mid- or end-season coefficient value
K_{c_FAO-56} is the FAO-56 mid- or end-season coefficient value

[2] These ranges for the crop coefficient values are time-period averaged since actual day-to-day swings in values occur for various reasons and will greatly exceed 1.20 (see Figure 2).

u_2 is mean value for daily wind speed at 2 m height during mid- or end-season period[3]
RH_{min} is mean value for daily minimum RH during mid- or end-season period
h is mean plant height during mid- or end-season period

Note that Eq. 3 produces a "tack-on" value that will be either added to (if positive) or subtracted from (if negative) to the default FAO-56 mid- or end-season crop coefficient value. This tack-on value is the *climate adjustment offset (*adj_{clim}*)*. Both wind speed and minimum relative humidity data are based on long-term averages.

Although Eq. 3 is straight forward, it may be difficult to obtain the needed long-term weather data to calculate the adj_{clim} offset value. To rectify this, the adj_{clim} offset values by month have been calculated for 177 cities in the USA and its possessions, plus Algiers City, Algeria (Table 2). The table includes the offset portion of Eq. 3 calculated using long-term climatic databases on monthly mean wind speed and afternoon relative humidity maintained by NOAA (USDC, 2009). Table 2 values are based on an average plant height of two feet. If the height of the crop in question differs from 2 feet then it needs to be adjusted. Table 2 includes an inset table with height adjustment factors (adj_h) that can be used to make the correct conversion (by: adj_{clim} x adj_h). An example of using this procedure to modify default FAO-56 mid- and end-crop coefficient values follows.

[3] If the local wind speed data is taken from an anemometer set at a height other then 2 m it should be modified (a simple equation is found in FAO-56).

Adjusting K_{c_mid} and K_{c_end} to Reflect Local Deviation from RH_{min} of 45% and Wind of 4 1/2 mph

Given:

Crop	=	sweet corn
Location	=	Fresno, CA
Planting date	=	Jan 15

Find:

Modified values for: K_{c_mid} and K_{c_end}

Procedure:

- Get default K_c values from FAO-56 ($K_{c\_FAO\text{-}56}$).
- Based on location/month find the climate adjustment factor (adj_{clim}) to be +/- to $K_{c\_FAO\text{-}56}$.
- Using inset table in Table 3to find height adjustment factor (adj_h) and multiply adj_{clim} by adj_h.
- Add this product to the original default value from FAO-56 ($K_{c\_FAO\text{-}56}$).

Results:

K_{c_mid} = 1.15 (FAO-56)
K_{c_end} = 1.05 (FAO-56)
K_{c_mid} : appears to occur April (FAO-56)
K_{c_end} : appears to occur May (FAO-56)
estimated height during mid period ≈ 5 ft
estimated height during end period ≈ 6 ft

$$\text{Modified } K_{c\_mid} = K_{c\_FAO\text{-}56} + (adj_{clim})\ (adj_h) = 1.15 + (0.06)\ (1.32) = 1.23$$

$$\text{Modified } K_{c\_end} = K_{c\_FAO\text{-}56} + (adj_{clim})\ (adj_h) = 1.05 + (0.09)\ (1.39) = 1.18$$

Table 2. Adjustment Factor to be Added to Default Mid and End Crop Coefficients of FAO-56 to Account for Wind Speed other then 2.0 m/s and RH_{min} other then 45% -- Based on Plant Height of 2.0 feet. (Adjust heights other than 2.0 feet by inset table [light blue] below).

Plant Height (ft)	0.5	1	2	3	4	5	6	7	8
Height Adjustment Factor (adj_h):	0.66	0.81	1.00	1.13	1.23	1.32	1.39	1.46	1.52

LOCATION	Wind Data * YRS	RH Data * YRS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
HUNTSVILLE, AL	39	39	-0.01	0.01	0.02	0.02	0.00	-0.02	-0.04	-0.04	-0.02	-0.01	-0.01	-0.01
MOBILE, AL	58	44	0.01	0.02	0.03	0.03	0.00	-0.01	-0.03	-0.03	-0.02	0.00	0.00	0.00
FAIRBANKS, AK	55	54	-0.08	-0.06	-0.01	0.03	0.05	0.04	0.01	-0.01	-0.01	-0.05	-0.08	-0.09
HOMER, AK	32	57	-0.04	-0.03	-0.01	0.00	0.00	-0.01	-0.03	-0.04	-0.03	-0.02	-0.03	-0.04
JUNEAU, AK	61	40	-0.04	-0.02	-0.01	0.01	0.01	0.00	-0.02	-0.03	-0.03	-0.02	-0.04	-0.04
PHOENIX, AZ	61	46	0.04	0.06	0.08	0.10	0.11	0.11	0.09	0.08	0.08	0.07	0.06	0.04
TUCSON, AZ	61	66	0.07	0.08	0.10	0.12	0.13	0.13	0.09	0.07	0.09	0.09	0.08	0.07
WINSLOW, AZ	46	29	0.03	0.08	0.11	0.14	0.14	0.14	0.10	0.08	0.08	0.08	0.06	0.02
YUMA, AZ	28	14	0.07	0.08	0.10	0.11	0.12	0.12	0.11	0.10	0.08	0.08	0.07	0.06
FORT SMITH, AR	61	42	-0.01	0.00	0.02	0.02	-0.01	-0.02	-0.02	-0.02	-0.02	-0.01	-0.01	-0.01
LITTLE ROCK, AR	64	42	-0.01	0.00	0.02	0.01	-0.01	-0.01	-0.02	-0.02	-0.02	-0.01	0.00	-0.01
BAKERSFIELD, CA	54	30	-0.04	0.00	0.02	0.06	0.08	0.09	0.09	0.08	0.06	0.04	-0.01	-0.03
FRESNO, CA	57	43	-0.05	-0.01	0.02	0.06	0.09	0.10	0.09	0.08	0.06	0.04	-0.02	-0.05
LONG BEACH, CA	37	36	-0.01	-0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01
LOS ANGELES C.O., CA	32	47	0.00	0.00	0.00	-0.01	-0.01	-0.02	-0.02	-0.02	-0.01	-0.02	0.01	0.01
SAN DIEGO, CA	66	46	-0.02	-0.01	0.00	0.00	-0.01	-0.02	-0.02	-0.02	-0.02	-0.03	-0.02	-0.02
SAN FRANCISCO C.O., CA	28	8	-0.02	-0.01	0.00	0.02	0.01	0.03	0.02	0.02	0.02	0.01	0.00	0.00
SANTA BARBARA, CA	35	7	-0.02	-0.02	-0.01	0.00	-0.02	-0.02	-0.02	-0.03	-0.03	-0.03	-0.02	-0.03
SANTA MARIA, CA	26	30	-0.02	-0.01	-0.01	0.00	0.00	0.00	-0.02	-0.02	-0.03	-0.03	-0.02	-0.02
STOCKTON, CA	46	30	-0.04	-0.01	0.02	0.05	0.08	0.09	0.09	0.08	0.06	0.04	-0.01	-0.04
ALAMOSA, CO	15	49	-0.01	0.02	0.07	0.10	0.10	0.10	0.05	0.04	0.06	0.05	0.01	-0.02
DENVER, CO	50	38	0.04	0.05	0.07	0.09	0.07	0.08	0.07	0.07	0.07	0.06	0.03	0.03

GRAND JUNCTION, CO	60	43	-0.03	0.02	0.07	0.10	0.11	0.12	0.11	0.10	0.10	0.07	0.02	-0.02
PUEBLO, CO	51	27	0.03	0.06	0.09	0.10	0.09	0.10	0.08	0.06	0.07	0.06	0.03	0.02
HARTFORD, CT	52	47	0.02	0.03	0.05	0.06	0.04	0.02	0.02	0.01	0.01	0.02	0.02	0.01
WILMINGTON, DE	58	59	0.02	0.04	0.05	0.05	0.03	0.02	0.01	0.01	0.01	0.02	0.03	0.02
DAYTONA BEACH, FL	61	62	0.02	0.03	0.03	0.03	0.02	-0.01	-0.02	-0.02	-0.01	0.01	0.01	0.01
FORT MYERS, FL	61	62	0.02	0.03	0.04	0.04	0.03	0.00	-0.01	-0.01	-0.01	0.02	0.01	0.01
GAINESVILLE, FL	23	23	-0.01	0.00	0.02	0.02	0.01	-0.01	-0.02	-0.03	-0.03	-0.02	-0.01	-0.02
JACKSONVILLE, FL	57	70	0.01	0.03	0.04	0.04	0.03	0.01	0.00	-0.01	-0.01	0.00	0.01	0.00
KEY WEST, FL	53	58	0.02	0.03	0.03	0.04	0.02	0.00	0.00	0.00	0.00	0.01	0.02	0.02
MIAMI, FL	57	42	0.02	0.03	0.04	0.04	0.02	-0.01	-0.01	-0.01	-0.01	0.01	0.02	0.01
TALLAHASSEE, FL	45	45	-0.01	0.01	0.02	0.02	0.01	-0.01	-0.03	-0.03	-0.02	0.00	-0.01	-0.01
TAMPA, FL	60	43	0.01	0.02	0.03	0.04	0.03	0.00	-0.02	-0.02	-0.01	0.01	0.01	0.01
ATHENS, GA	51	51	0.01	0.02	0.03	0.03	0.01	0.00	-0.01	-0.02	-0.01	0.00	0.01	0.01
ATLANTA, GA	68	46	0.03	0.04	0.06	0.05	0.03	0.01	0.00	0.00	0.01	0.02	0.03	0.03
AUGUSTA,GA	55	42	0.01	0.02	0.03	0.03	0.01	0.00	-0.01	-0.02	-0.01	0.00	0.00	0.01
MACON, GA	58	42	0.01	0.02	0.03	0.03	0.02	0.01	0.00	-0.01	0.00	0.01	0.01	0.01
HILO, HI	57	57	-0.02	-0.01	-0.02	-0.02	-0.02	-0.02	-0.03	-0.03	-0.03	-0.03	-0.04	-0.03
HONOLULU,HI	57	37	0.01	0.03	0.04	0.05	0.06	0.07	0.08	0.07	0.05	0.04	0.03	0.03
KAHULUI, HI	34	42	0.03	0.04	0.05	0.07	0.07	0.09	0.10	0.09	0.07	0.05	0.04	0.03
LIHUE, HI	56	57	0.02	0.03	0.04	0.05	0.04	0.05	0.05	0.04	0.03	0.03	0.03	0.03
BOISE, ID	67	67	-0.02	0.01	0.07	0.08	0.08	0.09	0.10	0.10	0.08	0.06	0.01	-0.02
POCATELLO, ID	54	43	0.00	0.02	0.06	0.10	0.09	0.10	0.10	0.11	0.09	0.08	0.02	-0.01
CHICAGO,IL	48	48	0.02	0.02	0.03	0.05	0.03	0.02	0.00	0.00	0.01	0.02	0.02	0.01
MOLINE, IL	63	46	0.01	0.01	0.03	0.05	0.03	0.01	-0.01	-0.02	-0.01	0.02	0.02	0.00
SPRINGFIELD, IL	59	47	0.02	0.02	0.04	0.05	0.04	0.02	0.00	-0.01	0.00	0.02	0.03	0.01
EVANSVILLE, IN	66	45	-0.01	0.00	0.02	0.02	0.00	-0.01	-0.03	-0.03	-0.02	-0.01	-0.01	-0.01
INDIANAPOLIS, IN	58	47	0.01	0.02	0.04	0.05	0.03	0.01	0.00	-0.01	0.01	0.02	0.02	0.00
DES MOINES, IA	57	45	0.01	0.02	0.04	0.06	0.04	0.02	0.00	0.00	0.01	0.02	0.02	0.01
SIOUX CITY, IA	65	47	0.01	0.01	0.03	0.06	0.04	0.02	0.00	0.00	0.01	0.03	0.02	0.00
WATERLOO, IA	50	47	0.01	0.01	0.03	0.05	0.04	0.02	-0.01	-0.01	0.00	0.02	0.01	0.00
CONCORDIA, KS	44	44	0.02	0.03	0.06	0.07	0.04	0.04	0.04	0.03	0.04	0.05	0.03	0.02
DODGE CITY, KS	64	43	0.06	0.07	0.09	0.10	0.08	0.08	0.08	0.07	0.08	0.08	0.07	0.06
GOODLAND, KS	58	40	0.05	0.07	0.10	0.12	0.10	0.10	0.10	0.09	0.09	0.08	0.05	0.05
TOPEKA, KS	57	42	0.00	0.01	0.04	0.04	0.02	0.00	0.00	-0.01	0.00	0.01	0.01	0.00
WICHITA, KS	53	53	0.03	0.04	0.07	0.08	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.03
JACKSON, KY	25	25	-0.02	-0.01	0.01	0.02	-0.02	-0.04	-0.04	-0.05	-0.03	-0.01	-0.01	-0.02

LOUISVILLE, KY	59	46	0.01	0.02	0.04	0.04	0.01	0.00	0.00	-0.01	0.00	0.01	0.01	0.00
PADUCAH KY	22	22	-0.02	-0.02	0.00	0.00	-0.03	-0.05	-0.05	-0.06	-0.05	-0.04	-0.02	-0.03
BATON ROUGE, LA	55	47	-0.01	0.00	0.01	0.00	-0.01	-0.03	-0.04	-0.04	-0.03	-0.02	-0.01	-0.01
LAKE CHARLES, LA	45	42	-0.01	0.00	0.00	0.00	-0.01	-0.03	-0.05	-0.04	-0.03	-0.01	-0.01	-0.01
NEW ORLEANS, LA	58	58	-0.01	0.01	0.01	0.01	-0.01	-0.03	-0.04	-0.04	-0.03	-0.01	0.00	-0.01
SHREVEPORT, LA	54	54	0.00	0.01	0.02	0.01	0.00	-0.01	-0.01	-0.02	-0.01	0.00	0.00	0.00
PORTLAND, ME	66	66	0.01	0.02	0.03	0.04	0.02	0.00	0.00	0.00	0.00	0.01	0.01	0.01
BALTIMORE, MD	56	53	0.02	0.04	0.06	0.06	0.03	0.03	0.01	0.01	0.01	0.02	0.02	0.02
BLUE HILL, MA	65	53	0.10	0.11	0.11	0.11	0.09	0.07	0.07	0.06	0.07	0.09	0.09	0.10
WORCESTER, MA	40	51	0.05	0.05	0.06	0.06	0.05	0.02	0.01	0.01	0.01	0.03	0.03	0.03
GRAND RAPIDS, MI	43	43	0.01	0.01	0.03	0.05	0.04	0.02	0.02	0.01	0.01	0.01	0.01	0.00
LANSING, MI	47	43	0.01	0.02	0.03	0.05	0.04	0.02	0.01	0.00	0.00	0.01	0.01	0.00
DULUTH, MN	57	45	0.01	0.02	0.03	0.05	0.05	0.02	0.01	0.00	0.01	0.02	0.01	0.00
ROCHESTER, MN	46	46	0.03	0.03	0.04	0.06	0.05	0.04	0.02	0.01	0.02	0.04	0.03	0.02
SAINT CLOUD, MN	20	54	-0.02	-0.01	0.00	0.03	0.03	0.00	-0.01	-0.02	-0.01	0.00	-0.02	-0.03
JACKSON, MS	43	43	-0.02	0.00	0.00	0.00	-0.02	-0.03	-0.04	-0.04	-0.03	-0.02	-0.02	-0.02
MERIDIAN, MS	47	42	-0.02	-0.01	0.00	-0.01	-0.03	-0.04	-0.05	-0.05	-0.04	-0.03	-0.02	-0.03
TUPELO, MS	23	23	-0.03	-0.02	-0.01	-0.01	-0.03	-0.05	-0.05	-0.05	-0.04	-0.04	-0.03	-0.03
COLUMBIA, MO	36	37	0.01	0.01	0.03	0.04	0.00	-0.01	-0.01	-0.01	0.00	0.01	0.01	0.00
ST. LOUIS, MO	57	46	0.01	0.02	0.04	0.04	0.01	0.01	0.00	-0.01	0.00	0.01	0.01	0.00
SPRINGFIELD, MO	61	46	0.02	0.03	0.05	0.05	0.01	0.00	0.00	0.00	0.00	0.03	0.03	0.02
BILLINGS, MT	67	47	0.06	0.07	0.07	0.09	0.08	0.08	0.09	0.10	0.09	0.08	0.07	0.07
GREAT FALLS, MT	65	45	0.07	0.08	0.08	0.10	0.09	0.08	0.10	0.10	0.09	0.10	0.08	0.08
HELENA, MT	66	41	-0.02	0.01	0.04	0.07	0.07	0.06	0.08	0.07	0.06	0.03	0.00	-0.02
MISSOULA, MT	62	46	-0.07	-0.04	0.01	0.04	0.04	0.04	0.06	0.06	0.03	0.00	-0.06	-0.08
GRAND ISLAND, NE	57	45	0.03	0.03	0.05	0.08	0.06	0.05	0.03	0.02	0.04	0.05	0.04	0.03
LINCOLN, NE	34	34	0.00	0.00	0.03	0.05	0.02	0.02	0.01	0.00	0.01	0.02	0.01	0.00
NORFOLK, NE	30	61	0.03	0.02	0.04	0.07	0.05	0.04	0.02	0.02	0.03	0.05	0.03	0.02
NORTH PLATTE, NE	54	42	0.00	0.01	0.04	0.06	0.04	0.03	0.02	0.02	0.03	0.03	0.01	0.00
OMAHA (NORTH), NE	9	9	0.02	0.01	0.03	0.04	0.02	0.02	-0.01	-0.01	0.01	0.03	0.01	0.00
SCOTTSBLUFF, NE	55	41	0.04	0.06	0.09	0.10	0.09	0.08	0.08	0.07	0.07	0.07	0.04	0.03
VALENTINE, NE	38	39	0.00	0.00	0.02	0.05	0.04	0.03	0.02	0.03	0.04	0.03	0.02	0.01
ELY, NV	65	54	0.04	0.05	0.08	0.10	0.11	0.12	0.13	0.12	0.12	0.10	0.06	0.04
LAS VEGAS, NV	58	46	0.06	0.09	0.12	0.14	0.15	0.15	0.14	0.13	0.12	0.10	0.08	0.07
RENO, NV	64	43	0.00	0.03	0.07	0.08	0.09	0.09	0.10	0.09	0.07	0.06	0.02	0.00
WINNEMUCCA, NV	50	57	0.00	0.03	0.07	0.08	0.09	0.10	0.12	0.11	0.10	0.07	0.03	0.00

CONCORD, NH	64	41	0.00	0.02	0.02	0.04	0.02	0.01	0.00	-0.01	-0.01	0.00	-0.01	-0.01
NEWARK, NJ	62	41	0.04	0.06	0.07	0.07	0.05	0.04	0.03	0.03	0.03	0.03	0.04	0.04
ALBUQUERQUE, NM	67	46	0.06	0.08	0.11	0.13	0.13	0.13	0.09	0.08	0.08	0.08	0.06	0.04
CLAYTON, NM	14	49	0.08	0.09	0.12	0.14	0.12	0.12	0.09	0.07	0.09	0.09	0.08	0.07
ROSWELL, NM	33	33	0.05	0.08	0.11	0.12	0.11	0.11	0.08	0.06	0.06	0.06	0.05	0.04
ALBANY, NY	68	41	0.01	0.03	0.05	0.06	0.03	0.02	0.01	0.00	0.00	0.01	0.01	0.00
BINGHAMTON, NY	55	55	0.01	0.02	0.03	0.05	0.04	0.02	0.01	0.01	0.00	0.02	0.01	0.01
BUFFALO, NY	67	46	0.04	0.04	0.05	0.06	0.05	0.04	0.04	0.03	0.03	0.04	0.03	0.03
SYRACUSE, NY	57	43	0.01	0.02	0.03	0.05	0.03	0.02	0.01	0.00	0.00	0.01	0.01	0.00
ASHEVILLE, NC	42	42	0.02	0.03	0.03	0.03	0.00	-0.02	-0.03	-0.04	-0.03	0.00	0.01	0.01
CHARLOTTE, NC	57	46	0.01	0.03	0.04	0.04	0.02	0.00	0.00	-0.01	0.00	0.01	0.01	0.01
RALEIGH, NC	57	42	0.02	0.03	0.04	0.05	0.02	0.00	-0.01	-0.01	-0.01	0.00	0.01	0.01
WILMINGTON, NC	55	43	0.03	0.04	0.05	0.05	0.03	0.01	0.00	-0.01	-0.01	0.01	0.02	0.02
BISMARCK, ND	67	47	0.00	0.00	0.02	0.05	0.05	0.03	0.03	0.03	0.03	0.03	0.00	-0.01
FARGO, ND	64	47	0.02	0.02	0.03	0.06	0.07	0.04	0.03	0.04	0.04	0.04	0.03	0.01
WILLISTON, ND	42	45	-0.02	-0.01	0.01	0.05	0.05	0.03	0.03	0.03	0.03	0.03	-0.01	-0.02
AKRON, OH	58	43	0.02	0.02	0.04	0.05	0.03	0.01	0.01	0.00	0.00	0.02	0.02	0.01
COLUMBUS, OH	57	47	0.00	0.01	0.04	0.04	0.02	0.01	0.00	-0.01	-0.01	0.01	0.01	0.00
DAYTON, OH	63	43	0.01	0.02	0.04	0.05	0.03	0.02	0.01	0.00	0.01	0.02	0.02	0.01
MANSFIELD, OH	22	40	0.02	0.02	0.03	0.05	0.03	0.01	0.00	0.00	0.00	0.02	0.02	0.01
OKLAHOMA CITY, OK	58	41	0.04	0.05	0.08	0.08	0.04	0.04	0.04	0.04	0.03	0.05	0.05	0.04
TULSA, OK	58	46	0.02	0.03	0.05	0.05	0.02	0.01	0.02	0.02	0.01	0.02	0.02	0.02
ASTORIA, OR	53	53	-0.03	-0.02	-0.02	-0.01	-0.01	-0.02	-0.01	-0.02	-0.03	-0.04	-0.04	-0.04
EUGENE, OR	54	49	-0.05	-0.03	-0.01	0.00	0.01	0.02	0.06	0.05	0.04	-0.02	-0.05	-0.06
MEDFORD, OR	57	45	-0.07	-0.03	0.00	0.01	0.03	0.05	0.06	0.06	0.04	0.00	-0.06	-0.08
PENDLETON, OR	53	65	-0.04	-0.01	0.04	0.07	0.07	0.09	0.10	0.10	0.08	0.03	-0.02	-0.04
SALEM, OR	58	44	-0.04	-0.02	0.00	0.00	0.00	0.01	0.04	0.04	0.02	-0.02	-0.05	-0.05
GUAM, PC	16	13	0.00	0.02	0.02	0.01	-0.01	-0.02	-0.05	-0.05	-0.06	-0.05	-0.02	0.00
JOHNSTON ISLAND, PC	23	23	0.05	0.07	0.08	0.07	0.06	0.07	0.07	0.06	0.04	0.05	0.06	0.07
KOROR, PC	41	55	-0.04	-0.04	-0.04	-0.04	-0.06	-0.06	-0.06	-0.05	-0.05	-0.05	-0.06	-0.05
KWAJALEIN, MARSHALL IS., PC	40	46	0.07	0.07	0.07	0.05	0.03	0.02	-0.01	-0.02	-0.03	-0.02	0.01	0.06
MAJURO, MARSHALL IS, PC	42	51	0.02	0.02	0.02	0.01	-0.01	-0.02	-0.04	-0.04	-0.05	-0.04	-0.03	0.00
PAGO PAGO, AMER SAMOA, PC	39	38	-0.02	-0.02	-0.03	-0.03	-0.01	0.01	0.02	0.02	0.02	0.01	-0.01	-0.02
POHNPEI, CAROLINE IS., PC	32	36	-0.04	-0.03	-0.04	-0.06	-0.06	-0.07	-0.08	-0.08	-0.08	-0.08	-0.08	-0.06
CHUUK, E. CAROLINE IS., PC	41	36	0.00	0.00	0.00	-0.02	-0.03	-0.05	-0.05	-0.04	-0.04	-0.04	-0.04	-0.02
WAKE ISLAND, PC	43	45	0.05	0.05	0.06	0.07	0.05	0.03	0.03	0.02	0.02	0.04	0.07	0.06

YAP, W CAROLINE IS., PC	37	58	-0.02	-0.01	-0.01	-0.02	-0.04	-0.05	-0.05	-0.05	-0.05	-0.06	-0.05	-0.03
ALLENTOWN, PA	57	56	0.02	0.03	0.05	0.05	0.03	0.02	0.01	0.00	0.00	0.01	0.02	0.02
ERIE, PA.	52	41	0.03	0.02	0.03	0.03	0.02	0.01	0.01	0.00	0.01	0.03	0.04	0.03
PITTSBURGH, PA	54	46	0.01	0.02	0.04	0.05	0.03	0.02	0.01	0.00	0.00	0.02	0.02	0.01
AVOCA, PA	51	51	0.00	0.01	0.03	0.04	0.03	0.01	0.01	0.00	0.00	0.00	0.00	-0.01
PROVIDENCE, RI	53	43	0.04	0.06	0.06	0.07	0.05	0.03	0.03	0.03	0.03	0.03	0.04	0.04
CHARLESTON AP,SC	57	64	0.03	0.04	0.05	0.05	0.03	0.01	0.00	-0.01	-0.01	0.01	0.02	0.02
COLUMBIA, SC	58	40	0.01	0.03	0.04	0.05	0.02	0.01	0.00	-0.01	-0.01	0.00	0.01	0.01
GREENVILLE-SPARTANBURG AP, SC	44	44	0.01	0.02	0.03	0.03	0.01	0.00	-0.01	-0.02	-0.01	0.01	0.01	0.01
ABERDEEN, SD	30	38	0.00	0.00	0.02	0.05	0.05	0.02	0.01	0.02	0.03	0.03	0.00	-0.01
HURON, SD	67	47	0.01	0.01	0.03	0.06	0.05	0.03	0.03	0.03	0.04	0.04	0.03	0.01
RAPID CITY, SD	56	56	0.02	0.04	0.07	0.09	0.08	0.06	0.07	0.09	0.09	0.07	0.04	0.02
SIOUX FALLS, SD	58	43	0.01	0.01	0.03	0.06	0.04	0.03	0.02	0.01	0.02	0.03	0.01	0.00
CHATTANOOGA, TN	66	76	-0.01	0.00	0.02	0.02	0.00	-0.02	-0.02	-0.03	-0.02	-0.02	-0.01	-0.02
KNOXVILLE, TN	64	46	-0.01	0.00	0.02	0.03	0.00	-0.01	-0.02	-0.03	-0.02	-0.01	-0.01	-0.01
MEMPHIS, TN	58	67	0.01	0.02	0.04	0.04	0.01	0.00	-0.01	-0.01	0.00	0.01	0.02	0.01
NASHVILLE, TN	65	41	0.00	0.01	0.03	0.02	-0.01	-0.01	-0.02	-0.03	-0.02	-0.01	0.00	0.00
ABILENE, TX	62	43	0.05	0.06	0.08	0.09	0.06	0.06	0.05	0.05	0.03	0.05	0.05	0.05
AMARILLO, TX	65	45	0.07	0.08	0.11	0.12	0.10	0.09	0.08	0.07	0.07	0.08	0.08	0.07
AUSTIN, TX	65	45	0.00	0.01	0.02	0.02	0.01	0.00	0.01	0.01	-0.01	0.00	0.00	0.00
CORPUS CHRISTI, TX	64	42	0.02	0.03	0.05	0.05	0.03	0.02	0.02	0.02	0.01	0.02	0.03	0.02
DALLAS-FORT WORTH, TX	53	43	0.03	0.04	0.05	0.05	0.02	0.03	0.03	0.02	0.02	0.02	0.03	0.03
EL PASO, TX	64	46	0.07	0.10	0.13	0.14	0.14	0.12	0.08	0.07	0.07	0.07	0.07	0.06
GALVESTON, TX	60	96	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.00
HOUSTON, TX	37	37	-0.02	-0.01	0.00	0.00	-0.02	-0.02	-0.03	-0.03	-0.03	-0.02	-0.02	-0.02
LUBBOCK, TX	57	59	0.06	0.08	0.11	0.12	0.10	0.09	0.06	0.04	0.04	0.06	0.07	0.06
MIDLAND-ODESSA, TX	53	43	0.05	0.06	0.09	0.10	0.09	0.08	0.07	0.05	0.04	0.05	0.05	0.05
PORT ARTHUR, TX	53	46	0.00	0.02	0.02	0.02	0.00	-0.02	-0.03	-0.03	-0.02	0.00	0.00	0.00
SAN ANGELO, TX	57	46	0.03	0.05	0.07	0.07	0.05	0.04	0.04	0.03	0.01	0.02	0.03	0.03
SAN ANTONIO, TX	64	64	0.01	0.02	0.03	0.03	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01
VICTORIA, TX	45	45	0.00	0.02	0.03	0.03	0.01	0.00	0.00	0.00	-0.01	0.00	0.00	0.00
WACO, TX	57	43	0.02	0.03	0.04	0.04	0.02	0.03	0.04	0.04	0.02	0.02	0.02	0.02
WICHITA FALLS, TX	58	46	0.04	0.05	0.07	0.07	0.05	0.05	0.06	0.05	0.03	0.04	0.04	0.04
BURLINGTON, VT	63	41	0.01	0.02	0.02	0.04	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01
LYNCHBURG, VA	39	43	0.02	0.02	0.03	0.04	0.01	-0.01	-0.02	-0.02	-0.01	0.00	0.01	0.01
NORFOLK, VA	58	58	0.04	0.05	0.06	0.07	0.04	0.03	0.01	0.01	0.02	0.03	0.04	0.04

ROANOKE, VA	58	42	0.04	0.04	0.06	0.05	0.02	0.00	0.00	-0.01	-0.01	0.01	0.02	0.03
OLYMPIA, WA	53	46	-0.06	-0.04	-0.01	0.00	0.00	0.00	0.01	0.01	-0.01	-0.04	-0.06	-0.07
QUILLAYUTE, WA	40	40	-0.07	-0.05	-0.05	-0.04	-0.04	-0.04	-0.04	-0.05	-0.05	-0.07	-0.08	-0.08
SPOKANE, WA	59	47	-0.04	-0.01	0.04	0.06	0.06	0.08	0.09	0.09	0.07	0.03	-0.03	-0.05
YAKIMA, WA	52	57	-0.06	-0.01	0.05	0.08	0.08	0.08	0.09	0.08	0.07	0.03	-0.03	-0.07
SAN JUAN, PR	51	51	0.00	0.00	0.01	0.01	-0.01	0.00	0.00	-0.01	-0.02	-0.03	-0.02	-0.01
CHARLESTON, WV	59	59	-0.02	-0.01	0.01	0.02	0.00	-0.02	-0.03	-0.03	-0.03	-0.02	-0.01	-0.02
HUNTINGTON, WV	44	45	-0.02	0.00	0.02	0.03	0.00	-0.02	-0.03	-0.03	-0.03	-0.01	-0.01	-0.02
GREEN BAY, WI	57	45	0.00	0.00	0.01	0.03	0.02	0.01	0.00	-0.02	-0.01	0.01	0.00	-0.01
LA CROSSE, WI	54	45	-0.01	-0.01	0.01	0.04	0.03	0.01	0.00	-0.01	0.00	0.01	0.00	-0.02
MADISON, WI	60	47	0.00	0.01	0.02	0.04	0.03	0.01	-0.01	-0.01	-0.01	0.01	0.00	-0.01
CASPER, WY	56	42	0.09	0.09	0.10	0.10	0.09	0.10	0.11	0.11	0.11	0.09	0.08	0.08
LANDER, WY	60	60	-0.02	0.00	0.03	0.05	0.06	0.07	0.08	0.08	0.06	0.03	-0.01	-0.02
SHERIDAN, WY	63	42	-0.01	0.00	0.04	0.06	0.05	0.04	0.06	0.07	0.05	0.03	-0.01	-0.01
ALGIERS CITY, ALGERIA	1	1	-0.05	-0.03	-0.02	-0.01	-0.07	-0.04	-0.02	-0.08	-0.05	-0.06	-0.07	-0.07

* Data ending 2006.

Modifying the Initial Crop Coefficient Value

It is the initial crop coefficient (K_{c_ini}) that will be the coefficient that will likely deviate the most from FAO-56 default values, due mostly to variations in wetting frequencies between various regions. For this reason FAO-56 clearly states that regions "are subject to the effects of large variations in wetting frequencies and therefore **refinements to the value used for K_{c_ini} should always be made"** (Allen et al., 1998) (emphasis by the authors). The K_{c_ini} values for various field crops in FAO-56 ranges around 0.3 to 0.4. However, when there are a significant number of rain/irrigation events this value could be off by as much as 200%. Examining data from Missouri shows that K_{c_ini} values needed to be doubled in many cases.

The adjusted K_{c_ini} value is graphically solved for using figures from FAO-56 that require (1) ET_o (in mm) and (2) wetting interval (in days) data during the initial period. Unfortunately, the required long-term climatic data needed for the graphical are hard to obtain, especially local wetting interval information. To obtain this data one would to need to look at several years of rainfall patterns. In addition, wetting events on two or more consecutive days is considered just one single wetting event, so weather files need to be gone over by hand. Fortunately, the U.S. Department of Commerce maintains on-line climatic databases for about 300 cities in the USA and its possessions (U.S. Department of Commerce, 2008). Because both ET_o and wetting frequency data are both required in the graphical solution, the list pares down to 180 useable locations. Table 3 lists frequency of rainfall events by month (contiguous rainfall days accounted for) for these cities in the USA and her possessions, plus Algiers City, Algeria. Table 3 also includes average daily ET_o data.

In order to make use of the USDC/NOAA data on average number of rainfall events > 0.01 inches per month an estimate is needed of the ratio of total non-contiguous rainfall events to the number of total rainfall events, which the NOAA dataset reports. This was done by counting total and total non-contiguous events for a subset of eight cities spread throughout the USA for the months Mar-June for the years 2000, 2002, 2004 and 2008. To account for the different number of days that can occur in a month (28, 29, 30 or 31) percentages were used. Different response equations were developed for sub-humid sites and arid sites (the demarcation between the two being 10 inches (250 mm) of total rain for the March to May period. Figure 3 shows the relationship of frequency of occurrence of total non-contiguous rainfall events to number of total individual rainfall events; the linear equation for both broad climate types can be seen within the figure. The number of total non-contiguous rainfall events each month was calculated based on climate type and then converted into the wetting interval for all the involved cities. Table 3 has both the frequency and average daily ET_o data.

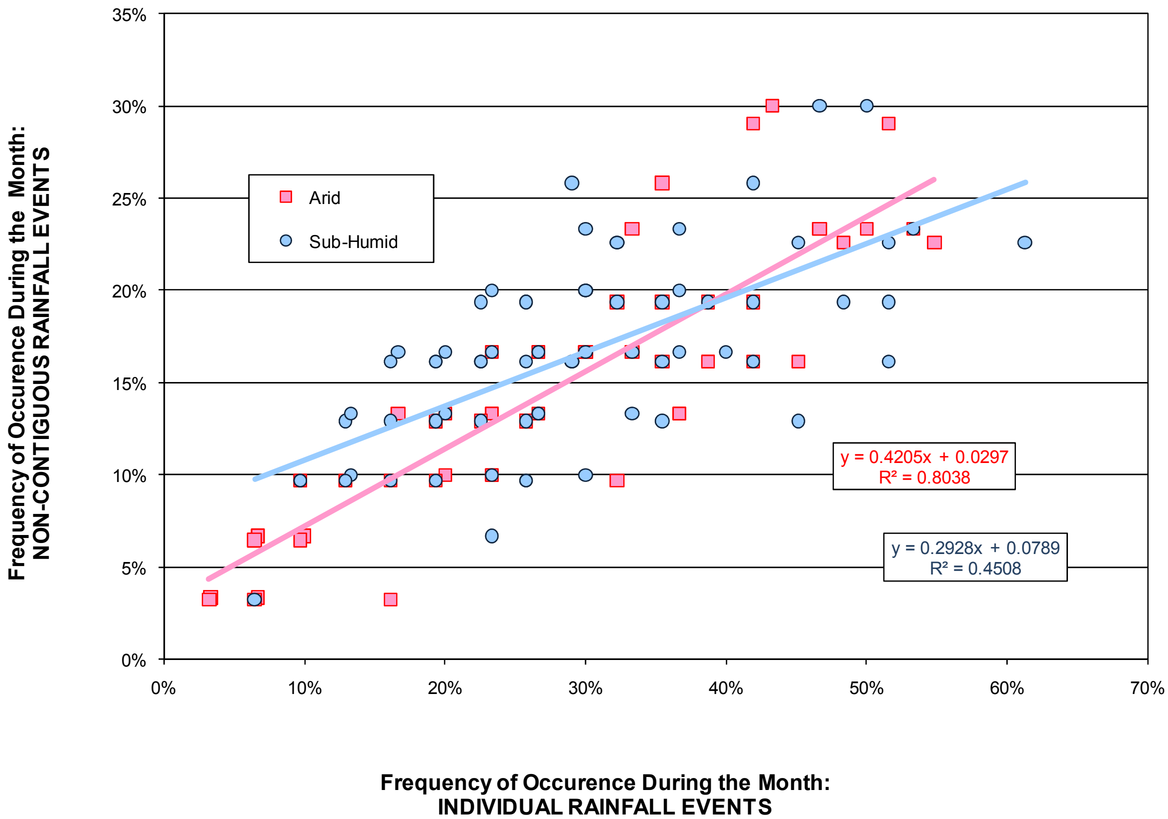


Figure 3 Relationship between frequency of occurrence of total non-contiguous rainfall events to total number of individual rainfall events in a month for arid and sub-humid regions.

The interval between wetting events in Table 3 does not account for wetting events that occur due to irrigation. If irrigation occurs then the interval between wetting events will decrease. Equation 4 shows how to calculate the new frequency interval of Table 3 should irrigation(s) take place.

The new frequency can be estimated by equation 4.

$$Freq_{New} = \frac{30}{(\frac{30}{Freq_{Table}}) + Irrs} \qquad \text{(Eq. 4)}$$

Where

$Freq_{New}$	=	The new interval between wetting events due to irrigation, days
$Freq_{Table}$	=	Interval from Table 3, days
Irrs	=	The number of irrigations that will occur during the initial period

An example of how the default K_{c_ini} value can be adjusted using this procedure is seen below.

Adjusting K_{c_ini} Based on ET_o and Rainfall/Irrigation Events and FAO-56.

Given:

Crop	=	soybean
Location	=	Omaha, NE
Planting date	=	Apr 10

Find:

Modified K_{c_ini} with <u>no irrigation</u> & for <u>1 irrigation</u> for that period.

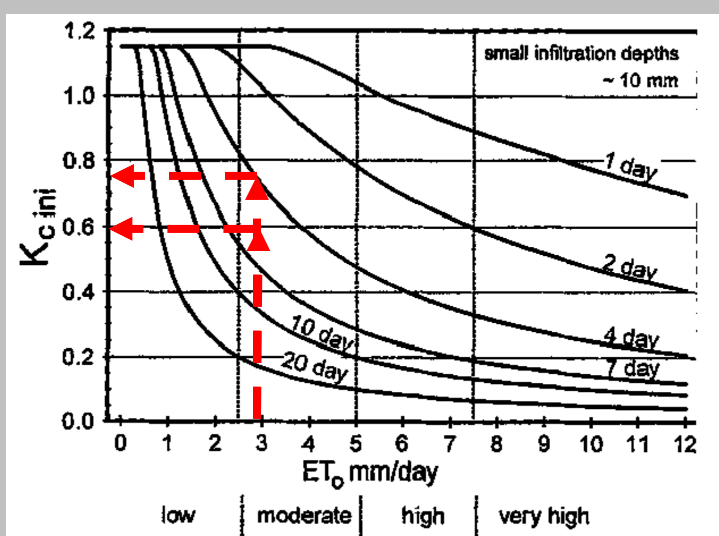
Procedure:

- Get frequency of rainfall events for Omaha, NE in April from Table 3.
- Get ET_o for Omaha, NE in April from Table 3.
- Plot those values on Figs. 29, 30, or 31 (dependent on soil/wetting amount) in FAO-56 to get K_{c_ini}.
- Recalculate interval to include the expected irrigation(s); re-plot using the new interval to get K_{c_ini} when irrigation occurs.

Results:

K_{c_ini}	=	0.40 (Table 12, FAO-56)
ET_o in Apr	=	2.8 mm (Table 3)
Wetting Frequency in Apr	=	5 days (Table 3)
New Wetting Frequency in Apr	=	4 days (Eq. 4)

$$Freq_{New} = \frac{30}{(\frac{30}{Freq_{Table}}) + Irrs} = \frac{30}{(\frac{30}{5}) + 1} = 4\ days$$



Answer:

K_{c_ini}	=	0.60 (no irrigation) – increased 50% from default value.
K_{c_ini}	=	0.75 (1 irrigation) – increased 88% from default value.

Table 3. Interval between non-contiguous rainfall events (days) and average daily ET_o as calculated by Hargreaves-Samani (mm) by month.

Location	YRS of Data	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	rain / ETo	Interval between Rainfall Events (days) / average daily ET_o (mm)											
HUNTSVILLE, AL	39 / 30	5 / 1.2	6 / 1.8	5 / 3.2	6 / 4.4	6 / 5.2	6 / 5.8	6 / 5.7	6 / 5.2	6 / 4.1	7 / 3.1	6 / 2.	6 / 1.5
MOBILE, AL	65 / 30	6 / 1.8	6 / 2.4	6 / 3.4	7 / 4.5	6 / 5.2	5 / 5.7	5 / 5.5	5 / 5.	6 / 4.3	8 / 3.4	7 / 2.4	6 / 1.8
FAIRBANKS, AK	55 / 30	8 / 0.0	8 / 0.0	10 / 0.0	12 / 1.4	9 / 2.9	6 / 4.	5 / 3.9	5 / 2.7	6 / 1.3	6 / .2	6 / 0.0	7 / 0.0
HOMER, AK	50 / 30	5 / 0.0	5 / 0.0	6 / .2	6 / 1.4	7 / 3.2	6 / 4.4	6 / 4.1	5 / 2.8	4 / 1.3	4 / .2	5 / 0.0	4 / 0.0
JUNEAU, AK	62 / 30	4 / 0.0	4 / 0.0	4 / .5	4 / 1.5	4 / 2.9	4 / 4.	4 / 4.	4 / 2.9	4 / 1.4	3 / .4	4 / 0.0	4 / 0.0
PHOENIX, AZ	67 / 30	14 / 0.1	11 / .2	14 / .7	23 / 1.5	34 / 2.4	34 / 3.2	12 / 3.2	12 / 2.4	17 / 1.3	18 / .5	17 / .1	14 / .
TUCSON, AZ	66 / 30	12 / 0.1	13 / .3	12 / .7	17 / 1.5	23 / 2.3	23 / 2.8	7 / 2.8	7 / 2.3	12 / 1.4	14 / .6	17 / .2	12 / .1
WINSLOW, AZ	75 / 30	12 / 1.1	11 / 1.4	12 / 2.2	14 / 3.3	18 / 4.6	17 / 5.9	9 / 5.9	7 / 5.1	10 / 4.	14 / 2.6	14 / 1.4	12 / 1.
YUMA, AZ	45 / 30	14 / 2.0	17 / 2.8	18 / 3.8	23 / 5.3	34 / 6.7	34 / 7.9	23 / 7.3	18 / 6.6	23 / 5.4	23 / 3.9	23 / 2.5	18 / 1.8
FORT SMITH, AR	61 / 30	7 / 2.0	7 / 2.8	6 / 3.8	6 / 5.2	6 / 6.5	6 / 7.6	7 / 7.	7 / 6.1	7 / 5.2	7 / 3.8	7 / 2.5	7 / 1.8
LITTLE ROCK, AR	64 / 30	6 / 1.1	6 / 1.9	6 / 2.9	6 / 4.4	6 / 5.7	6 / 7.1	6 / 6.8	7 / 6.	7 / 4.6	7 / 3.1	6 / 1.8	6 / 1.1
BAKERSFIELD, CA	69 / 30	9 / 2.1	8 / 3.	9 / 4.1	12 / 5.6	23 / 6.8	34 / 7.9	34 / 7.6	34 / 6.8	23 / 5.7	18 / 4.	12 / 2.6	10 / 2.
FRESNO, CA	57 / 30	8 / 1.2	7 / 1.8	8 / 2.9	12 / 4.4	18 / 5.1	34 / 5.8	23 / 6.2	23 / 5.6	23 / 4.4	18 / 3.1	10 / 1.9	8 / 1.2
LONG BEACH, CA	62 / 30	10 / 1.2	10 / 1.8	10 / 2.9	14 / 4.1	23 / 5.1	23 / 5.9	23 / 6.	23 / 5.5	23 / 4.1	18 / 3.1	14 / 1.8	10 / 1.2
LOS ANGELES C.O., CA	66 / 30	9 / 1.5	10 / 2.2	9 / 3.2	14 / 4.5	23 / 5.7	34 / 6.7	23 / 7.2	23 / 6.3	23 / 4.8	18 / 3.3	14 / 1.9	10 / 1.3
SAN DIEGO, CA	66 / 30	9 / 1.2	8 / 2.	9 / 2.9	12 / 4.5	18 / 6.	34 / 7.1	23 / 7.6	34 / 6.6	23 / 5.	18 / 3.3	12 / 1.8	9 / 1.1
SAN FRANCISCO C.O., CA	69 / 30	6 / 1.7	6 / 2.2	6 / 2.7	9 / 3.2	14 / 3.5	23 / 3.8	23 / 3.9	23 / 3.7	17 / 3.2	12 / 2.6	7 / 2.	6 / 1.6
SANTA BARBARA, CA	70 / 30	10 / 1.8	10 / 2.4	9 / 2.9	23 / 3.8	23 / 4.1	34 / 4.7	34 / 5.2	23 / 4.8	23 / 3.9	18 / 2.9	14 / 2.1	10 / 1.7
SANTA MARIA, CA	64 / 30	8 / 0.9	7 / 1.3	8 / 2.	12 / 3.1	23 / 4.4	34 / 5.4	23 / 6.2	23 / 5.5	23 / 3.9	18 / 2.3	10 / 1.1	8 / .7
STOCKTON, CA	64 / 30	7 / 1.1	7 / 1.9	7 / 2.6	10 / 3.8	18 / 5.5	34 / 6.6	23 / 7.4	23 / 6.5	23 / 4.7	14 / 2.9	8 / 1.4	8 / 1.
ALAMOSA, CO	60 / 30	14 / 1.1	11 / 1.8	10 / 2.7	10 / 4.	10 / 5.6	10 / 6.6	7 / 7.1	6 / 6.2	9 / 4.7	12 / 3.1	14 / 1.5	14 / 1.
DENVER, CO	64 / 30	10 / 1.1	10 / 1.7	7 / 2.3	7 / 3.1	6 / 3.7	7 / 4.3	7 / 4.1	7 / 3.8	9 / 3.3	10 / 2.3	10 / 1.4	10 / 1.1
GRAND JUNCTION, CO	60 / 30	9 / 1.1	8 / 1.5	8 / 2.1	9 / 2.7	9 / 3.1	12 / 3.2	12 / 3.2	9 / 2.8	9 / 2.6	10 / 2.1	10 / 1.3	10 / 1.
PUEBLO, CO	64 / 30	12 / 1.8	11 / 2.3	9 / 2.9	9 / 3.7	7 / 4.	8 / 4.3	7 / 4.3	7 / 4.	12 / 3.5	14 / 2.8	14 / 2.1	14 / 1.7
HARTFORD, CT	52 / 30	5 / 1.1	5 / 1.9	5 / 2.8	5 / 4.3	5 / 5.6	5 / 6.7	6 / 7.1	6 / 6.2	6 / 4.7	6 / 3.1	6 / 1.7	5 / 1.
WILMINGTON, DE	59 / 30	6 / 0.6	6 / 1.1	6 / 2.1	5 / 3.3	5 / 4.6	6 / 5.9	6 / 6.	6 / 5.2	6 / 3.9	7 / 2.4	6 / 1.2	6 / .6
DAYTONA BEACH, FL	63 / 30	8 / 1.1	7 / 1.7	8 / 2.6	10 / 4.	8 / 5.2	5 / 6.7	5 / 6.8	5 / 5.9	5 / 4.4	6 / 2.8	8 / 1.5	8 / 1.
FORT MYERS, FL	63 / 30	10 / 0.6	10 / .9	10 / 1.6	12 / 2.6	8 / 3.7	4 / 4.5	4 / 4.6	4 / 4.1	4 / 3.1	8 / 2.	12 / 1.1	12 / .6
GAINESVILLE, FL	23 / 30	6 / 0.6	7 / .9	6 / 1.7	8 / 3.1	7 / 4.5	5 / 5.3	5 / 5.6	4 / 4.8	5 / 3.4	7 / 2.1	7 / 1.1	7 / .6
JACKSONVILLE, FL	65 / 30	6 / 0.7	7 / 1.1	6 / 2.	7 / 3.2	7 / 4.4	5 / 5.2	5 / 5.2	5 / 4.5	5 / 3.4	6 / 2.2	7 / 1.3	7 / .7
KEY WEST, FL	58 / 30	9 / 0.9	10 / 1.2	10 / 2.2	12 / 3.5	8 / 4.8	5 / 5.7	5 / 5.7	5 / 5.	4 / 3.8	6 / 2.4	9 / 1.4	9 / .9
MIAMI, FL	64 / 30	9 / 0.9	8 / 1.2	9 / 2.2	9 / 3.5	6 / 4.5	4 / 5.2	4 / 5.2	4 / 4.6	4 / 3.5	5 / 2.3	7 / 1.3	9 / .9
TALLAHASSEE, FL	45 / 30	6 / 2.7	6 / 3.2	6 / 4.	7 / 5.	6 / 5.5	5 / 5.3	4 / 5.2	5 / 5.	6 / 4.3	8 / 3.5	7 / 3.	6 / 2.6
TAMPA, FL	60 / 30	9 / 2.2	8 / 2.8	9 / 3.8	12 / 5.	10 / 5.6	5 / 5.8	4 / 5.6	4 / 5.2	5 / 4.4	9 / 3.4	10 / 2.6	9 / 2.1
ATHENS, GA	63 / 30	5 / 2.4	6 / 3.	6 / 3.5	6 / 4.1	6 / 4.4	6 / 4.5	6 / 4.6	6 / 4.3	7 / 3.8	7 / 3.2	6 / 2.6	6 / 2.3
ATLANTA, GA	72 / 30	5 / 2.4	5 / 3.1	5 / 4.	6 / 5.	6 / 5.6	6 / 5.6	5 / 5.5	6 / 5.1	7 / 4.4	7 / 3.5	6 / 2.7	6 / 2.3
AUGUSTA,GA	56 / 30	6 / 1.7	6 / 2.3	6 / 3.2	7 / 4.1	6 / 4.9	6 / 5.3	5 / 5.1	6 / 4.8	7 / 4.	7 / 3.3	7 / 2.2	6 / 1.7
MACON, GA	58 / 30	6 / 2.3	6 / 2.9	6 / 3.8	7 / 4.7	6 / 5.4	6 / 5.3	5 / 5.1	6 / 4.9	7 / 4.3	8 / 3.5	7 / 2.7	6 / 2.2
HILO, HI	64 / 30	4 / 2.6	4 / 3.1	3 / 3.8	3 / 4.5	3 / 4.8	3 / 5.	3 / 5.	3 / 4.8	3 / 4.	3 / 3.3	3 / 2.6	4 / 2.3
HONOLULU,HI	57 / 30	7 / 1.3	7 / 2.	7 / 3.1	7 / 4.3	9 / 5.1	10 / 5.7	8 / 5.6	10 / 5.	9 / 4.	7 / 2.9	6 / 1.9	7 / 1.3
KAHULUI, HI	48 / 30	6 / 1.3	6 / 1.9	6 / 2.9	6 / 4.1	9 / 4.9	10 / 5.4	9 / 5.4	9 / 4.9	12 / 3.9	9 / 2.8	6 / 1.9	6 / 1.3
LIHUE, HI	56 / 30	5 / 1.6	4 / 2.2	4 / 3.4	4 / 4.7	4 / 5.6	4 / 6.1	3 / 6.	4 / 5.4	4 / 4.4	4 / 3.3	4 / 2.2	4 / 1.6
BOISE, ID	67 / 30	6 / 1.6	6 / 2.3	7 / 3.3	7 / 4.6	8 / 5.4	10 / 6.	18 / 5.7	18 / 5.2	14 / 4.3	10 / 3.3	6 / 2.1	6 / 1.6
POCATELLO, ID	57 / 30	5 / 1.6	6 / 2.3	7 / 3.4	7 / 4.7	7 / 5.6	9 / 6.1	12 / 6.	12 / 5.4	12 / 4.5	10 / 3.3	7 / 2.2	6 / 1.6

CHICAGO,IL	48 / 30	6 / 1.7	6 / 2.3	5 / 3.3	5 / 4.5	6 / 5.2	6 / 5.7	7 / 5.6	7 / 5.	6 / 4.	7 / 3.2	6 / 2.2	6 / 1.7
MOLINE, IL	74 / 30	7 / 3.1	7 / 3.4	6 / 3.8	5 / 4.	6 / 4.3	6 / 4.5	7 / 4.4	7 / 4.4	7 / 4.1	8 / 3.7	7 / 3.1	7 / 2.8
SPRINGFIELD, IL	59 / 30	7 / 2.6	7 / 3.	6 / 3.3	5 / 3.7	6 / 3.9	6 / 3.9	7 / 3.9	7 / 3.9	8 / 3.7	8 / 3.1	6 / 2.5	7 / 2.3
EVANSVILLE, IN	66 / 30	6 / 0.6	6 / 1.	5 / 2.	5 / 3.2	5 / 4.6	6 / 5.8	6 / 6.7	7 / 5.6	7 / 3.7	7 / 2.1	6 / .9	6 / .5
INDIANAPOLIS, IN	67 / 30	6 / 0.5	6 / .9	5 / 1.7	5 / 3.	5 / 4.4	6 / 5.7	7 / 6.6	7 / 5.7	8 / 3.7	7 / 2.1	6 / .8	6 / .5
DES MOINES, IA	67 / 30	8 / 0.5	7 / .8	7 / 1.6	6 / 3.	6 / 4.3	6 / 5.2	7 / 5.4	7 / 4.5	7 / 3.3	8 / 2.	8 / .9	8 / .5
SIOUX CITY, IA	66 / 30	9 / 0.5	8 / .8	7 / 1.7	6 / 3.2	6 / 4.5	6 / 5.6	7 / 5.5	7 / 4.8	7 / 3.4	9 / 2.1	10 / .9	9 / .5
WATERLOO, IA	56 / 30	8 / 0.5	8 / .9	7 / 1.7	6 / 3.2	6 / 4.5	6 / 5.4	7 / 5.4	7 / 4.6	7 / 3.5	8 / 2.2	8 / 1.1	8 / .5
CONCORDIA, KS	44 / 30	10 / 0.4	11 / .7	8 / 1.5	6 / 3.	6 / 4.4	6 / 5.3	7 / 5.4	7 / 4.5	8 / 3.3	9 / 2.	10 / .9	12 / .5
DODGE CITY, KS	64 / 30	12 / 0.6	11 / 1.	9 / 1.8	9 / 3.3	7 / 4.6	7 / 5.6	7 / 5.5	7 / 4.8	9 / 3.7	10 / 2.3	12 / 1.2	12 / .6
GOODLAND, KS	86 / 30	12 / 0.9	11 / 1.2	9 / 2.3	8 / 3.7	7 / 4.9	6 / 5.8	7 / 5.7	8 / 5.1	10 / 3.9	12 / 2.6	12 / 1.4	14 / .9
TOPEKA, KS	60 / 30	9 / 0.5	8 / .8	7 / 1.7	6 / 3.1	6 / 4.4	6 / 5.3	7 / 5.4	7 / 4.6	8 / 3.4	8 / 2.1	9 / .9	10 / .5
WICHITA, KS	53 / 30	10 / 0.6	10 / 1.	8 / 2.	8 / 3.3	6 / 4.5	6 / 5.4	8 / 5.4	8 / 4.8	8 / 3.7	9 / 2.2	10 / 1.2	10 / .6
JACKSON, KY	26 / 30	5 / 0.5	5 / .8	5 / 1.7	5 / 3.2	5 / 4.5	5 / 5.3	5 / 5.5	6 / 4.8	6 / 3.4	6 / 2.1	5 / .9	5 / .5
LOUISVILLE, KY	59 / 30	5 / 0.4	5 / .8	5 / 1.6	5 / 3.3	5 / 4.5	6 / 5.4	6 / 5.6	6 / 4.8	7 / 3.4	7 / 2.1	6 / .9	5 / .5
PADUCAH KY	23 / 30	6 / 0.4	6 / .7	6 / 1.5	5 / 3.1	5 / 4.4	6 / 5.4	6 / 5.4	7 / 4.6	7 / 3.3	6 / 2.	6 / .8	6 / .4
BATON ROUGE, LA	55 / 30	6 / 0.7	6 / 1.1	6 / 2.1	7 / 3.4	7 / 4.5	6 / 5.8	5 / 6.1	5 / 5.2	6 / 3.8	8 / 2.4	7 / 1.2	6 / .7
LAKE CHARLES, LA	45 / 30	6 / 1.0	6 / 1.4	7 / 2.4	7 / 3.9	7 / 4.9	6 / 6.	6 / 6.5	6 / 5.6	6 / 4.	7 / 2.7	7 / 1.4	6 / .9
NEW ORLEANS, LA	58 / 30	6 / 2.1	6 / 2.4	6 / 3.1	7 / 3.8	7 / 4.1	5 / 4.7	5 / 5.4	5 / 5.4	6 / 5.	7 / 4.	7 / 2.8	6 / 2.1
SHREVEPORT, LA	54 / 30	6 / 0.7	6 / 1.2	6 / 2.3	6 / 3.7	6 / 4.8	6 / 5.6	7 / 5.7	7 / 5.1	7 / 3.9	7 / 2.6	6 / 1.3	6 / .7
PORTLAND, ME	66 / 30	5 / 0.7	6 / 1.1	5 / 2.1	5 / 3.4	5 / 4.6	5 / 5.4	6 / 5.4	6 / 4.9	6 / 3.7	6 / 2.3	5 / 1.2	5 / .7
BALTIMORE, MD	56 / 30	6 / 0.9	6 / 1.3	6 / 2.3	6 / 3.5	6 / 4.5	6 / 5.1	7 / 5.1	7 / 4.6	8 / 3.5	8 / 2.3	7 / 1.4	7 / .9
BLUE HILL, MA	121 / 30	5 / 0.9	5 / 1.2	5 / 2.2	5 / 3.5	5 / 4.5	5 / 5.4	6 / 5.4	6 / 4.9	6 / 3.7	6 / 2.3	6 / 1.3	5 / .9
WORCESTER, MA	51 / 30	5 / 0.9	5 / 1.3	5 / 2.4	5 / 3.7	5 / 4.8	5 / 5.7	6 / 5.6	6 / 5.1	6 / 3.9	6 / 2.7	5 / 1.4	5 / 1.
GRAND RAPIDS, MI	43 / 30	4 / 1.6	5 / 2.2	5 / 3.3	5 / 4.5	6 / 5.2	6 / 5.8	7 / 6.	7 / 5.6	6 / 4.5	6 / 3.3	5 / 2.1	4 / 1.6
LANSING, MI	52 / 30	5 / 0.5	5 / .8	5 / 1.3	5 / 2.5	6 / 3.7	6 / 4.6	7 / 4.9	7 / 4.1	6 / 3.	7 / 1.7	5 / .8	5 / .5
DULUTH, MN	65 / 30	6 / 0.6	6 / .9	6 / 1.5	6 / 2.5	5 / 3.7	5 / 4.6	6 / 4.8	6 / 4.	5 / 3.	7 / 1.8	6 / .9	6 / .6
ROCHESTER, MN	46 / 30	7 / 0.5	7 / .8	6 / 1.6	5 / 2.8	5 / 4.3	5 / 5.2	6 / 5.4	7 / 4.6	6 / 3.3	7 / 2.	6 / .9	7 / .5
SAINT CLOUD, MN	66 / 30	7 / 0.4	8 / .7	7 / 1.5	6 / 2.7	6 / 4.1	5 / 5.1	6 / 5.2	7 / 4.4	6 / 3.1	8 / 1.7	8 / .8	7 / .5
JACKSON, MS	43 / 30	6 / 0.4	6 / .7	6 / 1.5	6 / 2.8	6 / 4.3	6 / 5.3	6 / 5.4	6 / 4.5	7 / 3.2	7 / 1.8	6 / .8	6 / .5
MERIDIAN, MS	61 / 30	6 / 0.4	6 / .6	6 / 1.2	6 / 2.5	6 / 4.	6 / 5.1	5 / 5.2	6 / 4.3	7 / 2.8	8 / 1.6	6 / .7	6 / .4
TUPELO, MS	23 / 30	6 / 0.4	5 / .7	6 / 1.5	6 / 2.8	6 / 4.3	6 / 5.3	6 / 5.5	7 / 4.6	7 / 3.2	7 / 1.8	6 / .8	6 / .5
COLUMBIA, MO	37 / 30	8 / 0.4	7 / .7	6 / 1.3	5 / 2.6	5 / 4.	7 / 4.8	7 / 5.	7 / 4.1	7 / 3.	7 / 1.7	6 / .8	7 / .4
ST. LOUIS, MO	49 / 30	7 / 0.2	7 / .4	6 / 1.	5 / 2.1	6 / 3.8	6 / 4.7	7 / 5.	7 / 4.	8 / 2.7	7 / 1.3	6 / .6	7 / .2
SPRINGFIELD, MO	61 / 30	6 / 0.1	6 / .3	6 / 1.	6 / 2.1	5 / 3.7	6 / 4.6	6 / 4.9	6 / 3.9	7 / 2.5	6 / 1.3	6 / .5	6 / .2
BILLINGS, MT	72 / 30	8 / 0.0	7 / .2	7 / 1.	6 / 2.4	6 / 3.9	5 / 4.8	8 / 5.1	9 / 4.1	8 / 2.5	9 / 1.2	9 / .5	9 / .1
GREAT FALLS, MT	69 / 30	7 / 0.2	7 / .6	7 / 1.2	6 / 2.7	6 / 4.1	5 / 5.1	8 / 5.2	8 / 4.4	8 / 3.	9 / 1.7	9 / .7	8 / .2
HELENA, MT	66 / 30	8 / 0.1	8 / .4	7 / 1.2	7 / 2.7	6 / 4.3	5 / 5.3	8 / 5.5	8 / 4.5	9 / 3.	10 / 1.6	9 / .6	8 / .2
MISSOULA, MT	62 / 30	5 / 1.7	6 / 2.3	6 / 3.4	6 / 4.7	6 / 5.5	5 / 6.1	8 / 6.	8 / 5.6	8 / 4.6	7 / 3.4	5 / 2.2	5 / 1.7
GRAND ISLAND, NE	68 / 30	10 / 1.2	10 / 1.9	8 / 2.9	7 / 4.3	6 / 5.	6 / 5.8	7 / 5.7	8 / 5.2	8 / 4.3	10 / 3.1	12 / 1.9	12 / 1.2
LINCOLN, NE	35 / 30	10 / 0.7	10 / 1.1	7 / 2.1	6 / 3.5	6 / 4.5	6 / 5.4	7 / 5.9	7 / 5.1	8 / 3.7	9 / 2.3	9 / 1.3	10 / .7
NORFOLK, NE	61 / 30	10 / 0.6	10 / 1.1	8 / 2.1	6 / 3.4	6 / 4.5	6 / 5.3	7 / 5.6	7 / 4.9	8 / 3.7	10 / 2.3	10 / 1.2	10 / .7
NORTH PLATTE, NE	54 / 30	12 / 0.7	10 / 1.2	9 / 2.2	7 / 3.5	6 / 4.6	6 / 5.4	7 / 5.5	7 / 4.9	9 / 3.7	10 / 2.3	12 / 1.3	14 / .7
OMAHA (NORTH), NE	18 / 30	10 / 0.5	8 / .9	6 / 1.6	5 / 2.8	5 / 4.	6 / 5.3	6 / 6.1	7 / 5.1	6 / 3.2	8 / 1.7	9 / .7	8 / .4
SCOTTSBLUFF, NE	63 / 30	10 / 0.1	10 / .4	8 / 1.2	7 / 2.7	6 / 4.1	6 / 5.3	7 / 5.9	9 / 5.	9 / 3.	10 / 1.6	12 / .6	10 / .2
VALENTINE, NE	51 / 30	12 / 0.4	11 / .8	9 / 1.5	7 / 2.7	6 / 4.	6 / 5.1	7 / 5.9	8 / 4.9	9 / 3.	10 / 1.6	12 / .7	12 / .4
ELY, NV	68 / 30	9 / 0.4	7 / .8	7 / 1.5	8 / 2.8	8 / 4.	12 / 5.3	10 / 6.1	10 / 5.1	12 / 3.1	12 / 1.7	10 / .7	9 / .4
LAS VEGAS, NV	58 / 30	14 / 0.4	13 / .7	14 / 1.3	23 / 2.7	23 / 3.9	34 / 5.	18 / 5.7	18 / 4.9	23 / 3.	23 / 1.5	23 / .5	18 / .2
RENO, NV	64 / 30	9 / 0.4	8 / .8	9 / 1.6	12 / 3.	12 / 4.1	14 / 5.2	18 / 6.1	18 / 5.1	17 / 3.2	18 / 1.6	12 / .6	9 / .4
WINNEMUCCA, NV	57 / 30	7 / 0.6	7 / 1.	8 / 2.	9 / 3.4	9 / 4.6	12 / 5.8	18 / 5.9	18 / 5.1	14 / 3.7	12 / 2.3	8 / 1.1	7 / .6
CONCORD, NH	65 / 30	6 / 0.6	6 / 1.	6 / 2.	5 / 3.5	5 / 4.8	5 / 5.8	6 / 6.	7 / 5.1	6 / 3.7	7 / 2.3	5 / 1.2	6 / .6

NEWARK, NJ	65 / 30	6 / 0.6	6 / 1.1	5 / 2.	5 / 3.4	5 / 4.6	6 / 5.8	6 / 6.1	6 / 5.4	6 / 3.9	6 / 2.3	6 / 1.2	6 / .6
ALBUQUERQUE, NM	67 / 30	14 / 0.5	11 / .9	12 / 1.8	14 / 3.4	12 / 4.6	14 / 5.7	7 / 5.7	7 / 4.9	10 / 3.5	12 / 2.2	14 / 1.1	12 / .5
CLAYTON, NM	57 / 30	14 / 0.5	13 / .9	12 / 1.7	10 / 3.2	8 / 4.4	8 / 5.3	7 / 5.4	7 / 4.6	10 / 3.3	14 / 2.1	14 / .9	14 / .5
ROSWELL, NM	34 / 30	14 / 0.7	13 / 1.2	14 / 2.	17 / 3.4	12 / 4.6	12 / 5.9	9 / 6.6	7 / 5.6	9 / 3.9	12 / 2.3	14 / 1.1	14 / .6
ALBANY, NY	60 / 30	5 / 0.5	6 / .9	5 / 1.7	5 / 3.2	5 / 4.6	5 / 5.9	6 / 6.3	6 / 5.4	6 / 3.7	7 / 2.2	5 / .9	5 / .5
BINGHAMTON, NY	55 / 30	4 / 0.7	4 / 1.2	4 / 2.	5 / 3.3	5 / 4.6	5 / 6.	6 / 7.1	6 / 6.1	6 / 4.3	6 / 2.4	4 / 1.1	4 / .6
BUFFALO, NY	63 / 30	3 / 0.9	4 / 1.3	4 / 2.	4 / 3.2	5 / 4.5	6 / 5.9	6 / 6.7	6 / 5.7	5 / 4.	6 / 2.4	4 / 1.2	3 / .7
SYRACUSE, NY	57 / 30	3 / 0.9	4 / 1.2	4 / 2.1	4 / 3.2	5 / 4.4	5 / 5.2	6 / 5.2	6 / 4.6	5 / 3.5	5 / 2.3	4 / 1.3	4 / .9
CHARLOTTE, NC	67 / 30	6 / 1.2	6 / 1.9	6 / 2.9	6 / 4.4	6 / 5.6	6 / 6.7	5 / 6.6	6 / 5.6	7 / 4.4	7 / 2.9	7 / 1.7	6 / 1.1
RALEIGH, NC	62 / 30	6 / 1.6	6 / 2.3	6 / 3.4	6 / 4.8	6 / 6.	6 / 7.1	5 / 6.7	6 / 6.	7 / 4.7	7 / 3.4	6 / 2.2	6 / 1.6
WILMINGTON, NC	55 / 30	6 / 0.5	6 / .8	6 / 1.6	7 / 3.	6 / 4.4	6 / 5.4	5 / 5.6	5 / 4.8	6 / 3.3	7 / 2.	7 / .9	6 / .5
BISMARCK, ND	67 / 30	8 / 0.4	8 / .7	7 / 1.3	8 / 2.5	7 / 3.8	5 / 4.6	7 / 4.8	7 / 4.	8 / 2.8	10 / 1.7	9 / .8	8 / .5
FARGO, ND	64 / 30	7 / 0.5	7 / .7	8 / 1.3	7 / 2.6	6 / 3.8	6 / 4.6	7 / 4.8	7 / 4.	7 / 3.	9 / 1.7	9 / .8	7 / .5
WILLISTON, ND	45 / 30	7 / 0.6	8 / .9	8 / 1.6	7 / 2.7	7 / 3.8	5 / 4.5	7 / 4.5	8 / 4.	9 / 2.7	10 / 2.	9 / 1.1	7 / .7
AKRON, OH	58 / 30	4 / 0.6	4 / 1.	4 / 1.7	4 / 3.	5 / 4.1	5 / 4.8	6 / 5.	7 / 4.3	6 / 3.1	6 / 2.	5 / 1.1	4 / .6
COLUMBUS, OH	67 / 30	5 / 0.6	5 / .9	5 / 1.6	5 / 2.7	5 / 3.8	5 / 4.6	6 / 4.6	7 / 4.	7 / 3.	7 / 1.8	5 / .9	5 / .6
DAYTON, OH	63 / 30	5 / 0.5	6 / .7	5 / 1.5	5 / 2.7	5 / 4.	6 / 5.	6 / 5.1	7 / 4.3	7 / 3.1	7 / 1.8	5 / .8	6 / .5
MANSFIELD, OH	47 / 30	5 / 0.5	5 / .8	5 / 1.5	5 / 2.7	5 / 4.1	5 / 5.1	6 / 5.2	6 / 4.4	6 / 3.1	7 / 1.8	5 / .8	5 / .5
OKLAHOMA CITY, OK	67 / 30	10 / 1.2	8 / 1.8	8 / 2.8	8 / 4.	7 / 4.9	7 / 5.6	9 / 5.5	9 / 4.9	8 / 3.9	9 / 2.7	10 / 1.8	10 / 1.2
TULSA, OK	67 / 30	9 / 1.1	8 / 1.7	7 / 2.7	7 / 3.9	6 / 4.9	6 / 5.4	9 / 5.5	9 / 4.9	8 / 3.8	9 / 2.7	9 / 1.7	9 / 1.1
ASTORIA, OR	53 / 30	3 / 1.2	4 / 1.8	4 / 2.8	4 / 4.1	5 / 5.	5 / 5.6	7 / 5.5	7 / 4.9	6 / 3.9	4 / 2.8	4 / 1.8	3 / 1.2
EUGENE, OR	64 / 30	4 / 1.5	4 / 2.	4 / 3.1	5 / 4.3	6 / 5.1	7 / 5.2	10 / 5.2	9 / 4.8	8 / 4.1	5 / 3.1	4 / 2.1	4 / 1.5
MEDFORD, OR	77 / 30	5 / 0.1	5 / .4	6 / 1.2	6 / 2.7	7 / 4.3	12 / 5.3	23 / 5.9	23 / 5.	14 / 3.1	8 / 1.7	5 / .6	5 / .2
PENDLETON, OR	71 / 30	5 / 0.1	6 / .3	6 / 1.	6 / 2.6	7 / 4.3	9 / 5.2	18 / 5.5	18 / 4.6	12 / 3.	8 / 1.6	5 / .6	5 / .1
GUAM, PC	49 / 30	4 / 0.1	4 / .4	4 / 1.2	4 / 2.7	4 / 4.3	3 / 5.4	3 / 5.9	3 / 5.	3 / 3.1	3 / 1.6	3 / .6	3 / .2
JOHNSTON ISLAND, PC	28 / 30	6 / 0.5	5 / .8	4 / 1.7	4 / 3.	5 / 4.1	5 / 5.1	5 / 5.2	5 / 4.4	4 / 3.2	4 / 2.	4 / .9	4 / .5
KOROR, PC	55 / 30	3 / 0.6	4 / 1.	4 / 2.	4 / 3.2	3 / 4.5	3 / 5.3	3 / 5.4	4 / 4.6	4 / 3.5	3 / 2.2	3 / 1.1	3 / .6
KWAJALEIN, MARSH. IS., PC	54 / 30	5 / 0.6	5 / 1.	5 / 2.	4 / 3.2	4 / 4.4	3 / 5.4	3 / 5.5	3 / 4.8	3 / 3.5	3 / 2.2	3 / 1.1	4 / .6
MAJURO, MARSHALL IS, PC	52 / 30	4 / 0.5	4 / .9	4 / 1.7	4 / 3.	3 / 4.1	3 / 5.1	3 / 5.1	3 / 4.4	3 / 3.2	3 / 2.	3 / .9	3 / .6
PAGO PAGO, AM. SAM., PC	40 / 30	3 / 0.5	3 / .8	3 / 1.6	4 / 3.1	4 / 4.4	4 / 5.4	4 / 5.5	4 / 4.6	4 / 3.4	4 / 2.	4 / .9	3 / .5
POHNPEI, CAROLINE IS., PC	55 / 30	3 / 0.5	4 / .8	3 / 1.6	3 / 3.	3 / 4.3	3 / 5.1	3 / 5.2	3 / 4.5	3 / 3.2	3 / 2.	3 / .9	3 / .5
CHUUK, E. CAROLINE IS., PC	55 / 30	4 / 1.1	4 / 1.8	4 / 2.8	4 / 4.	3 / 4.9	3 / 5.7	3 / 6.2	3 / 5.6	3 / 4.1	3 / 2.8	3 / 1.7	3 / 1.1
WAKE ISLAND, PC	50 / 30	6 / 1.1	6 / 1.7	5 / 2.8	4 / 4.1	4 / 4.9	4 / 5.7	3 / 6.	3 / 5.5	3 / 4.	3 / 2.8	4 / 1.7	5 / 1.1
YAP, W CAROLINE IS., PC	58 / 30	4 / 0.6	4 / 1.1	4 / 1.7	4 / 2.5	4 / 3.2	3 / 3.5	3 / 3.7	3 / 3.3	3 / 2.7	3 / 1.6	3 / .8	3 / .5
ERIE, PA.	53 / 30	4 / 0.6	4 / 1.2	5 / 2.	4 / 3.	5 / 4.	6 / 5.	7 / 5.7	6 / 5.	6 / 3.5	5 / 2.	4 / .8	4 / .6
PITTSBURGH, PA	54 / 30	4 / 0.7	4 / 1.4	4 / 2.3	5 / 3.5	5 / 4.9	5 / 6.	6 / 6.8	7 / 6.	6 / 4.3	6 / 2.4	5 / 1.1	4 / .6
AVOCA, PA	51 / 30	5 / 0.6	6 / .9	5 / 1.5	5 / 2.4	5 / 3.4	5 / 4.3	6 / 4.8	6 / 4.1	6 / 3.	7 / 1.6	5 / .7	5 / .5
PROVIDENCE, RI	53 / 30	5 / 3.2	6 / 3.5	5 / 4.	5 / 4.4	5 / 4.5	6 / 4.4	6 / 4.4	6 / 4.3	6 / 4.3	6 / 3.8	6 / 3.3	5 / 3.1
CHARLESTON AP,SC	64 / 30	7 / 3.5	7 / 3.9	7 / 4.1	8 / 4.3	7 / 4.1	5 / 4.	5 / 3.9	5 / 4.	6 / 4.	9 / 3.9	8 / 3.8	7 / 3.5
COLUMBIA, SC	59 / 30	6 / 3.1	6 / 3.4	6 / 3.7	6 / 3.7	6 / 3.7	6 / 3.5	5 / 3.7	6 / 3.8	7 / 3.8	7 / 3.5	7 / 3.2	6 / 2.9
GREENVIL-SPART AP, SC	44 / 30	6 / 3.1	6 / 3.3	6 / 3.5	6 / 3.5	6 / 3.5	6 / 3.5	5 / 3.5	6 / 3.7	6 / 3.7	7 / 3.5	6 / 3.3	6 / 3.1
ABERDEEN, SD	75 / 30	9 / 4.3	8 / 4.2	8 / 3.9	7 / 3.4	7 / 2.8	6 / 2.5	7 / 2.6	7 / 2.9	9 / 3.4	10 / 3.7	10 / 4.	9 / 4.1
HURON, SD	67 / 30	10 / 3.5	8 / 3.7	8 / 4.	7 / 4.1	6 / 4.1	6 / 4.1	7 / 4.4	7 / 4.5	9 / 4.5	10 / 4.4	10 / 4.	10 / 3.5
RAPID CITY, SD	64 / 30	9 / 3.2	8 / 3.3	7 / 3.5	6 / 3.8	6 / 3.8	5 / 3.8	7 / 3.9	8 / 4.	9 / 4.	10 / 3.9	10 / 3.5	10 / 3.2
SIOUX FALLS, SD	61 / 30	9 / 2.6	8 / 2.9	7 / 3.4	6 / 3.8	6 / 4.	5 / 4.1	7 / 4.1	7 / 4.	7 / 3.8	9 / 3.3	9 / 2.7	9 / 2.4
CHATTANOOGA, TN	76 / 30	5 / 3.4	5 / 3.6	5 / 4.	6 / 4.3	6 / 4.1	6 / 4.	5 / 4.	6 / 4.1	6 / 4.1	7 / 3.9	6 / 3.5	6 / 3.3
KNOXVILLE, TN	64 / 30	5 / 0.5	5 / .8	5 / 1.5	6 / 2.5	5 / 3.8	6 / 4.6	5 / 4.6	6 / 4.	6 / 2.8	7 / 1.7	6 / .8	6 / .5
MEMPHIS, TN	56 / 30	6 / 0.6	6 / 1.	6 / 1.8	6 / 3.2	6 / 4.4	6 / 5.2	6 / 5.4	7 / 4.6	7 / 3.4	7 / 2.1	6 / 1.1	6 / .6
NASHVILLE, TN	65 / 30	5 / 0.6	5 / 1.	5 / 1.8	6 / 3.2	5 / 4.4	6 / 5.2	6 / 5.4	6 / 4.6	7 / 3.4	7 / 2.1	6 / 1.1	6 / .6
ABILENE, TX	67 / 30	12 / 0.7	10 / 1.1	12 / 2.	10 / 3.2	8 / 4.4	9 / 5.2	12 / 5.2	10 / 4.6	10 / 3.4	10 / 2.2	12 / 1.2	12 / .7
AMARILLO, TX	65 / 30	12 / 0.6	11 / .9	12 / 1.8	10 / 3.1	7 / 4.4	7 / 5.2	8 / 5.2	7 / 4.5	10 / 3.3	12 / 2.1	14 / 1.1	12 / .6
AUSTIN, TX	65 / 30	8 / 0.5	7 / .8	8 / 1.6	8 / 2.8	7 / 4.1	9 / 5.	12 / 5.1	10 / 4.4	9 / 3.2	9 / 1.8	8 / .9	8 / .5

CORPUS CHRISTI, TX	67 / 30	8 / 0.6	8 / .9	10 / 1.7	12 / 3.1	9 / 4.4	9 / 5.2	12 / 5.4	10 / 4.5	6 / 3.3	9 / 2.	10 / 1.1	9 / .6
DALLAS-FORT WORTH, TX	53 / 30	9 / 0.6	8 / .9	8 / 1.6	8 / 2.8	7 / 3.9	9 / 4.8	12 / 5.	12 / 4.4	9 / 3.3	9 / 2.1	9 / 1.1	9 / .6
EL PASO, TX	67 / 30	14 / 1.6	13 / 2.2	18 / 3.2	23 / 4.3	18 / 5.	14 / 5.4	8 / 5.4	8 / 4.9	10 / 3.9	12 / 3.1	17 / 2.2	14 / 1.6
GALVESTON, TX	63 / 30	6 / 1.6	7 / 2.2	7 / 3.3	9 / 4.6	9 / 5.6	8 / 6.	7 / 6.	7 / 5.2	6 / 4.3	8 / 3.2	7 / 2.1	6 / 1.6
HOUSTON, TX	37 / 30	6 / 1.2	7 / 1.9	7 / 2.9	9 / 4.1	7 / 5.1	6 / 5.6	7 / 5.5	7 / 4.9	7 / 3.9	8 / 2.8	7 / 1.8	7 / 1.2
LUBBOCK, TX	60 / 30	14 / 0.2	11 / .6	12 / 1.3	12 / 2.8	8 / 4.4	8 / 5.3	9 / 5.9	9 / 5.1	10 / 3.3	10 / 1.8	14 / .7	14 / .2
MIDLAND-ODESSA, TX	59 / 30	14 / 0.2	13 / .7	18 / 1.5	14 / 3.	10 / 4.5	12 / 5.6	12 / 5.9	10 / 5.	10 / 3.4	12 / 2.	14 / .8	14 / .4
PORT ARTHUR, TX	53 / 30	6 / 0.5	6 / .9	7 / 1.7	7 / 3.	7 / 4.3	6 / 5.4	5 / 6.	5 / 5.2	6 / 3.5	7 / 2.	7 / .9	6 / .5
SAN ANGELO, TX	59 / 30	12 / 0.4	11 / .7	12 / 1.5	12 / 3.1	9 / 4.5	10 / 5.6	12 / 5.7	10 / 4.9	10 / 3.3	10 / 2.	12 / .8	14 / .4
SAN ANTONIO, TX	64 / 30	8 / 1.0	7 / 1.5	8 / 2.6	9 / 3.8	7 / 4.8	9 / 5.4	12 / 5.4	10 / 4.9	9 / 3.9	9 / 2.7	9 / 1.5	8 / 1.1
VICTORIA, TX	45 / 30	7 / 1.1	7 / 1.8	8 / 2.8	9 / 4.1	8 / 5.	7 / 5.8	8 / 5.6	7 / 5.1	6 / 3.9	8 / 2.8	9 / 1.8	7 / 1.2
WACO, TX	63 / 30	8 / 1.1	7 / 1.7	8 / 2.8	8 / 4.	7 / 5.	9 / 5.7	12 / 5.6	10 / 5.1	9 / 4.	9 / 2.7	9 / 1.7	9 / 1.1
WICHITA FALLS, TX	63 / 30	12 / 1.2	10 / 1.8	9 / 2.8	9 / 4.	7 / 4.9	9 / 5.8	10 / 5.7	10 / 5.2	9 / 4.	9 / 2.9	10 / 1.8	12 / 1.2
BURLINGTON, VT	63 / 30	5 / 1.1	5 / 1.7	5 / 2.7	5 / 4.	5 / 5.	5 / 5.7	5 / 5.7	5 / 5.1	5 / 4.	6 / 2.8	4 / 1.7	5 / 1.1
LYNCHBURG, VA	62 / 30	6 / 1.6	6 / 2.2	6 / 3.4	6 / 4.6	5 / 5.5	6 / 6.1	5 / 6.3	6 / 5.9	6 / 4.4	7 / 3.3	6 / 2.1	6 / 1.6
NORFOLK, VA	58 / 30	6 / 1.3	6 / 1.9	6 / 2.9	6 / 4.4	6 / 5.4	6 / 6.3	5 / 6.3	6 / 5.6	6 / 4.3	7 / 2.9	6 / 1.8	6 / 1.2
ROANOKE, VA	59 / 30	6 / 1.8	6 / 2.4	6 / 3.4	6 / 4.4	5 / 5.	6 / 5.8	5 / 6.1	6 / 5.7	6 / 4.7	7 / 3.5	6 / 2.5	6 / 1.8
OLYMPIA, WA	65 / 30	4 / 2.3	4 / 3.0	4 / 3.9	5 / 4.6	5 / 4.9	6 / 5.3	9 / 5.5	8 / 5.4	6 / 4.5	5 / 3.8	4 / 2.8	4 / 2.3
QUILLAYUTE, WA	40 / 30	3 / 2.1	4 / 2.8	4 / 3.8	4 / 4.5	4 / 5.	5 / 5.3	6 / 5.6	6 / 5.4	5 / 4.5	4 / 3.7	3 / 2.7	3 / 2.1
SPOKANE, WA	59 / 30	5 / 1.5	6 / 2.1	6 / 3.2	6 / 4.4	7 / 5.1	8 / 6.1	12 / 6.3	12 / 5.9	10 / 4.5	8 / 3.2	5 / 2.	5 / 1.5
YAKIMA, WA	60 / 30	7 / 2.1	7 / 2.8	9 / 3.9	10 / 5.1	10 / 5.6	12 / 6.1	18 / 6.3	18 / 6.	14 / 4.7	10 / 3.5	7 / 2.5	7 / 2.
SAN JUAN, PR	51 / 30	4 / 1.7	4 / 2.4	5 / 3.7	5 / 5.	4 / 6.2	4 / 7.3	3 / 6.8	4 / 6.1	4 / 4.7	4 / 3.5	4 / 2.2	3 / 1.7
CHARLESTON, WV	59 / 30	5 / 1.5	5 / 1.9	5 / 2.4	5 / 3.	5 / 3.3	5 / 3.7	5 / 3.8	6 / 3.5	6 / 3.1	6 / 2.4	5 / 1.8	5 / 1.5
HUNTINGTON, WV	45 / 30	5 / 1.5	5 / 2.2	5 / 3.3	5 / 4.6	5 / 5.6	5 / 6.3	5 / 6.2	6 / 5.5	6 / 4.3	6 / 3.2	5 / 2.	5 / 1.5
GREEN BAY, WI	57 / 30	6 / 1.8	7 / 2.4	6 / 3.4	6 / 4.3	6 / 5.	6 / 5.4	7 / 5.6	6 / 5.2	6 / 4.3	7 / 3.4	6 / 2.4	6 / 1.8
LA CROSSE, WI	54 / 30	7 / 1.7	7 / 2.4	7 / 3.8	6 / 5.1	6 / 6.	5 / 6.6	6 / 6.8	7 / 6.2	6 / 4.6	7 / 3.4	7 / 2.4	7 / 1.7
MADISON, WI	58 / 30	6 / 2.0	7 / 2.6	6 / 3.7	5 / 4.7	6 / 5.2	6 / 5.8	6 / 6.	7 / 5.7	6 / 4.6	7 / 3.7	6 / 2.5	7 / 2.
CASPER, WY	56 / 30	9 / 2.0	7 / 2.6	7 / 3.7	6 / 4.5	6 / 5.	7 / 5.6	8 / 5.7	10 / 5.5	9 / 4.5	9 / 3.5	9 / 2.6	9 / 2.1
LANDER, WY	60 / 30	12 / 1.5	10 / 2.1	8 / 3.2	7 / 4.5	7 / 5.5	9 / 6.3	10 / 6.7	12 / 6.	10 / 4.5	10 / 3.2	10 / 2.	12 / 1.5
SHERIDAN, WY	66 / 30	7 / 0.6	7 / 1.1	6 / 2.1	6 / 3.2	6 / 4.6	6 / 5.9	8 / 6.6	9 / 5.6	8 / 3.9	8 / 2.3	8 / 1.1	7 / .6
ALGERIES CITY, ALGERIA	1 / 1	4 / 1.0	6 / 1.5	4 / 1.9	12 / 2.4	6 / 3.7	12 / 4.8	10 / 5.0	10 / 4.6	6 / 3.5	5 / 2.4	3 / 1.6	4 / 1.3

Conclusion

The mid- and end-season default crop coefficient values in FAO-56 were developed for a climate that has an average wind speed of 4 ½ mph (2 m/s) and an average minimum relative humidity value of 45%. If the climate of a local region deviates very much from these values then the "off-the-shelf crop coefficient values" from FAO-56 may be causing over- or under-irrigation.

The initial crop coefficient for the single coefficient procedure (K_{c_ini}), which is the method normally used in computer program, is influenced by interval between wetting events. The default FAO-56 values w3ere based on approximately a 10-day interval. If rainfall/irrigation events occur more frequently then this the default FAO-56 values can greatly underestimate crop water use.

The enclosed simple procedures provide a method to adjust the default FAO-56 crop coefficient values for any locale in the USA and her possessions.

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