

User's Guide

C U P⁺- M

Consumptive Use Program ^{Plus}

Version 1.0

California Land and Water Use, Department of Water Resources and Department of Air, Land and Water Resources, University of California, Davis

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Software Recommendations:

Minimum Platform:

IBM PC compatible Pentium-equivalent or higher, 16MB RAM, Windows 95/98, NT 4.0, Windows 2000, Windows XP

Recommended Platform:

32 MB RAM, or greater

Spreadsheet:

Windows Excel 97, Excel 2000, Excel XP

OVERVIEW

A user-friendly Microsoft Excel application program “Consumptive Use Program +” or “CUP+” was developed to help growers and water agencies to improve the dissemination of crop coefficient (K_c), crop evapotranspiration (ET_c), and evapotranspiration of applied water (ET_{aw}), which provides an estimate of the net irrigation water diversion needed to produce a crop. A major goal of this project was to estimate daily soil water balances for surfaces that account for evapotranspiration losses and water contributions from rainfall, seepage of groundwater, fog, dew, and irrigation. CUP+ computes reference evapotranspiration (ET_o) from daily solar radiation, maximum and minimum temperature, dew point temperature, and wind speed using the daily Penman-Monteith equation. In addition to using daily weather data, it uses monthly means of weather data to estimate ET_o using the daily Penman-Monteith and Hargreaves-Samani equations. The program uses a curve fitting technique to derive one year of daily weather and ET_o data from the monthly data. In addition, daily rainfall data are used to estimate bare soil evaporation as a function of mean of ET_o and wetting frequency in days. A bare soil K_c value is calculated to estimate the off-season evapotranspiration and as a baseline for in-season K_c calculations. CUP+ accounts for the influence of orchard cover crops on K_c values and it accounts for immaturity effects on K_c values for tree and vine crops. Further, the program computes and applies all ET_o and K_c values on a daily basis to determine crop water requirements by month, by season, by year. The application outputs a wide range of tables and charts that are useful for irrigation planning. CUP+’s input and output data are in metric units.

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Chapter 1

EXCEL WORKSHEETS

CUP+ has 28 Excel worksheets. The worksheets are “Disclaimer,” “HelpAbout,” “Help,” “ETo Zones Map,” “ETo Zones,” “Monthly Climate Input,” “Daily Weather Input,” “Seepage;Fog;Dew Input,” “Input_Output,” “Crop References,” “Climate Change,” “Kc, ETc, and ETaw Calculations,” “Weather Output,” “Daily Water Balance,” “Kc Chart,” “ETo Chart,” “Daily ETc and ETaw Chart,” “ETo-ETc-ETaw Chart,” “CETaw,” “NA vs. DETaw Plot,” “WB Chart,” “Summary of Kc,” “Summary of ETo,” “Summary of ETc,” “Summary of ETaw.” The first nine worksheets are explained below.

The ‘Disclaimer’ Worksheet:

This worksheet explains that California Department of Water Resources is not responsible for the accuracy, completeness, and quality of the data predicted from the CUP+ program.

The ‘HelpAbout’ Worksheet:

It provides information about the program.

The ‘About CUP+’ Worksheet:

This worksheet provides documentation and explains the CUP+ program.

The ‘Help’ Worksheet:

It explains the various components of the program and also provides step-by-step instructions how to manage the CUP+ program for making daily soil water balance calculations for crops.

The ‘ETo Zones Map’ Worksheet:

CUP+ contains a map showing 18 zones of similar ET_o rates in inches per day for California, which can be input into the CUP+ model for estimating crop evapotranspiration.

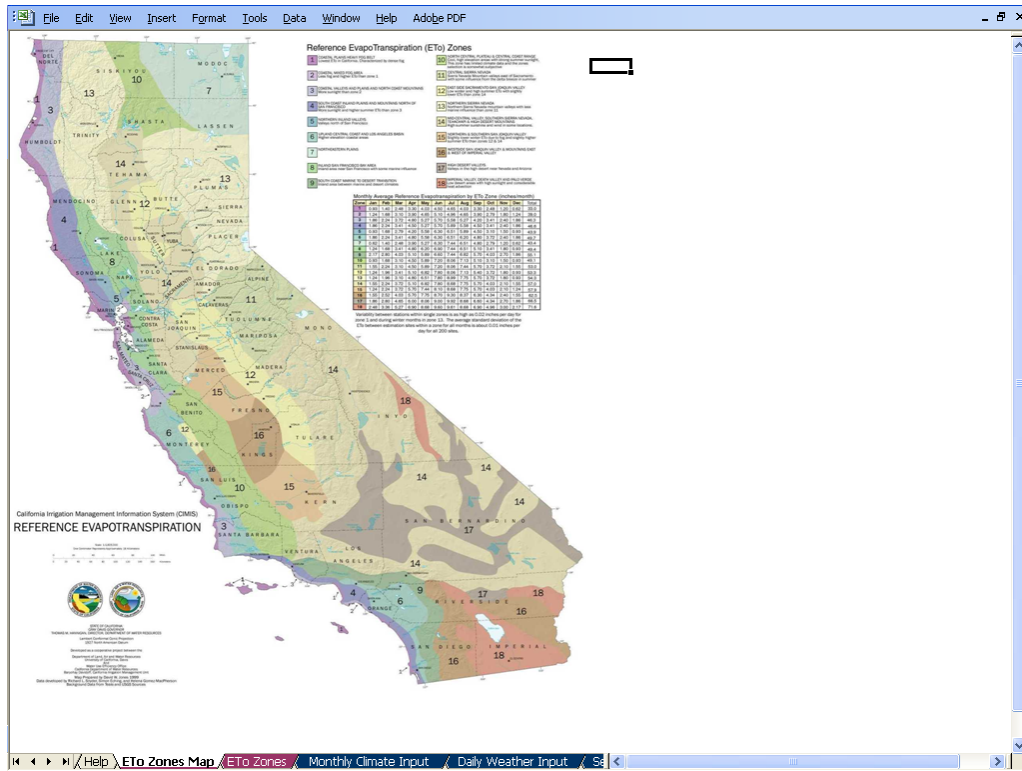


Figure 1. Showing the 'ETo Zone Map' worksheet.

The 'ETo Zones' Worksheet:

CUP+ also contains a table of monthly mean ET_o rates in inches per day by ET_o zones. When you enter an ET_o zone number in the program, CUP+ will automatically use the corresponding monthly mean ET_o values for the crop evapotranspiration calculations.

Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.76	1.27	2.03	2.79	3.30	3.81	3.81	3.30	2.79	2.03	1.02	0.51
2	1.02	1.52	2.54	3.30	3.81	4.32	4.06	3.81	3.30	2.29	1.52	1.02
3	1.52	2.03	3.05	4.06	4.32	4.83	4.57	4.32	3.56	2.79	2.03	1.52
4	1.52	2.03	2.79	3.81	4.32	4.83	4.83	4.57	3.81	2.79	2.03	1.52
5	0.76	1.52	2.29	3.56	4.57	5.33	4.83	4.83	3.81	2.54	1.27	0.76
6	1.52	2.03	2.79	4.06	4.57	5.33	5.33	5.08	4.06	3.05	2.03	1.52
7	0.51	1.27	2.03	3.30	4.32	5.33	6.10	5.33	4.06	2.29	1.02	0.51
8	1.02	1.52	2.79	4.06	5.08	5.84	6.10	5.33	4.32	2.79	1.52	0.76
9	1.78	2.54	3.30	4.32	4.83	5.59	6.10	5.59	4.83	3.30	2.29	1.52
10	0.76	1.52	2.54	3.81	4.83	6.10	6.60	5.84	4.32	2.54	1.27	0.76
11	1.27	2.03	2.54	3.81	4.83	6.10	6.60	6.10	4.83	3.05	1.78	1.27
12	1.02	1.78	2.79	4.32	5.59	6.60	6.60	5.84	4.57	3.05	1.52	0.76
13	1.02	1.78	2.54	4.06	5.33	6.60	7.37	6.35	4.83	3.05	1.52	0.76
14	1.27	2.03	3.05	4.32	5.59	6.60	7.11	6.35	4.83	3.30	1.78	1.27
15	1.02	2.03	3.05	4.83	6.10	6.86	7.11	6.35	4.83	3.30	1.78	1.02
16	1.27	2.29	3.30	4.83	6.35	7.37	7.62	6.86	5.33	3.56	2.03	1.27
17	1.52	2.54	3.81	5.08	6.60	7.62	8.13	7.11	5.59	3.56	2.29	1.52
18	2.03	3.05	4.32	5.84	7.11	8.13	7.87	7.11	5.84	4.06	2.54	1.78
Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Daily Weather Input Data	0.92	1.41	2.83	3.83	5.27	6.64	7.27	6.17	4.82	3.41	1.33	0.89

Figure 2. Showing the 'ET_o Zones' worksheet .

The cells at the bottom of the table show the monthly mean ET_o rates in mm/day that are used by CUP+ for estimating crop evapotranspiration. The cell on the far left-hand side at the bottom shows type of ET_o data.

The 'Monthly Climate Input' Worksheet:

This worksheet is used to input monthly mean weather, ET_o , and E_{pan} data for estimating crop evapotranspiration (ET_c). Weather data include: solar radiation, maximum and minimum temperature, dew point temperature, wind speed, and total precipitation and number of rainy days. If monthly mean ET_o data are input directly, those values are used by CUP+. If the solar radiation, temperature, and wind speed data are input, then the

Penman-Montieth equation is used to calculate ET_o . If only temperature data are input into the table, then the Hargreaves-Samani equation is used to calculate ET_o . If pan data are input, the program automatically estimates daily ET_o rates using a fetch value (i.e. upwind distance of grass around the pan).

CIMIS and Pan Site Description Input

Station Name: Davis

Latitude (deg): 38.5

Elevation (m): 18.0

Pan Fetch (m):

Albedo, α : 0.23

Atm. Press. (kPa): 101.09

Solar Const. G_{sc} : 0.08

ϕ (latitude in radians): 0.67

Stefan-B. Const., σ : 4.90E-09

λ (MJ kg⁻¹): 2.45

γ (kPa °C⁻¹): 0.067

Input ET_o and/or Epan data or daily average weather data to calculate PM and/or HS ET_o

Month	R_s (MJ m ⁻² d ⁻¹)	T_{max} (°C)	T_{min} (°C)	U_2 (m s ⁻¹)	T_d (°C)	Pcp (mm)	NRD (#)	ET_o (mm day ⁻¹)	E_{pan} (mm day ⁻¹)	PM (mm day ⁻¹)	HS (mm day ⁻¹)
Canopy Resistance (s m⁻¹) = 70.00											
Use priority >>> 1 fetch 2 3											
1	6.5	12.7	3.6	2.6	5.4	102.6	8.6			1.01	1.17
2	10.4	16.0	5.0	2.7	6.6	107.3	6.5			1.70	1.87
3	15.9	19.0	6.0	2.7	7.2	69.6	5.8			2.74	2.92
4	21.5	22.8	7.8	3.0	6.9	17.8	1.7			4.40	4.27
5	25.5	26.3	10.4	3.0	9.2	19.0	1.5			5.54	5.42
6	28.8	30.1	12.7	3.0	10.8	6.0	0.6			6.80	6.42
7	29.0	32.9	13.7	2.7	12.7	3.3	0.3			7.11	6.87
8	26.0	32.5	13.2	2.5	11.5	2.3	0.1			6.51	6.13
9	20.9	30.8	12.1	2.4	10.2	7.4	0.7			5.36	4.82
10	14.8	26.3	9.6	2.4	7.6	17.6	1.5			3.86	3.13
11	9.4	18.4	5.4	2.4	5.3	35.7	3.5			2.10	1.71
12	6.5	12.8	2.7	2.7	4.3	60.8	4.9			1.15	1.10
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

List of Symbols and their Common Units

R_s - solar radiation (MJ m ⁻² d ⁻¹)	T_d - dew point temperature (°C)	NRD - # rainy days per month
T_{max} - maximum temperature (°C)	U_2 - wind speed at 2 m height (m s ⁻¹)	(with Pcp > 2 x daily ET_o)
T_{min} - minimum temperature (°C)	Pcp - precipitation (mm)	E_{pan} - pan evaporation (mm/day)

Figure 3. The 'Monthly Climate Input' worksheet allows for monthly mean weather, ET_o , and E_{pan} data input.

The 'Daily Weather Input' Worksheet:

This worksheet is used to input measured daily weather data from California Irrigation Management Information System (CIMIS) to estimate daily soil water balance for crops. Weather data include: solar radiation, maximum and minimum temperature, dew point temperature, wind speed, and precipitation. If the solar radiation, temperature, and wind speed data are input, the program automatically computes daily ET_o rates using the daily

Penman-Montieth equation. If only temperature data are input into the table, then the Hargreaves-Samani equation is used to calculate ET_o .

CIMIS Site Description Input

Station Name is: Colusa

Latitude (deg) is: 39.20

Elevation (m) is: 17.00

Canopy Resistance (s/m): 70.00

r_a (s/m): 208.00

albedo, α : 0.23

Atm. Press. (kpa): 101.10

Solar Const. G_{sc} : 0.08

ϕ (rad): 0.68

Stefan-B. Const., σ : 0.00

λ (MJ kg⁻¹): 2.45

γ (Kpa °C⁻¹): 0.067

r_o/r_a : 0.34

Input daily raw weather data to calculate PM and/or HS ET_o

Date	DOY	R_i MJ m ⁻² d ⁻¹	T_{max} °C	T_{min} °C	U_2 m s ⁻¹	T_d °C	Pcp mm	ET _o mm
1/1/1996	1	8.73	21.00	9.30	3.70	5.50	0.00	3.01
1/2/1996	2	8.82	20.10	10.30	3.30	8.30	0.00	2.27
1/3/1996	3	3.46	13.10	6.20	1.40	9.30	0.00	0.49
1/4/1996	4	5.96	14.30	6.10	1.10	8.60	0.00	0.66
1/5/1996	5	5.01	14.00	5.60	1.30	8.60	0.00	0.63
1/6/1996	6	9.08	16.80	3.10	0.90	7.10	0.00	0.80
1/7/1996	7	6.14	13.60	4.20	0.90	7.80	1.00	0.59
1/8/1996	8	4.24	12.20	4.50	0.90	8.00	0.00	0.50
1/9/1996	9	0.86	9.90	7.10	2.30	8.50	2.00	0.06
1/10/1996	10	9.59	17.70	5.90	4.50	6.10	0.00	2.26
1/11/1996	11	5.70	14.60	1.80	1.30	6.40	0.00	0.77
1/12/1996	12	2.85	7.10	1.50	1.30	5.50	0.00	0.18
1/13/1996	13	2.94	6.70	4.30	1.30	5.70	0.00	0.29
1/14/1996	14	1.64	6.20	4.40	1.60	5.30	1.00	0.14
1/15/1996	15	2.42	10.40	5.90	4.10	7.90	4.00	0.31
1/16/1996	16	5.62	19.80	5.90	4.60	9.80	20.00	1.85
1/17/1996	17	8.99	13.00	3.40	2.00	2.50	0.00	1.32
1/18/1996	18	1.64	12.20	3.50	3.20	6.90	11.00	0.48
1/19/1996	19	9.51	15.50	1.40	1.80	5.20	0.00	1.16
1/20/1996	20	3.72	12.60	2.30	4.30	7.10	7.00	0.62
1/21/1996	21	9.68	14.50	5.60	2.30	4.20	0.00	1.55
1/22/1996	22	10.72	11.10	0.10	2.40	0.90	0.00	1.27
1/23/1996	23	2.59	7.10	3.70	5.50	4.00	1.00	0.58
1/24/1996	24	5.01	14.20	6.80	5.90	9.30	4.00	0.91
1/25/1996	25	10.98	13.80	1.30	1.60	1.20	0.00	1.37
1/26/1996	26	3.72	8.30	-0.10	1.00	3.00	5.00	0.54
1/27/1996	27	7.61	15.50	3.50	5.20	7.60	15.00	1.34

Symbols and their Common Units

R_i - solar radiation (MJ m⁻²d⁻¹)

T_{max} - maximum temperature (°C)

T_{min} - minimum temperature (°C)

T_d - dew point temperature (°C)

U_2 - wind speed at 2 m height (m s⁻¹)

Pcp - precipitation (mm)

ET_o - reference evapotranspiration (mm d⁻¹)

Figure 4. The 'Daily Weather Input' worksheet allows for daily measured weather data input.

The "Seepage;Fog;Dew Input" worksheet:

This worksheet is used to enter water contributions from seepage of groundwater, fog, and dew by month. The daily change in soil water content in the program is calculated as $Dsw = ET_c - Es_{fd} - Er$ for agricultural crops, where ET_c is the crop evapotranspiration, Es_{fd} is the effective water contribution from seepage, fog, and dew, and Er is the effective rainfall.

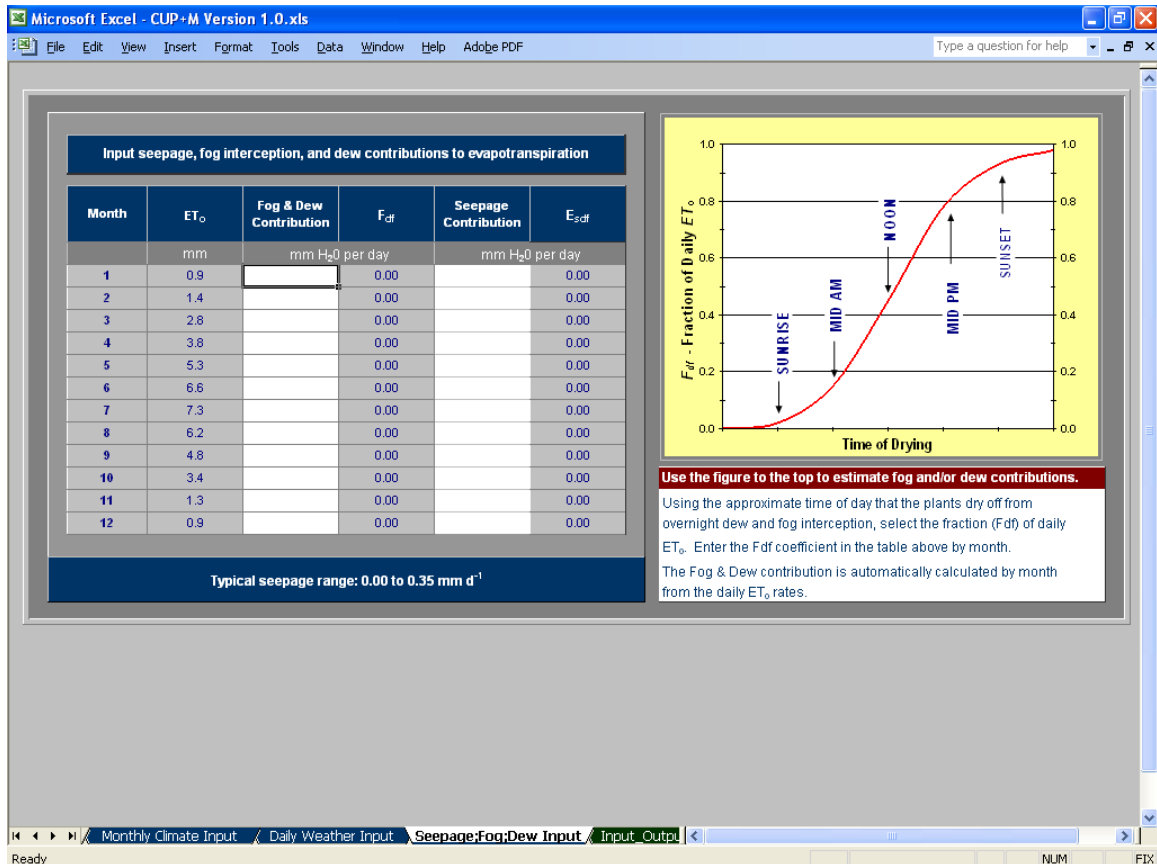


Figure 5. The 'Seepage;Fog;Dew Input' worksheet allows for monthly water contributions from seepage of groundwater, fog, and dew.

The 'Input_Output' Worksheet:

This worksheet is used to select or enter the weather data and crop/soil information into the program. The cells on the left-hand side of the worksheet are used for selecting or entering the input data into the program and the cells on the right-hand side of the worksheet are used for displaying the output values. After input data requirements are entered into the 'Input_Output' worksheet, it displays the summary of inputs and monthly and seasonal outputs. The output consists of monthly mean of daily crop coefficients for

currently entered crop/soil information during the growing season, monthly total values of ET_o , ET_c , and ET_{aw} and seasonal total values of ET_o , ET_c , and ET_{aw} .

CUP plus - M Version

Summary of Input Data

Daily Weather Input: 66
Plant Year: 1996

Crop/Soil Data Entry

Your Crop No. is: 3.04
Crop is: Kiwifruit
Enter Starting Date:
Default Starting Date: 1-May-96
Enter End Date:
Default Ending Date: 31-Oct-96
AWH Capacity (mm/mm): 0.13
Max. Soil Depth (mm): 2000
Max. Root Depth (mm): 1500
Allow. Depl. (%): 50

Enter 1st Cover Crop (mon/day)

Start Date (mon/day):
End Date (mon/day):
Enter 2nd Cover Crop (mon/day)

Start Date (mon/day):
End Date (mon/day):
Enter Ground Cover in Percentage (%)

C:
D:

Calculated ET_o , ET_c , and ET_{aw} (mm/mon) and weighted mean K_c values

Month:	May	Jun	Jul	Aug	Sep	Oct
K_c ():	0.64	1.02	1.05	1.05	1.03	1.02
ET_o (mm):	163.47	199.32	225.26	191.15	144.65	105.64
ET_c (mm):	100.11	202.29	235.43	199.79	149.40	107.15
ET_{aw} (mm):	62.11	201.29	235.43	199.78	149.39	21.81
Seasonal ET_o (mm):	1,029.50			Seasonal ET_c (mm):		
Seasonal ET_{aw} (mm):	869.81			Annual ET_{aw} (mm):		
				921.73		

Add Data to Summary Sheets

- * To copy and paste the cell values on summary worksheets, click the copy / paste button
- * To delete all summary cell values, click the delete button

Caution! Using the delete button will delete all existing data in the summary worksheets

Copy / Paste Delete

Developed by Land and Water Use, California Department of Water Resources
And
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DEPARTMENT OF WATER RESOURCES
LAND AND WATER USE PROGRAM

UNIVERSITY OF CALIFORNIA, DAVIS
LAND, AIR AND WATER RESOURCES

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Figure 6. The 'Input_Output' worksheet allows for daily, monthly mean weather, ET_o , E_{pan} and crop/soil information selection.

The 'Crop References' Worksheet:

CUP+ provides a list of crop numbers and crop names in the 'Crop References' worksheet. This worksheet also contains the percentage of the season to various growths, K_c values at critical growth points, and plant and harvest dates for the season, which are used as default values in the program. If crops are not available from the list, you can enter your own crop numbers, crop names, estimated growth dates, K_c information, and plant and harvest dates into this worksheet. To add a new crop in the worksheet, use the

blank rows at the bottom of the worksheet for entering your own crop information into the program.

Lengths of Crop Development Stages for Various Crops									
Crop Number	Crop Name	% season B	% season C	% season D	K _c A-B	K _c C-D	K _c E	Planting Date	Harvest Date
1.43	Tomato	25	50	80	0.30	1.10	0.65	1-Apr-96	31-Aug-96
1.44	Vegetables	33	67	92	0.80	0.90	0.90	1-Mar-96	31-Aug-96
1.45	Wheat	20	45	75	0.33	1.10	0.15	1-Nov-96	31-May-97
1.46	Watermelon	20	50	75	0.80	1.00	0.75	1-Apr-96	15-Nov-96
2.01	Alfalfa (annual)	25	50	75	1.00	1.00	1.00	1-Jan-96	31-Dec-96
2.02	Improved Pasture	25	50	75	0.95	0.95	0.95	1-Jan-96	31-Dec-96
2.03	Turfgrass (cool-season)	25	50	75	0.80	0.80	0.80	1-Jan-96	31-Dec-96
2.04	Turfgrass (warm-season)	25	50	75	0.60	0.60	0.60	1-Jan-96	31-Dec-96
3.01	Almonds	0	50	90	0.55	1.05	0.65	1-Mar-96	15-Oct-96
3.02	Apple	0	50	75	0.55	1.05	0.80	1-Apr-96	15-Nov-96
3.03	Grapevines	0	25	75	0.45	0.80	0.35	1-Apr-96	1-Nov-96
3.04	Kiwifruit	0	22	67	0.30	1.05	1.00	1-May-96	31-Oct-96
3.05	Stone fruits	0	50	90	0.55	1.05	0.65	1-Mar-96	15-Oct-96
3.06	Walnuts	0	50	75	0.55	1.05	0.80	1-Apr-96	15-Nov-96
4.01	Avocado	0	33	67	0.70	0.70	0.70	1-Jan-96	31-Dec-96
4.02	Citrus	0	33	67	1.30	1.00	1.30	1-Jan-96	31-Dec-96
4.03	Citrus (desert)	0	33	67	1.30	1.00	1.30	1-Jan-96	31-Dec-96
4.04	Date Palm	0	33	67	0.95	0.95	0.95	1-Jan-96	31-Dec-96
4.05	Evergreen	0	33	67	1.15	1.15	1.15	1-Jan-96	31-Dec-96
4.06	Olives	0	33	67	0.80	0.80	0.80	1-Jan-96	31-Dec-96
Enter new crops below									

Figure 7. The 'Crop References' worksheet.

Crops have been divided into four categories: type-1 crops (vegetable crops), type-2 crops (pasture), type-3 crops (deciduous tree and vine crops), and type-4 crops (subtropical tree crops).

- Type-1 crops are the row crops with initial, rapid, mid season, and late season stages. The season is separated into initial, rapid, midseason and late season growth periods.

- Type-2 crops are the field crops with a fixed crop coefficient all year. Pasture crops start on January 1 and end on December 31.
- Type-3 crops are the deciduous tree and vine crops without the initial growth period.
- Type-4 crops are the subtropical tree crops. The crop coefficient values are fixed all year. They start on January 1 and end December 31.

The crop numbers have one digit to the left and two digits to the right of decimal point. The left-hand digit identifies the crop type and the right-hand two digits identify the crop.

Chapter 2

WHERE TO START

To begin working, you need to select or enter weather and crop/soil information into the program to execute the CUP+ application to make the daily water balance calculations for a crop.

Reading Weather Data:

It is possible to enter weather data from other sites within or outside of California as long as the input data are in the same format as used in the CUP+ program. You can use either monthly mean weather data or raw daily weather data from CIMIS in CUP+ for the calculations of crop evapotranspiration (ET_o) and evapotranspiration of applied water (ET_{aw}). Weather data include: solar radiation, maximum and minimum temperature, dew point temperature, wind speed, and rainfall.

The application is specifically designed to use daily weather data and soil/crop information to compute daily soil water balance of individual crops for the period of one year. Using monthly mean weather and ET_o data, one year daily data are derived first and then ET_c calculations are made for each day in the period from the predicted data. In California, monthly mean weather data are available on the California Irrigation Management Information System (CIMIS) Internet WEB site. The monthly mean weather and ET_o data averaged over the period of record from CIMIS are also available from the California Climate Data program on your CD.

The program allows for input of daily mean evaporation pan and rainfall data by month. If pan data are input, then the program automatically estimates daily ET_o rates using a fetch value (i.e. upwind distance of grass around the pan) without the need for wind speed and relative humidity data.

Entering Monthly Weather Data:

Monthly mean weather, ET_o , and pan evaporation data by day can be input and analyzed by the CUP+ model. The data can come from the California Irrigation Management Information System (CIMIS), the ETo Zones map, or as raw pan evaporation data. Raw monthly mean weather and ET_o data can be input into the CUP+ model with the same format as in the table shown in Figure 8.

CIMIS and Pan Site Description Input

Station Name: Davis

Latitude (deg): 38.5

Elevation (m): 18.0

Pan Fetch (m): 100

albedo, α : 0.23

Atm. Press. (kPa): 101.09

Solar Const. G_{sc} : 0.08

ϕ (latitude in radians): 0.67

Stefan-B. Const., σ : 4.90E-09

λ (MJ kg⁻¹): 2.45

γ (kPa °C⁻¹): 0.067

Input ET_o and/or Epan data or daily average weather data to calculate PM and/or HS ET_o

Month	R_s (MJ m ⁻² d ⁻¹)	T_{max} (°C)	T_{min} (°C)	U_2 (m s ⁻¹)	T_d (°C)	Pcp (mm)	NRD (#)	ET_o (mm day ⁻¹)	E_{pan} (mm day ⁻¹)	PM (mm day ⁻¹)	HS (mm day ⁻¹)
Canopy Resistance ($s\ m^{-1}$) = 70.00											
Use priority >>> 1 fetch 2 3											
1	6.5	12.7	3.6	2.6	5.4	102.6	8.6			1.01	1.17
2	10.4	16.0	5.0	2.7	6.6	107.3	6.5			1.70	1.87
3	15.9	19.0	6.0	2.7	7.2	69.6	5.8			2.74	2.92
4		22.8	7.8	3.0	6.9	17.8	1.7				4.27
5		26.3	10.4	3.0	9.2	19.0	1.5				5.42
6	28.8	30.1	12.7	3.0	10.8	6.0	0.6	6.50		6.80	6.42
7	29.0	32.9	13.7	2.7	12.7	3.3	0.3	7.02		7.11	6.87
8	26.0	32.5	13.2	2.5	11.5	2.3	0.1			6.51	6.13
9	20.9	30.8	12.1	2.4	10.2	7.4	0.7		5.40	5.36	4.82
10	14.8	26.3	9.6	2.4	7.6	17.6	1.5		4.01	3.86	3.13
11	9.4	18.4	5.4	2.4	5.3	35.7	3.5			2.10	1.71
12	6.5	12.8	2.7	2.7	4.3	60.8	4.9			1.15	1.10
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.01	1.70	2.74	4.27	5.42	6.50	7.02	6.51	5.36	3.86	2.10	1.15
PM	PM	PM	HS	HS	ETo	ETo	PM	PM	PM	PM	PM

List of Symbols and their Common Units

R_s - solar radiation (MJ m ⁻² d ⁻¹)	T_d - dew point temperature (°C)	NRD - # rainy days per month
T_{max} - maximum temperature (°C)	U_2 - wind speed at 2 m height (m s ⁻¹)	(with Pcp > 2 x daily ET_o)
T_{min} - minimum temperature (°C)	Pcp - precipitation (mm)	E_{pan} - pan evaporation (mm/day)

Figure 8. The 'Monthly Climate Input' worksheet.

The cells on the left-hand side of the 'Monthly Climate Input' worksheet ask for the site information, including the station name, latitude, and elevation. In this example, we defined the site information in the program, including Davis as the station name, 38.5 degrees for latitude, 18 meter for elevation and 100 meter for fetch. If raw pan

evaporation data are entered, CUP+ then asks for fetch value in meter. Weather data are entered into cells on the right-hand side of the worksheet.

For estimating ET_o , a modified version of the Penman-Monteith equation (Allen et al., 1998) with some fixed parameters is applied. Data can be entered one cell at a time or one can cut and paste rows and columns from another file into the 'weather input' worksheet. If monthly mean ET_o data are input directly, those values are used by CUP+. If the solar radiation, temperature, and wind speed data are input, then the Penman-Monteith equation is used to calculate ET_o . If only temperature data are input into the table, then the Hargreaves-Samani equation is used to calculate ET_o . If pan data are input, the program automatically estimates daily ET_o rates using a fetch value (i.e. upwind distance of grass around the pan). Without a fetch value, pan evaporation data are not used. The cells at the bottom of the table show the ET_o values that are used by CUP+ and also show the methods used to estimate ET_o values.

Note:

In all cases, the NUMBER OF RAINY DAYS (NRD) per month must be input to use K_c values that are adjusted for rainfall frequency. A rainy day is a day with a rainfall depth greater than mean ET_o for that date.

The California Climate Data Program

The California Climate Data program (CCDP) was also developed in Microsoft Excel to provide monthly mean weather and ET_o data by day from CIMIS to input into the CUP+ model. To select weather and ET_o data from a CIMIS station, we enter a CIMIS station number in the program. Then it provides monthly mean weather and ET_o data in metric and English units. This program contains three worksheets. The worksheets are ‘Title’, ‘Climate Data’, and ‘Sites’.

The ‘Title’ worksheet:

It provides information about the program.

The ‘Site’ Worksheet:

This worksheet provides a list of CIMIS station numbers, CIMIS station names, and period of record.

The ‘Climate Data’ Worksheet:

It provides instructions for selecting weather and ET_o data from CIMIS and also provides site description and monthly mean weather and ET_o data for the selected CIMIS.

California Monthly Weather and ET_o Data for SIMETAW and CUP

Please enter CIMIS No.

CIMIS Station No. is:

Station Name:

Latitude (deg):

Elevation (m):

Elevation (ft):

Period of Record

Start Date:

End Date:

How to select climate data from a CIMIS

To select climate and ET_o data from a CIMIS station in California, you must enter a CIMIS station number in the "Enter CIMIS No." cell.

The climate data are in the same format as used in the CUP and SIMETAW models. Simply copy only values and paste to use the data.

Note that some stations do not have rainfall. It is recommended to use the number of rainy days (NRD) and precipitation from a nearby station for use in CUP and SIMETAW.

Climate Data in Metric

Mo	Solar	TMax	TMin	Wind	Td	Pcp	NRD	Pan	Mo	ET_o
#	MMm ²	°C	°C	m/s	°C	mm	#	mm	#	mm
1	6.5	12.7	3.6	2.6	5.4	102.6	8.6	-999	1	1.0
2	10.4	16.0	5.0	2.7	6.6	107.3	6.5	-999	2	1.7
3	15.9	19.0	6.0	2.7	7.2	69.6	5.8	-999	3	2.7
4	21.5	22.8	7.8	3.0	6.9	17.8	1.7	-999	4	4.4
5	25.5	26.3	10.4	3.0	9.2	19.0	1.5	-999	5	5.5
6	28.8	30.1	12.7	3.0	10.8	6.0	0.6	-999	6	6.8
7	29.0	32.9	13.7	2.7	12.7	3.3	0.3	-999	7	7.0
8	26.0	32.5	13.2	2.5	11.5	2.3	0.1	-999	8	6.4
9	20.9	30.8	12.1	2.4	10.2	7.4	0.7	-999	9	5.3
10	14.8	26.3	9.6	2.4	7.6	17.6	1.5	-999	10	3.8
11	9.4	18.4	5.4	2.4	5.3	35.7	3.5	-999	11	2.1
12	6.5	12.8	2.7	2.7	4.3	60.8	4.9	-999	12	1.1

Climate Data in English

Mo	Solar	TMax	TMin	Wind	Td	Pcp	NRD	Pan	Mo	ET_o
#	ly/day	°F	°F	mph	°F	in	#	in	#	in
1	155.3	54.9	38.5	5.8	41.7	4.0	8.6	-999	1	0.04
2	248.5	60.8	41.0	6.0	43.9	4.2	6.5	-999	2	0.07
3	379.9	66.2	42.8	6.0	45.0	2.7	5.8	-999	3	0.11
4	513.6	73.0	46.0	6.7	44.4	0.7	1.7	-999	4	0.17
5	609.2	79.3	50.7	6.7	48.6	0.7	1.5	-999	5	0.22
6	688.0	86.2	54.9	6.7	51.4	0.2	0.6	-999	6	0.27
7	692.8	91.2	56.7	6.0	54.9	0.1	0.3	-999	7	0.28
8	621.2	90.5	55.8	5.6	52.7	0.1	0.1	-999	8	0.25
9	499.3	87.4	53.8	5.3	50.4	0.3	0.7	-999	9	0.21
10	353.6	79.3	49.3	5.3	45.7	0.7	1.5	-999	10	0.15
11	224.6	65.1	41.7	5.3	41.5	1.4	3.5	-999	11	0.08
12	155.3	55.0	36.9	6.0	39.7	2.4	4.9	-999	12	0.04

Figure 9. Shows an example of monthly mean weather and ET_o values by day for Davis.

The left-hand side of the ‘Climate Data’ worksheet shows CIMIS site description and the period of record and the right-hand side of the worksheet displays the monthly mean weather and ET_o values by day in metric and English units for the selected CIMIS station.

Note:

The monthly climate data are in the same format as used in the CUP+ program. Simply copy values and paste to use the data. Some stations do not have rainfall. It is recommended to use the number of rainy days (NRD) and precipitation (Pcp) from a nearby station for use in CUP+.

Exercise 1

Input monthly mean pan evaporation data in mm/day into the table in the ‘Monthly Climate Input’ worksheet for Davis. Enter 100 meter for fetch. When pan data are input, the program automatically estimates daily ET_o rates using a fetch value without a need for wind speed and relative humidity. The monthly mean pan evaporation data for Davis are available on your pan folder.

Exercise 2

Input monthly mean maximum and minimum air temperature data and monthly total precipitation and number of rainy days into the ‘Weather Input’ worksheet for calculating ET_o values for Davis. When you input temperature data into the table, CUP+ uses the Hargreaves-Samani equation (temperature based equation) to calculate ET_o . Use the California Climate Data program for temperature and rainfall data.

Exercise 3

Enter monthly mean weather data into the ‘Monthly Climate Input’ worksheet for calculating ET_o values for Davis. Weather data include solar radiation, maximum and minimum air temperature, dew point temperature, wind speed, and total precipitation and number of rainy days. If the solar radiation, temperature, and wind speed data are input

into the table in the 'Weather Input' worksheet, then CUP+ automatically estimates ET_o using the Penman-Montieth equation. Use the California Climate Data program for weather data.

Exercise 4

Enter monthly mean ET_o data in mm per day and monthly total precipitation and number of rainy days into the program for Davis. When you input monthly mean ET_o data directly into the program, those values are used by CUP+. Use the California Climate Data program for ET_o and rainfall data.

Entering Crop and Soil Information:

To run the application to determine ET_c and ET_{aw} for a crop, you are also required to enter the crop and soil information into the program. The input data include as following:

Crop number

Planting date

Ending date

Available water holding capacity

Maximum soil depth

Maximum rooting depth during the growing season

Allowable Depletion

Initial growth wetting frequency from rainfall or irrigation. Number of days between irrigation events during the initial growth period.

Ground cover percentage on date B, C, D, and E. Used to account for immaturity effect on K_c values for tree and vine crops. The '70%' indicates that the tree or vine crop is mature. If a tree or vine crop is immature, the value will be less than 70%. When canopy reaches 70% ground cover, it is assumed that the crop is mature.

- Cover crop dates. If there is a cover crop for tree and vine crops, enter cover crop dates.

Chapter 3

Selecting and/or Entering Weather and Crop/Soil Information

The 'Input_Output' Worksheet:

This worksheet is where weather and crop and soil information are selected or entered into the program for estimating evapotranspiration of applied water for a crop.

CUP plus - M Version

Calculated ET_o , ET_c , and ET_{AW} (mm/mon) and weighted mean K_c values

Month:	May	Jun	Jul	Aug	Sep	Oct			
K_c ():	0.58	1.02	1.05	1.05	1.03	1.01			
ET_o (mm):	168.05	193.91	216.06	200.83	159.89	118.75			
ET_c (mm):	99.04	197.56	225.82	209.90	165.14	119.70			
ET_{AW} (mm):									
Seasonal ET_o (mm):	1,057.49			Seasonal ET_c (mm):			1,017.16		
Seasonal ET_{AW} (mm):				Annual ET_{AW} (mm):					

Add Data to Summary Sheets

- * To copy and paste the cell values on summary worksheets, click the copy / paste button
- * To delete all summary cell values, click the delete button

Caution! Using the delete button will delete all existing data in the summary worksheets

Copy / Paste Delete

Developed by Land and Water Use, California Department of Water Resources
And
Department of Land, Air and Water Resources, University of California, Davis
Morteza N. Orangi, Richard L. Snyder, J. Scott Matyac

DEPARTMENT OF WATER RESOURCES
LAND AND WATER USE PROGRAM

UNIVERSITY OF CALIFORNIA, DAVIS
LAND, AIR AND WATER RESOURCES

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Figure 10. Shows an example for selecting weather and crop information in the 'Input_Output' worksheet.

Weather and crop/soil information are selected or entered into cells on the left-hand side of the 'Input_Output' worksheet. The cells on the right-hand side of the worksheet are used to display the monthly total values of ET_o , ET_c , and ET_{aw} and weighted mean K_c by month during the growing season for the currently entered weather and crop/soil information. In addition to monthly values, the model also outputs seasonal ET_o , ET_c , and ET_{aw} .

Selecting Weather, ET_o , and E_{pan} from the “Weather Input” Worksheet:

CUP+ can either use raw daily weather data or daily means by month. When daily data are selected, daily data are used for daily soil water balance calculations for surfaces that account for ET losses and water contributions from rainfall, seepage, and irrigation.

To use daily weather data to estimate daily soil water balance for crops, 66 is input into the California ET_o Zone number. The data can come from California Irrigation Management Information System (CIMIS) as raw daily data. The weather data contain the daily values for solar radiation, maximum and minimum temperature, wind speed, dew point temperature, and precipitation from CIMIS. If weather data such as the solar radiation, temperature, and wind speed are input, then the program will use the daily Penman-Montieth equation to compute ET_o . If only temperature data are input, then the program will use the Hargreaves-Samani equation to calculate ET_o .

To use monthly mean weather, raw ET_o , and pan evaporation data with monthly total precipitation and number of rainy days, 88 is input into the California ET_o Zone number.

You are also required to enter the year to account for leap year. Then the program asks for a crop number. A crop number is entered into the 'Crop Number' cell. CUP+ provides a

list of crops and crop numbers in the 'Crop References' worksheet. That worksheet also contains the percentage of the season to various growth dates (explained later), K_c values at critical growth points, and sample start and end dates for the season.

Note:

The crop numbers have one digit to the left and two digits to the right of a decimal point. The single digit identifies the crop type, and the double digit identifies the crop. In this example, we selected type-1 crop (Asparagus) for ET calculations.

When a crop is selected, the growth, K_c , and default start-end information is automatically used for the calculations. The start date corresponds to planting for field and row crops and to leaf-out date for tree and vine crops. Non-deciduous trees, turf grass, and pasture crops start on January 1 and end on December 31. If different from the default values, the start and end dates can be changed in the 'Input_Output' worksheet.

The initial K_c value for most crops depends on wetting frequency from rainfall and/or irrigation. In the 'Input_Output' worksheet, the irrigation frequency is entered and a K_c determined for near bare-soil evaporation during initial growth of field and row crops.

The initial K_c value for most crops depends on wetting frequency from rainfall and/or irrigation. As the canopy shading increases, the contribution of soil evaporation to ET_c decreases while the contribution of transpiration increases. In the 'Input_Output' worksheet, the rainfall frequency during early growth is input to determine a K_c for near bare soil evaporation. Similarly, the irrigation frequency is entered and a K_c determined for near bare-soil evaporation during initial growth of field and row crops. CUP compares K_c values from the Crop References worksheet with those based on rainfall and irrigation frequency and selects the largest of the three for use in calculating ET_c . If no rainfall or irrigation frequency is entered, the K_c from the A-B column in the 'Crop References' worksheet is used as the initial growth K_c . The starting K_c for type-2 crops (for example, turfgrass and pasture) and for type-4 crops (for example, subtropical orchards) is not affected by the irrigation or rainfall frequency entries.

Cover crops affect ET_c rates, and CUP+ accounts for the contributions. The cover crop start and end dates are input into cells under the “Enter 1st Cover Crop (day/mon).” Because some crops have cover crops in spring and fall but not in the summer, a second set of cover crop dates can be input under “Enter 2nd Cover Crop (day/mon)”. During a period with a cover crop, the value 0.35 is added to the “clean cultivated” K_c value. However, the K_c is not allowed to exceed 1.20 or to fall below 0.90.

The right-hand side of the ‘Input_Output’ worksheet shows the weighted mean K_c , ET_o , ET_c , and seasonal ET_c values by month for the selected crop and input information. The daily mean ET_o rates by month are also shown below the other data. Below that set of cells, there are “Copy/Paste” and “Delete” buttons. When the Copy/Paste button is pressed results of the calculations are sent to ‘Summary of K_c ,’ ‘Summary of ET_o ,’ ‘Summary of ET_c ,’ and ‘Summary of ET_{aw} ’ worksheets. The Delete button clears all entries from the summary worksheets. To retain all of the data entries, save the CUP+ file as an Excel workbook with a different name. To save only the summary sheets, with the summary sheet displayed, save as a tab or comma delimited file. After saving the desired output data, click the Delete button to erase data from the summary worksheets.

Exercise 5

Run the CUP+ program to estimate daily crop evapotranspiration data for the following weather and crop information.

- Use monthly mean weather data and monthly total rainfall and number of rainy days from CIMIS at Davis.
- Enter a crop number 2.02 in the 'Enter Crop No.' cell in the 'Input_Output' worksheet for Improved Pasture as your type-2 crop.
- Use the default planting date.
- Use the default ending date.

After you entered the weather and crop information into the program, press the Copy/Paste button in the "Input_Output" worksheet to write the current crop information, calculated crop coefficients, ETo , and ETc data in the 'Summary of Kc', 'Summary of ETo ', and 'Summary of ETc ' worksheets.

Exercise 6

Use CUP+ to estimate daily crop evapotranspiration data for the following weather and crop information.

- Use monthly mean weather data and monthly total rainfall and number of rainy days from CIMIS at Davis.
- Enter a crop number 3.01 in the 'Enter Crop No.' cell in the 'Input_Output' worksheet for the almond tree crop as your type-3 crop.
- Either enter your planting date or use the default value. If no entries are input for plant date, defaults will be automatically used.
- Either enter ending date or use the default value.
- Use the following cover crop dates.

First Cover Crop Dates: Start Date: January 01, 2004
 End Date: April 30, 2004

Second Cover Crop Dates: Start Date: November 01, 2004
 End Date: December 31, 2004

- Do not use ground cover percentages on dates C and D. 70 is the default value, then it is assumed that the tree crop is mature.

After you entered the weather and crop information into the program, press the Copy/Paste button in the "Input_Output" worksheet to write the current crop information,

calculated crop coefficients, ET_o , and ET_c data in the ‘Summary of K_c ’, ‘Summary of ET_o ’, and ‘Summary of ET_c ’ worksheets.

Exercise 7

Use CUP+ again to estimate daily crop evapotranspiration data for the following weather and crop information.

- Use monthly mean weather data and monthly total rainfall and number of rainy days from CIMIS at Davis.
- Enter a crop number 3.01 in the ‘Enter Crop No.’ cell in the ‘Input_Output’ worksheet for the almond tree crop as your type-3 crop.
- Use the same planting and ending dates as Exercise 7.
- Use the following cover crop dates.

First Cover Crop Dates: Start Date: January 01, 2004

End Date: April 15, 2004

- Use 55 for ground cover percentage on date C and 60 on date D for the almond tree crop.

After you entered the weather and crop information into the program, press the Copy/Paste button in the “Input_Output” worksheet to write the current crop information,

calculated crop coefficients, ET_o , and ET_c data in the 'Summary of K_c ', 'Summary of ET_o ', and 'Summary of ET_c ' worksheets.

Exercise 8

Use the program to estimate daily crop evapotranspiration data for the following weather and crop information.

- Use monthly mean temperature data and monthly total rainfall and number of rainy days from CIMIS at Davis.
- Enter a crop number 4.01 in the 'Enter Crop No.' cell in the 'Input_Output' worksheet for the avocado subtropical tree crop as your type-4 crop.
- Either enter your planting date or use the default value. If no entries are input for plant date, defaults will be automatically used.
- Either enter ending date or use the default value.
- Use the following cover crop dates.

First Cover Crop Dates: Start Date: January 01, 2004
End Date: April 15, 2004

- Enter 45 for ground cover percentage on date B, 55 on date C, and 65 on date D for the crop.

- After you entered the temperature data and crop information into the program, press the Copy/Paste button in the “Input_Output” worksheet to write the current crop information, calculated crop coefficients, ETo, and ETc data in the ‘Summary of Kc’, ‘Summary of ETo’, and ‘Summary of ETc’ worksheets.

Exercise 9

Use the program again to estimate daily crop evapotranspiration data for the following weather and crop information.

- Use monthly mean temperature data and monthly total rainfall and number of rainy days from CIMIS at Davis.
- Enter a crop number 4.01 in the ‘Enter Crop No.’ cell in the ‘Input_Output’ worksheet for the avocado subtropical tree crop as your type-4 crop.
- Use the same planting and ending dates as used in Exercise 9.
- Use the following cover crop dates.

First Cover Crop Dates: Start Date: January 01, 2004
 End Date: April 30, 2004

Second Cover Crop Dates: Start Date: November 01, 2004
 End Date: December 31, 2004

- Do not enter ground cover percentages on dates B, C, D, and E. 70 is the default value, then it is assumed that the tree crop is mature.
- After you entered the temperature data and crop information into the program, press the Copy/Paste button in the “Input_Output” worksheet to write the current crop information, calculated crop coefficients, E_{To} , and E_{Tc} data in the ‘Summary of K_c ’, ‘Summary of E_{To} ’, and ‘Summary of E_{Tc} ’ worksheets.

Exercise 10

Use the program to estimate daily crop evapotranspiration data for the following weather and crop information.

- Use monthly mean pan evaporation data and monthly total rainfall and number of rainy days from CIMIS at Davis.
- Enter a crop number 1.15 in the ‘Enter Crop No.’ cell in the ‘Input_Output’ worksheet for cotton crop as your type-1 crop.
- Enter May 1, 2004 for your planting date.
- Enter November 30, 2004 for your ending date.
- After you entered the pan evaporation data and crop information into the program, press the Copy/Paste button in the “Input_Output” worksheet to write the current crop information, calculated crop coefficients, E_{To} , and E_{Tc} data in the ‘Summary of K_c ’, ‘Summary of E_{To} ’, and ‘Summary of E_{Tc} ’ worksheets.

Selecting ET_o from the “ETo Zones” Worksheet:

To use ET_o data from the ‘ETo Zones Map’ worksheet, 1 to 18 are input into the ‘California ET_o Zone number’ cell. Then the program automatically uses the corresponding monthly mean ET_o data.

Figure 11. Shows an example for selecting ET_o and crop information in the 'Input_Output' worksheet.

Note:

If you enter numbers other than 1-18 or 66, and 88 in the 'California ET_o Zone number' cell, the CUP+ program will display an error message with a tip.

Exercise 11

Run the CUP+ application program to estimate daily crop evapotranspiration data for the following weather and crop information.

- Use ET_o data from zone 14 in the 'ETo Zones Map' worksheet.

- Enter a crop number 1.15 in the ‘Enter Crop No.’ cell in the ‘Input_Output’ worksheet for cotton as your type-1 crop.
- Either enter your planting date or use the default value. If no entries are input for plant date, defaults will be automatically used.
- Either enter ending date or use the default value.
- Use 3 days for wetting frequency from irrigation and 10 days for rainfall frequency for adjusting the crop coefficient during the initial growth period. CUP compares the rainfall and irrigation frequency and selects the largest value for calculating ET_c .
- After the data entry, press the Copy/Paste button in the “Input_Output” worksheet to write the current crop information, calculated crop coefficients, ET_o , and ET_c data in the ‘Summary of Kc’, ‘Summary of ET_o ’, and ‘Summary of ET_c ’ worksheets.

Chapter 4

Viewing Output Worksheets

The ‘K_c, ET_c, and ET_{aw} Calculations’ Worksheet:

After data entry, CUP+ shows all of the growth date and K_c as well as the daily calculations of ET_o , K_c , ET_c , ET_{aw} for each of the growth periods in the ‘K_c, ET_c, and ET_{aw} Calculations’ worksheet.

Initial Stage					Rapid Growth					Mid-Season		
Day of Month ()	ET _o (mm/day)	K _c ()	ET _c (mm/day)	ET _{aw} (mm/day)	Day of Month ()	ET _o (mm/day)	K _c ()	ET _c (mm/day)	ET _{aw} (mm/day)	Day of Month ()	ET _o (mm/day)	
1-May	6.62	0.32	2.08	1.02	23-May	7.46	0.48	3.56	2.49	18-Jun	7.18	
2-May	5.74	0.30	1.74	0.67	24-May	7.70	0.42	3.26	2.19	19-Jun	7.30	
3-May	5.53	0.29	1.61	0.54	25-May	7.87	0.38	3.02	1.95	20-Jun	6.60	
4-May	5.37	0.28	1.51	0.45	26-May	5.91	0.36	2.13	1.06	21-Jun	7.16	
5-May	5.81	0.27	1.58	0.52	27-May	6.05	0.35	2.12	1.06	22-Jun	6.76	
6-May	5.29	0.26	1.39	0.33	28-May	5.41	0.38	2.06	1.00	23-Jun	6.80	
7-May	5.69	0.26	1.46	0.39	29-May	5.13	0.41	2.11	1.05	24-Jun	6.53	
8-May	5.68	0.25	1.41	0.35	30-May	5.48	0.44	2.42	1.36	25-Jun	5.35	
9-May	5.38	0.24	1.31	0.24	31-May	5.85	0.47	2.76	1.70	26-Jun	3.79	
10-May	5.69	0.24	1.35	0.28	1-Jun	7.26	0.50	3.64	3.64	27-Jun	4.86	
11-May	6.39	0.23	1.47	0.41	2-Jun	7.12	0.53	3.79	3.79	28-Jun	5.89	
12-May	6.89	0.22	1.54	0.48	3-Jun	7.21	0.56	4.05	4.05	29-Jun	6.71	
13-May	6.34	0.22	1.39	0.32	4-Jun	6.83	0.59	4.04	4.04	30-Jun	7.09	
14-May	4.38	0.22	0.94	0.00	5-Jun	7.35	0.62	4.57	4.57	1-Jul	7.52	
15-May	2.16	0.21	0.46	0.00	6-Jun	7.41	0.65	4.83	4.83	2-Jul	8.25	
16-May	2.74	1.22	3.34	0.00	7-Jun	7.30	0.68	4.99	4.99	3-Jul	8.80	
17-May	2.03	1.22	2.48	0.41	8-Jun	7.24	0.71	5.16	5.16	4-Jul	7.47	
18-May	3.27	1.10	3.61	0.54	9-Jun	7.04	0.74	5.23	5.23	5-Jul	7.18	
19-May	4.57	0.81	3.69	2.63	10-Jun	6.80	0.77	5.26	5.26	6-Jul	7.20	
20-May	4.84	0.66	3.21	2.14	11-Jun	6.96	0.80	5.60	5.60	7-Jul	7.70	
21-May	2.50	0.61	1.53	0.00	12-Jun	7.22	0.83	6.02	6.02	8-Jul	7.55	
22-May	3.72	0.56	2.06	1.00	13-Jun	6.41	0.86	5.54	5.54	9-Jul	7.19	
End of Initial Stage					14-Jun	6.68	0.89	5.97	5.97	10-Jul	8.08	
					15-Jun	6.60	0.92	6.10	6.10	11-Jul	8.33	
					16-Jun	6.40	0.95	6.11	6.11	12-Jul	7.15	
					17-Jun	5.48	0.98	5.40	5.40	13-Jul	7.49	
					End of Rapid Growth					14-Jul	7.82	
										15-Jul	6.82	
										16-Jul	6.33	
										17-Jul	6.85	
										18-Jul	6.21	
										19-Jul	7.09	

Figure 12. The ‘K_c, ET_c, and ET_{aw} Calculations’ worksheet.

The ‘Weather Output’ Worksheet:

After you enter the data, CUP+ outputs one year of daily solar radiation, maximum and minimum air temperature, wind speed, dew point temperature, and rainfall data for the currently entered weather data.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Daily Mean Weather Data													
2	Date	DOY	Rs	Tmax	Tmin	Wind	Td	Pcp	ET _o					
3		#	MJ/m ²	°C	°C	m/s	°C	mm	mm					
4	1-Jan-96	1	8.73	21.00	9.30	3.70	5.50	0.00	3.01					
5	2-Jan-96	2	8.82	20.10	10.30	3.30	8.30	0.00	2.27					
6	3-Jan-96	3	3.46	13.10	6.20	1.40	9.30	0.00	0.49					
7	4-Jan-96	4	5.96	14.30	6.10	1.10	8.60	0.00	0.66					
8	5-Jan-96	5	5.01	14.00	5.60	1.30	8.60	0.00	0.63					
9	6-Jan-96	6	9.08	16.80	3.10	0.90	7.10	0.00	0.80					
10	7-Jan-96	7	6.14	13.60	4.20	0.90	7.80	1.00	0.59					
11	8-Jan-96	8	4.24	12.20	4.50	0.90	8.00	0.00	0.50					
12	9-Jan-96	9	0.86	9.90	7.10	2.30	8.50	2.00	0.06					
13	10-Jan-96	10	9.59	17.70	5.90	4.50	6.10	0.00	2.26					
14	11-Jan-96	11	5.70	14.60	1.80	1.30	6.40	0.00	0.77					
15	12-Jan-96	12	2.85	7.10	1.50	1.30	5.50	0.00	0.18					
16	13-Jan-96	13	2.94	6.70	4.30	1.30	5.70	0.00	0.29					
17	14-Jan-96	14	1.64	6.20	4.40	1.60	5.30	1.00	0.14					
18	15-Jan-96	15	2.42	10.40	5.90	4.10	7.90	4.00	0.31					
19	16-Jan-96	16	5.62	19.80	5.90	4.60	9.80	20.00	1.85					
20	17-Jan-96	17	8.99	13.00	3.40	2.00	2.50	0.00	1.32					
21	18-Jan-96	18	1.64	12.20	3.50	3.20	6.90	11.00	0.48					
22	19-Jan-96	19	9.51	15.50	1.40	1.80	5.20	0.00	1.16					
23	20-Jan-96	20	3.72	12.60	2.30	4.30	7.10	7.00	0.62					
24	21-Jan-96	21	9.68	14.50	5.60	2.30	4.20	0.00	1.55					
25	22-Jan-96	22	10.72	11.10	0.10	2.40	0.90	0.00	1.27					
26	23-Jan-96	23	2.59	7.10	3.70	5.50	4.00	1.00	0.58					
27	24-Jan-96	24	5.01	14.20	6.80	5.90	9.30	4.00	0.91					
28	25-Jan-96	25	10.98	13.80	1.30	1.60	1.20	0.00	1.37					
29	26-Jan-96	26	3.72	8.30	-0.10	1.00	3.00	5.00	0.54					
30	27-Jan-96	27	7.61	15.50	3.50	5.20	7.60	15.00	1.34					
31	28-Jan-96	28	8.82	14.10	0.70	1.10	5.00	0.00	0.93					
32	29-Jan-96	29	3.72	9.40	1.90	1.00	5.90	0.00	0.44					
33	30-Jan-96	30	3.54	10.00	6.60	2.70	7.20	5.00	0.60					
34	31-Jan-96	31	3.63	12.80	6.80	2.70	9.10	6.00	0.60					
35	1-Feb-96	32	11.24	16.30	2.70	1.50	7.20	0.00	1.19					

Figure 13. The 'Weather Output' worksheet showing one year of daily weather and ET_o data.

Note that there are two header rows. The first has the variable names and the second has the variable units.

The 'Daily Water Balance Output' Worksheet:

CUP+ also outputs one year of daily calculated crop coefficients, ET_o , ET_c , and ET_{aw} data for the current crop and soil information during the growing season and off-season in the 'Daily Water Balance Output' worksheet.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Daily Values of Corn (silage)												
2	Date	DOY	OKc	IKc	CCKc	ETo	Kc	ETc	Espg	Er	Dsw	DETaw	
3	#					mm		mm	mm	mm	mm	mm	
4	1-Jan-96	1	1.22		0.00	3.01	1.22	3.67	0.00	0.00	3.67	0.00	
5	2-Jan-96	2	1.11		0.00	2.27	1.11	2.51	0.00	0.00	2.51	0.00	
6	3-Jan-96	3	1.06		0.00	0.49	1.06	0.52	0.00	0.00	0.52	0.00	
7	4-Jan-96	4	1.00		0.00	0.66	1.00	0.66	0.00	0.00	0.66	0.00	
8	5-Jan-96	5	0.96		0.00	0.63	0.96	0.60	0.00	0.00	0.60	0.00	
9	6-Jan-96	6	0.91		0.00	0.80	0.91	0.73	0.00	0.00	0.73	0.00	
10	7-Jan-96	7	0.87		0.00	0.59	0.87	0.52	0.00	1.00	-0.48	0.00	
11	8-Jan-96	8	0.85		0.00	0.50	0.85	0.42	0.00	0.00	0.42	0.00	
12	9-Jan-96	9	0.85		0.00	0.06	0.85	0.05	0.00	2.00	-1.95	0.00	
13	10-Jan-96	10	1.22		0.00	2.26	1.22	2.76	0.00	0.00	2.76	0.00	
14	11-Jan-96	11	1.22		0.00	0.77	1.22	0.94	0.00	0.00	0.94	0.00	
15	12-Jan-96	12	1.22		0.00	0.18	1.22	0.22	0.00	0.00	0.22	0.00	
16	13-Jan-96	13	1.22		0.00	0.29	1.22	0.36	0.00	0.00	0.36	0.00	
17	14-Jan-96	14	1.22		0.00	0.14	1.22	0.18	0.00	1.00	-0.82	0.00	
18	15-Jan-96	15	1.22		0.00	0.31	1.22	0.38	0.00	4.00	-3.62	0.00	
19	16-Jan-96	16	1.22		0.00	1.85	1.22	2.26	0.00	8.77	-6.51	0.00	
20	17-Jan-96	17	1.22		0.00	1.32	1.22	1.61	0.00	0.00	1.61	0.00	
21	18-Jan-96	18	1.22		0.00	0.48	1.22	0.59	0.00	2.19	-1.61	0.00	
22	19-Jan-96	19	1.22		0.00	1.16	1.22	1.41	0.00	0.00	1.41	0.00	
23	20-Jan-96	20	1.22		0.00	0.62	1.22	0.76	0.00	2.17	-1.41	0.00	
24	21-Jan-96	21	1.22		0.00	1.55	1.22	1.89	0.00	0.00	1.89	0.00	
25	22-Jan-96	22	1.22		0.00	1.27	1.22	1.55	0.00	0.00	1.55	0.00	
26	23-Jan-96	23	1.22		0.00	0.58	1.22	0.71	0.00	1.00	-0.29	0.00	
27	24-Jan-96	24	1.22		0.00	0.91	1.22	1.11	0.00	4.00	-2.89	0.00	
28	25-Jan-96	25	1.22		0.00	1.37	1.22	1.67	0.00	0.00	1.67	0.00	
29	26-Jan-96	26	1.22		0.00	0.54	1.22	0.66	0.00	2.59	-1.93	0.00	

Figure 14. The 'Daily Water Balance Output' worksheet showing one year of daily crop coefficient, ET_o , ET_c , and ET_{aw} data.

The first row of the worksheet identifies the crop and the second row identifies variables. The variables are described below.

Date - Calculation date

DOY - Day of the year

OKc - Off-season crop coefficient. This Kc for a bare soil based on a two-stage soil evaporation model using ET_o and the number of days between rainfall. This is the

baseline K_c value for the model. The K_c used to estimate ET_c cannot be less than the off-season K_c value.

IK_c - In-season crop coefficient. This is the K_c during the growing season of a crop. It is based on crop development, irrigation frequency, cover crops, and crop physiology. The IK_c is determined from the 'Calculation' worksheet.

CCK_c - Cover crop K_c correction. This a correction for K_c values to account for the presence of cover crops in orchards and vineyards. The default value for a cover crop is 0.35, which is added to the IK_c to determine the crop coefficient to apply. When cover crop is present, the K_c is not permitted to fall below 0.90 or to go above 1.15.

ET_o - Reference evapotranspiration. These values come from the 'Calculation' worksheet.

K_c - Crop coefficient. These K_c values are the factors actually used to calculate crop evapotranspiration. During the off-season, $K_c = OK_c$ unless there is a cover crop present. Then $K_c = 0.9$ during the season. The $K_c = IK_c + CCK_c$. If there is no cover crop, then $CCK_c = 0$.

ET_c - Crop evapotranspiration. It is an estimate of the reference evapotranspiration multiplied by the crop coefficients.

E_{spg} - Effective seepage. It is the effective water contribution from seepage.

E_r - Effective rainfall. It is the effective water contribution from rainfall.

D_{sw} - Change in soil water content. It is an estimate of the crop evapotranspiration minus any water supplied by effective rainfall and effective seepage on each day.

DETaw – Daily evapotranspiration of applied water. It is an estimate of the change in soil water content minus the difference in soil water content (ΔWC) from the beginning to the end of the season.

The ‘Monthly Output’ Worksheet:

CUP+ also provides monthly mean crop coefficients and monthly total values of ET_o , ET_c , ET_{aw} and rainfall during the growing season and off-season for the entered weather, crop, and soil information.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Corn (silage)															
2	Mon	In-Kc	In-ETo	In-ETc	In-ETaw	A-Kc	A-ETo	A-ETc	A-Pcp	A-Er	A-Espg	A-ETaw				
3	#		mm	mm	mm		mm	mm	mm	mm	mm	mm				
4	1	--	--	--	--	1.15	28.55	33.51	82.00	33.51	0.00	0.00				
5	2	--	--	--	--	1.00	39.53	38.57	102.00	36.85	0.00	0.00				
6	3	--	--	--	--	0.72	87.88	58.97	54.00	26.88	0.00	33.40				
7	4	--	--	--	--	0.59	114.97	63.10	45.00	45.00	0.00	18.03				
8	5	0.44	163.47	64.59	26.58	0.44	163.47	64.59	38.00	38.00	0.00	25.37				
9	6	0.85	199.32	167.11	166.10	0.85	199.32	167.11	1.00	1.00	0.00	160.81				
10	7	0.98	225.26	221.86	221.85	0.98	225.26	221.86	0.00	0.00	0.00	221.31				
11	8	0.98	101.15	99.62	66.28	0.53	191.15	108.58	0.00	0.00	0.00	73.81				
12	9	--	--	--	--	0.09	144.65	13.27	0.00	0.00	0.00	0.00				
13	10	--	--	--	--	0.16	105.64	12.42	31.00	31.00	0.00	0.00				
14	11	--	--	--	--	0.88	39.93	33.99	21.00	21.00	0.00	0.00				
15	12	--	--	--	--	0.97	27.65	26.35	80.00	69.58	0.00	0.00				
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Figure 15. An example of monthly mean crop coefficient and monthly total values of ET_c and ET_o during the season and off-season for the current crop information.

In-Kc - Monthly mean of daily calculated crop coefficients during the growing season for the currently entered crop information.

In-ET_o - Monthly total reference evapotranspiration values during the growing season.

In-ET_c - Monthly total crop and soil evapotranspiration values during the growing season for the current crop information.

In-ET_{aw} - Monthly total evapotranspiration of applied water values during the growing season for the current crop and soil information.

A-K_c - Monthly mean of daily calculated crop coefficients during the year for the current crop and soil information.

A-ET_o - Monthly total reference evapotranspiration values over the period of one year.

A-ET_c - Monthly total crop evapotranspiration values over the period of one year.

A-P_{cp} - Monthly total rainfall values over the period of one year.

A-ET_{aw} - Monthly total evapotranspiration of applied water values over the period of one year.

The ‘K_c Chart’ Worksheet:

The CUP+ program plots daily calculated bare soil and crop coefficient values with different colored lines for each growth period for currently entered daily weather and crop / soil information during the growing season and off-season.

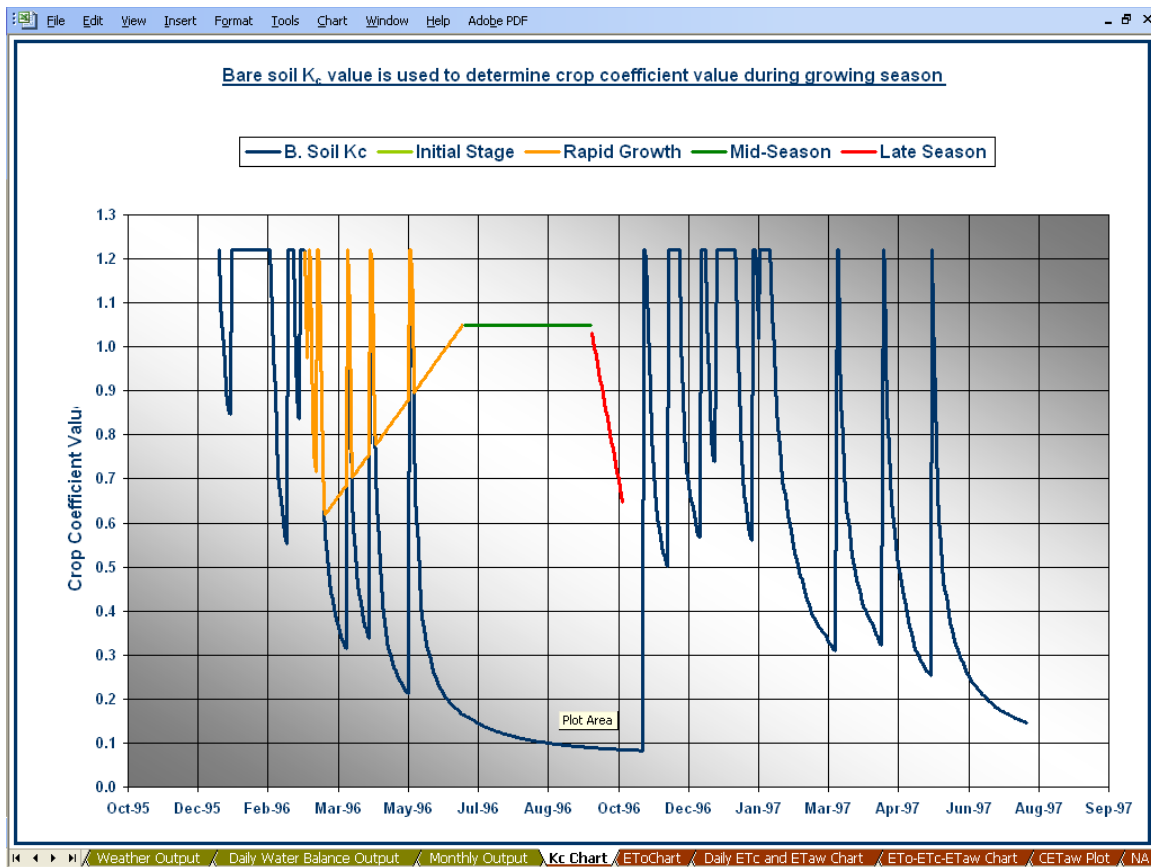


Figure 16. A sample of a calculated seasonal crop and bare soil coefficients plot from daily weather data during the season and off-season.

Then it uses the baseline to determine crop coefficients during the initial growth periods. During the off-season and initial growth period, soil evaporation is the main component of ET. Therefore, CUP+ uses a two stage soil evaporation model for estimating bare soil coefficients as a function of mean ET_o and wetting frequency in days from rainfall or irrigation. As shown in figure 16, the crop coefficient values for the almond tree crop has been adjusted for wetting frequency from rainfall during the initial growth period.

In addition to using daily weather data, the program also uses monthly climate data, including the number of significant rainy days per month to calculate a baseline soil evaporation curve. Please see figures 17.

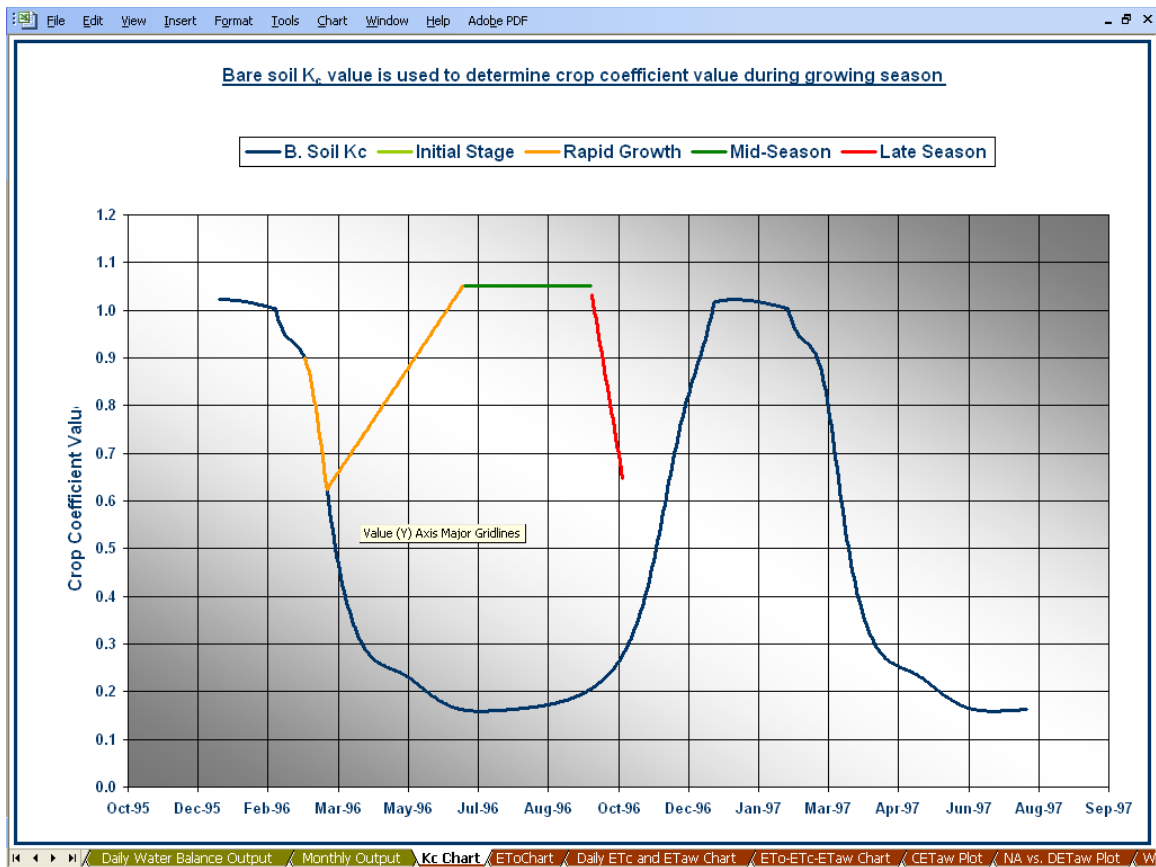


Figure 17. A sample of a calculated seasonal crop and bare soil coefficients plot from monthly climate means during the season and off-season.

The 'ETo Chart' Worksheet:

After data entry, the CUP+ program also plots daily calculated reference evapotranspiration with different colored lines for each growth period during the season.

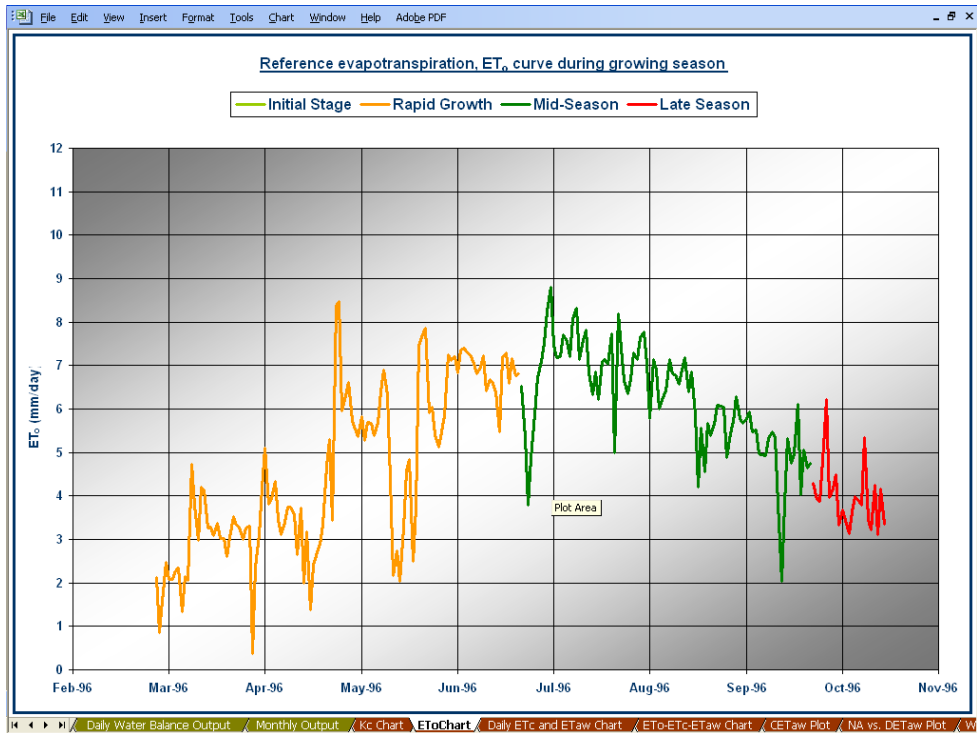


Figure 18. A sample of a daily calculated ET_0 plot from daily weather data during the growing season at Colusa, California.

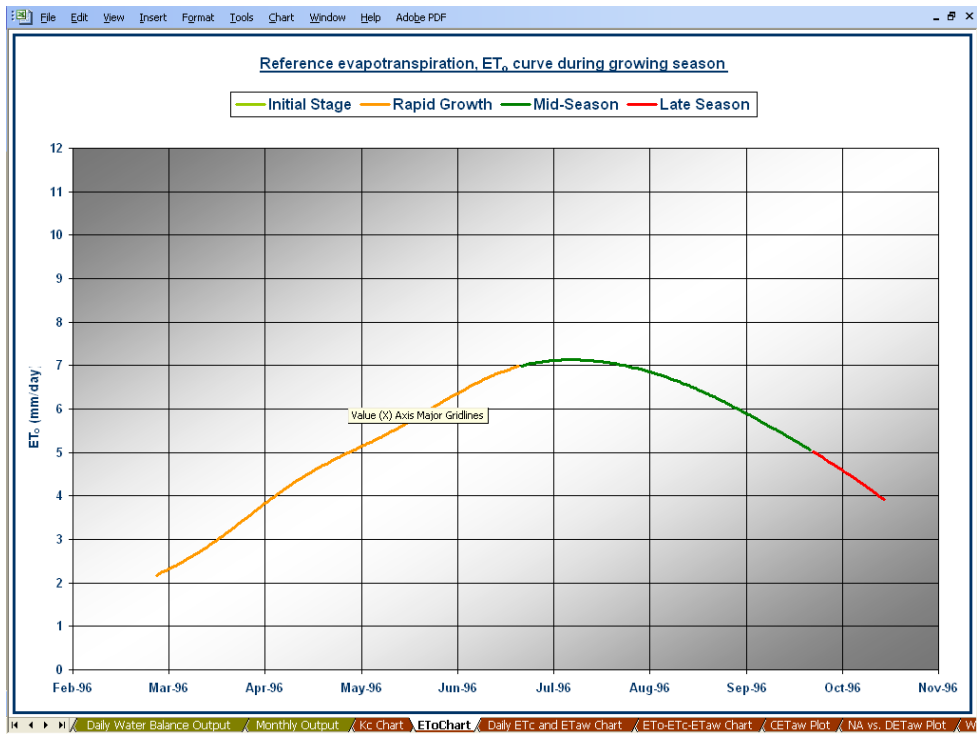


Figure 19. A sample of a daily calculated ET_0 plot from monthly means during the growing season at Davis, California.

The 'ET_o_ET_c_ET_{aw} Chart' Worksheet:

CUP+ provides a bar graph of ET_o , ET_c , and ET_{aw} totals by month during the growing season for the current crop and soil information.

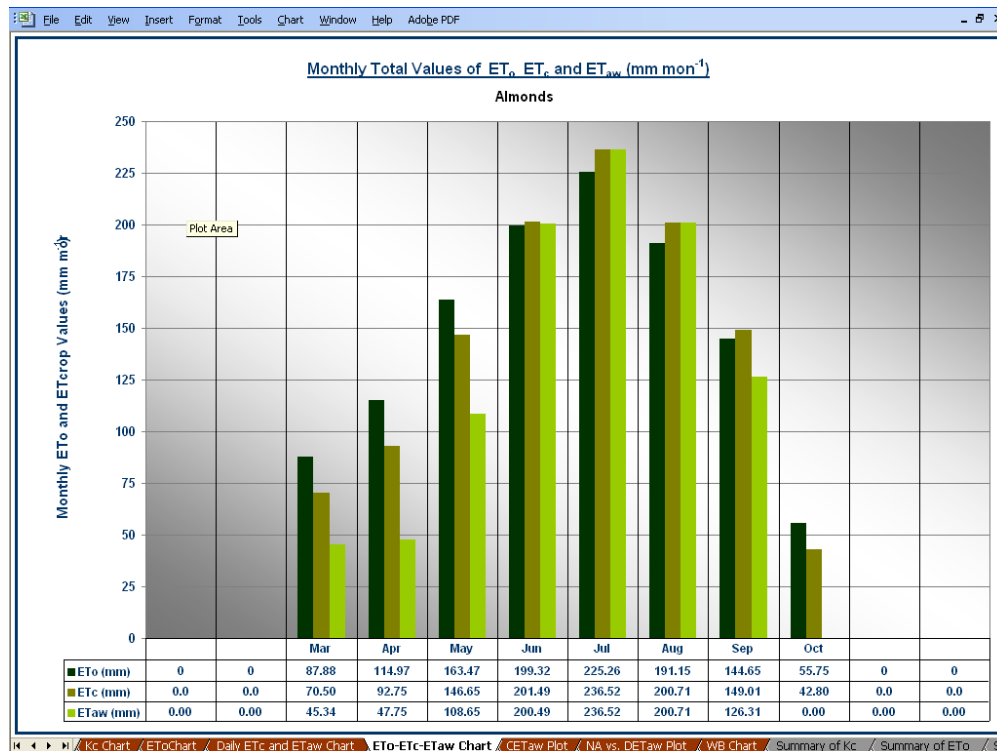


Figure 20. An example of a bar graph of monthly total values of ET_o , ET_c , and ET_{aw} during the growing season for the almond tree crop at Colusa, California.

The 'CETaw Plot' Worksheet:

CUP+ also displays a plot of cumulative of crop evapotranspiration (ET_c), cumulative of effective seepage of groundwater, fog, and dew (CESdf), cumulative of net application (Cum. NA), and cumulative of evapotranspiration of applied water (CET_{aw}) versus time for the almond tree crop using daily weather data from CIMIS at Colusa from January 1997 to July 1998.

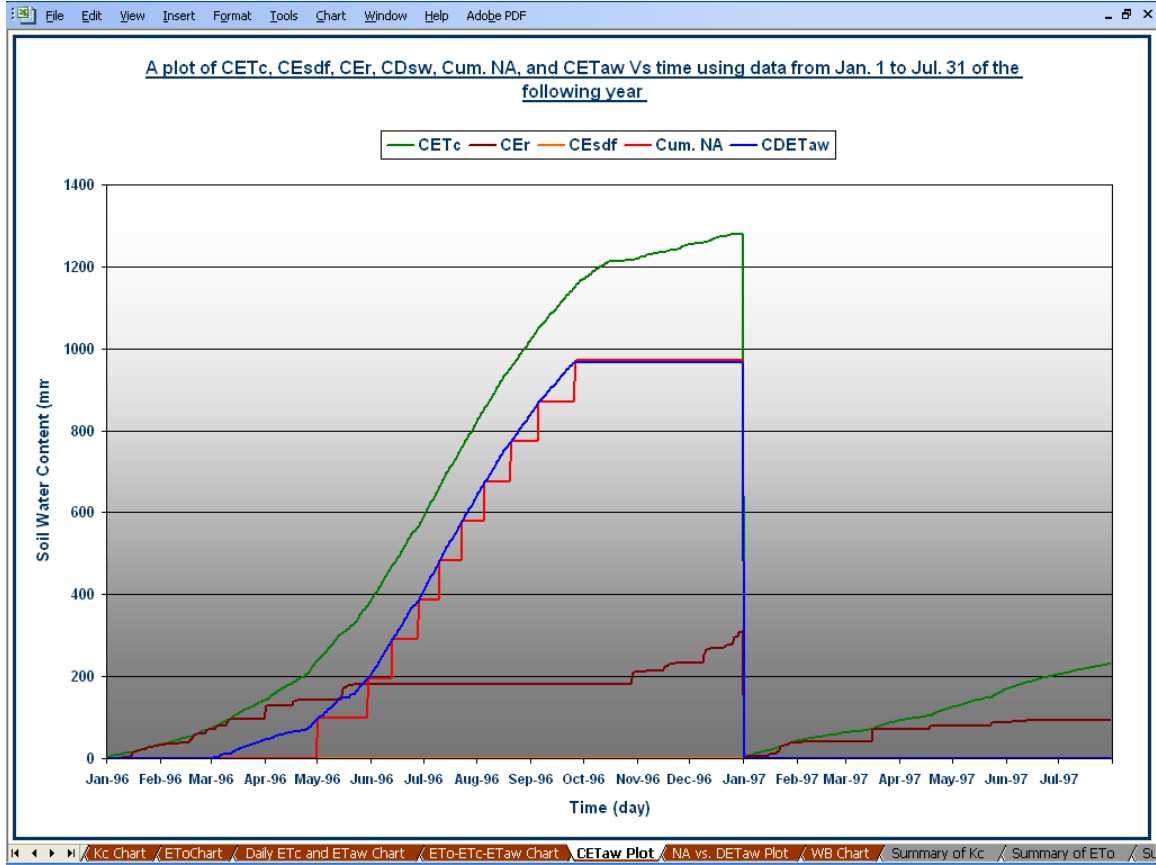


Figure 21. An example of a plot of CET_c , CE_{sf} , CD_{sw} , $Cum.NA$, and CET_{aw} versus time for the almond tree crop during the 1996 growing season at Colusa site illustrating the close estimation of ET_{aw} by two methods.

ET_{aw} is the sum of the net irrigation applications to a crop during its growing season, where each net irrigation application (NA) is equal to the product of the gross application (GA) and an application efficiency fraction (AE), i.e., $NA = GA \times AE$. The gross application is equivalent to the applied water, and the application efficiency is the fraction of GA that contributes to crop evapotranspiration (ET_c). Alternatively, ET_{aw} can be calculated as the daily evapotranspiration (DET_c) minus the estimated daily effective seepage contribution (DE_{spg}) minus the daily estimated effective rainfall contribution (DE_r) minus the difference in soil water content (ΔWC) from the beginning to the end of the season. Therefore, the ET_{aw} can also be expressed as

$$ET_{aw} = CD_{sw} - \Delta WC.$$

The above figure shows the comparison of the cumulative daily ET_{aw} values with the cumulative net application (Cum. NA) for the almond tree crop over the period of one year.

The 'WB Chart' Worksheet:

The CUP+ program also plots daily calculated water balance for crops using daily weather data. The plot shows fluctuations in soil water content between field capacity and the maximum depletion during the off-season and between field capacity and maximum soil water content during the growing season. The plot also shows the daily values for crop evapotranspiration (ET_c) and rainfall. Irrigation events are given when the maximum soil water depletion exceeds the maximum soil water content.

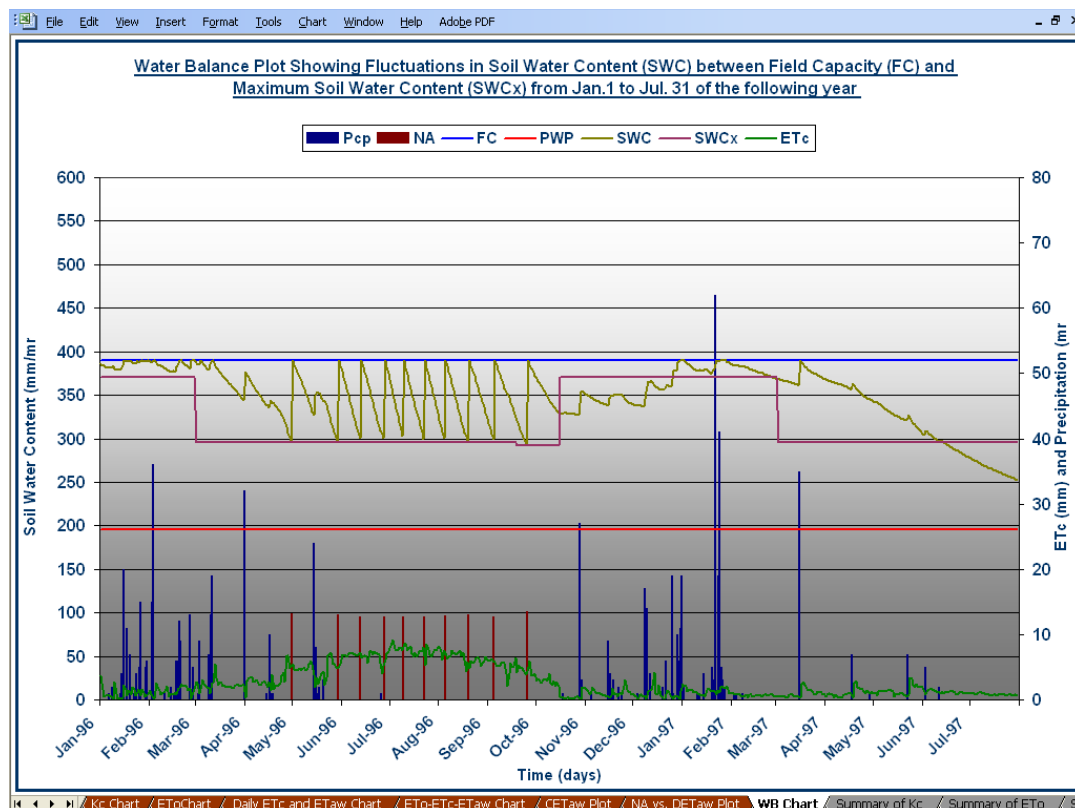


Figure 22. A daily water balance plot for the almond tree crop at Colusa during the 1996 growing season illustrating the estimation of seasonal ET_{aw} .

The “Summary of K_c ,” “Summary of ET_o ,” “Summary of ET_c ,” and “Summary of ET_{aw} ” Woksheets:

There are also summary worksheets for K_c values, ET_o , ET_c , and ET_{aw} . After data entry, the current crop and soil information and calculated K_c data in the ‘Input_Output’ worksheet can be printed to one row in the ‘Summary of Kc’ worksheet. ET_o data are printed to ‘Summary of ETo’, ET_c data are printed to ‘Summary of ETc’, and ET_{aw} data are printed to ‘Summary of ETaw’.

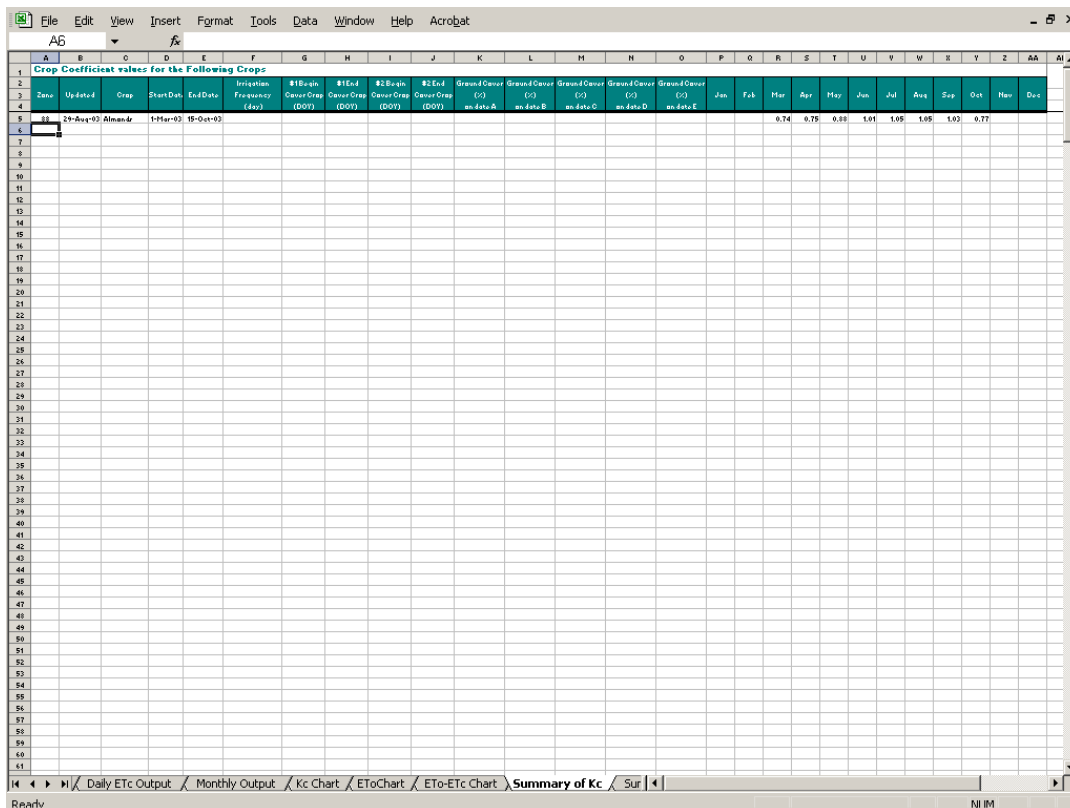


Figure 19. The ‘Summary of K_c ’, ‘Summary of ET_o ’, ‘Summary of ET_c ’, and ‘Summary of ET_{aw} ’ worksheets are used to compile the calculated crop coefficient, ET_o , ET_c , and ET_{aw} data .

When the Copy/Paste button in the “Input_Output” worksheet is pressed results of the calculations are sent to ‘Summary of Kc,’ ‘Summary of ETo’, ‘Summary of ETc’, and ‘Summary of ETaw’ worksheets. Use the Delete button in the “Input_Output” worksheet to clear all entries from the summary worksheets. To retain all of the data entries, save the CUP+ file as an Excel workbook with a different name. To save only the summary sheets, with the summary sheet displayed, save as a tab or comma delimited file. After saving the desired output data, click the Delete button to erase data from the summary worksheets.