KcMod: Crop Coefficient Model

How to Use it

This Program was written in July 2009 (by R.L. Snyder[1] and A. Swelam[3]), and revised in July 2010 and 2018 (by R.L. Snyder[1] and E. Guerra[2]).

[1]DEPT. OF LAND, AIR AND WATER RESOURCES, UNIVERSITY OF CALIFORNIA, DAVIS, CA;

[2]DEPT. OF FOOD AND AGRICULTURAL SCIENCE, UNIVERSITY OF BOLOGNA, BOLOGNA, ITALY;

[3]IRCARDA, CAIRO, EGYPT

Tabel of content

Purpose of KcMod use:

This program helps to determine crop coefficient values for several different field crops and trees. The model includes corrections for precipitation and irrigation effects on ET.

How to use KcMod?

Dailymet Worksheet

The model can be used starting from the DailyMet worksheet. Inputs include:

• maximum and minimum air temperature, either dew point temperature or maximum and minimum relative humidity, and wind speed.

• The model calculates standardized reference evapotranspiration (ETo) following the methods of the Allen et al. (2006) using daily climate data as inputs into DailyMet. The required input data includes solar radiation, maximum and minimum temperature, wind speed at 2 m height, and either the mean daily dew point temperature or the maximum and minimum relative humidity.

The mean monthly climate data in the Climate worksheet are calculated from the daily climate data in the DailyMet worksheet.

Climate Worksheet

The daily data entered into the DailyMet worksheet are used in the Climate worksheet to calculate ETo using the monthly mean climate data. To simulate the effect on the ETo due to increasing atmospheric CO_2, the value of the canopy resistance can be modified in the Climate worksheet. See Snyder (2017) for information on how the canopy resistance changes with CO_2 concentration.

KcInfo Worksheet

The crop selected to simulate is chosen from the sheet Kc_Info: for example Apple and Pear are crop number 2 and Peach & Plum (Stonefruit) are crop number 50. These numbers are the same as those given in the CropList worksheet and in the Input Worksheets.

CropList Worksheet

The KcInfo worksheet contains the crop coefficient information that was compiled for this application program. If you want to change or add crop coefficient information, the changes should be done in the KcInfo worksheet in cells that are not colored. Most users are not interested to use all of the crop information from KcInfo, so the CropList worksheet is used to create a working list of crop coefficient information. Find the crop numbers corresponding to crops of interest in the KcInfo worksheet and input those crop numbers into the CropList worksheet. Then, the crop information in the CropList worksheet are used to compute seasonal crop coefficient curves for your crops of interest. The program automatically copies the crop coefficient information for selected crops from KcInfo to CropList. If you want to change the copied crop information, you can edit the data in the open (uncolored) cells in the KcInfo worksheet.

YTD Worksheet

The yield threshold depletion (YTD) is computed in the YTD worksheet. The YTD is the depth of water that can be depleted before the lack of soil water is expected to impact growth of the crop. In most cases, the crop should be irrigated before more water is depleted from the soil exceeds the YTD. The YTD is determined by computing the available water in the rooting zone and multiplying by the allowable depletion (AD) percentage, i.e. the percentage of available water that can be depleted without affecting crop growth. For most crops, the allowable depletion is about 50% of the available water, but the AD is increased to 60 or 65% for drought tolerant crops with high root length density or is decreased to 35 to 40% for drought sensitive crops with low root length density. The YTD is often adjusted for differences in the area wetted by specific irrigation systems. For example, the adjustment coefficient is 100% for irrigation methods that wet the entire soil surface but could be as low as 10 to 20% for drip irrigation that only wets a small part of the soil surface. All of the factors are considered in the YTD worksheet to give an adjusted YTD for scheduling irrigation.

Irrig Worksheet

If you have data on the optimal irrigation application amounts, you can use the "Irrig" worksheet to determine an acceptable irrigation schedule. The Irrig worksheet provides estimates of the ETc, CETc, soil water depletion (Depl.), and precipitation. Users can input net irrigation application amounts, i.e. the amount applied to the low quarter of the cropped field, on dates when the soil water depletion exceeds the YTD. The program automatically adjusts the Depl for precipitation and irrigation applications. The plot at the top of the worksheet shows how the irrigation applications compare with the ETc. Irrigation can stop when the Depl at the end of the season is approximately equal to the difference between the CETc and irrigation application curves.

Weather Worksheet

The Weather worksheet is used for irrigation scheduling and Kc calculation. In this sheet you can enter the data of ETo, Temperature (minimum and maximum) and precipitation. When not available, the model automatically uses historical data. To estimate bare soil Kc values (Ke) that depend on rainfall, we calculate the square root of cumulative ETo on each day of the year until precipitation is recorded.

The program tests to see if the precipitation is greater than two times ETo on that day. If so, the Ke value is calculated as: cumulative

The Ke value is not permitted to exceed 1.20.

Immature Worksheet

The Immature worksheet shows the appropriate corrections concerning the early years of the orchards. These values can be modified in the Input worksheet in column Q (cells 8-12), relatively to the degree of ground shading (Ground Shading, in percentage), for each growth phase.

Input Worksheet

Input the crop number of interest in cell K3 in the Input sheet. Type the four digit year number into cell K2 to determine if it is a leap year and to generate the dates in column B. Input the maximum crop height into cell K5. Cells I8 to I12 list the end

dates for the Kc trend curve for the selected crop. If you want to change the season start and end dates, input the desired dates into columns J8 and J12. The intermediate growth dates are automatically calculated from the percentages of the season to dates B, C, and D from the information in the CropList worksheet. For orchard and vine crops, periods with ground cover can be input into cells Q2-Q6 and the percentage canopy shading can be input into cells Q8-Q12. The percentage of the surface area wetted by irrigation is input into cell Q7. Sample surface wetting percentages are indicated in the cell comment for various irrigation systems.

In the input worksheet, we start with our best guess at the tabular basal Kc values (K_{ctab}) for the crop based on the Kc estimate for a climate having a midseason ET_o rate of about 7.3 mm/day. Using the July mean daily ET_o rate, we calculate the climate corrected K_c (K_{cmid}) during midseason using the equation:

$$K_{cmid} = K_{ctab} + 0.1654(ET_o - 7.3)(K_{ctab} - 1)$$

Thus, for a $K_{cmid} > 1.0$ in a climate with ETo=7.3, the K_{cmid} value will be higher in a climate with ET_o>7.3 and it will be lower in a climate with ET_o<7.3. The K_{cmid} value is the climate adjusted basal Kc in the model. Next we determine the basal Kc on date B at the onset of the rapid growth period by comparing the table Kc on date B with estimated bare soil evaporation on the same date. The smaller of the two values is selected for the basal Kc on date B. This approach will lower the basal Kc on date B from the table value in locations where precipitation is likely lower than at the site where the table value was originally determined. Thus, we can adjust the basal Kc on date B downward, but we do not increase the basal Kc to adjust for locations with higher rainfall. We have no information to justify the magnitude for an increase in the basal Kc on date B due to precipitation. This is acceptable, because the model will adjust the dual Kc upward to adjust for rainfall during the season.

A linear interpolation is used to estimate the basal Kc between the selected Kc on date B and the climate adjusted date C. The same procedure used to determine the K_c on date B is used to adjust for soil evaporation on date E. That is, the table K_c on date E is used if the value is less than the bare soil K_c on that date. It is lowered to the bare soil K_c if that value is less than the table K_c value. Thus, the K_c at the end of the season is lowered for locations having less precipitation at the end of the season. The basal Kc on date E is not increased above the table value because of lack of information and the fact that the dual Kc will adjust for higher precipitation at the end of the season.

To estimate bare soil Kc values that depend on irrigation (K_i), we calculate the square root of cumulative ETo on each day of the year until an irrigation greater than two times ETo on that day is recorded. On that date, the cumulative ET_c is reset to zero and it begins to accumulate again on the following date. On each date without irrigation, the Ki value is calculated as: $K_i = 2.725(\Sigma ET_o)^{-0.516}$, but the Ki value is not permitted to exceed 1.20. To estimate bare soil Kc values that depend on precipitation, the procedure is similar except the ΣETo is reset to zero on a date when the significant precipitation exceeds two times the ETo on that date. On dates without significant precipitation, the Ke value is calculated as: $K_e = 2.725(\Sigma ET_o)^{-0.516}$.

The daily irrigation data from the Irrig worksheet are copied to column BB in the Input worksheet and precipitation data are copied from the Weather worksheet into column F of the Input worksheet. The historic and current ETc data are copied from the Weather worksheet into columns G and H in the Input worksheet, and the current data are copied to column I if available or the historic data are copied to column I for use in water balance calculations. The Input worksheet calculates water balance on each day of the year using the dual Kc method. The single Kc values are computed to give the best fit of the dual Kc values averaged over each growth period. Plots of the results are shown in the charts ETo, Kc, ETc, and CETc. The Kc chart shows estimates of bare soil evaporation, the dual Kc values that fluctuate from the basal Kc value up to Kc=1.2 after irrigation or precipitation. The single Kc values that are estimated from the dual Kc plots are also shown. These Kc values are used to compute the dual and single ETc curves in the ETc chart. In most cases, there is little difference in the ETc estimated from the dual or single Kc values. The CETc chart shows the cumulative ETc curves from the dual and single Kc methods, and they are typically similar.

Where can I find Kc, ETc, CETc values?

Kc values are output in graphical format as discussed above but also in table format:

- Data are presented in a sequential daily list in spreadsheet Daily
- Data are presented in a weekly means in spreadsheet Weekly
- Data are presented in a month and day format in spreadsheet Monthly

Where can I find degree day information?

- The Kc_A_DD chart shows a plot of Kc versus the agronomic method degree days.
- The KC_T_DD chart shows a plot of Kc versus the triangle method degree days.

The STvsAM chart shows a plot of the degree days from the single triangle and the agronomic methods versus date.

Notes and instructions are also included in the program in the sheets: **Notes** and **Help** worksheets.

References

Allen, R.G., Pruitt, W.O., Wright, J.L., Howell, T.A., Ventura, F., Snyder, R.L., Itenfisu, D., Steduto, P., Berengena, J., Baselga Yrisarry, J., Smith, M., Pereira, L.S., Raes, D., Perrier, A., Alves, I., Walter, I. and Elliott, R. 2006. *A recommendation on standardized surface resistance for hourly calculation of reference ETo by the FAO56 Penman-Monteith method.* Agricultural Water Manual, 81: 1-22.

Snyder, R.L. 2017. Climate Change Impacts on Water Use in Horticulture. Horticulturae 2017, 3, 27; doi:10.3390/horticulturae3020027