CALCULATING CROP EVAPOTRANSPIRATION USING A DUAL CROP COEFFICIENT – PART 2

By Pieter van Heerden and Isobel van der Stoep

INTRODUCTION

As discussed in part 1, the water used by a crop, or crop evapotranspiration (ET_c) is determined by multiplying the short grass reference evapotranspiration (ET_o) with a growth stage-specific crop coefficient (K_c), which serves as an aggregation of the physical and physiological differences between crops and the reference condition. The relationship can be expressed by:

Equation 1

$$ET_c = K_c \times ET_o$$

Modern ET_c calculation methods as described in FAO 56 recognises that wetting events (such as rainfall or irrigation) has an effect on K_c, a fact that has been ignored in the earlier days of irrigation science. The number of wetting events as well as the percentage of wetted soil surface area influence the ET_c and this needs to be taken into account when determining K_c. This is done by splitting K_c into two separate coefficients, one for crop transpiration, known as the basal crop coeficient (K_{cb}), and one for soil evaporation (K_e). The calculation of ET_c now becomes:

$$ET_c = (K_{cb} + K_e) \times ET_o$$

Equation 2a

Or

$$ET_c = (K_{cb} \times ET_o) + (K_e \times ET_o)$$

Equation 2b

The first component of Equation 2b ($K_{cb} \times ET_o$) represents primarily the transpiration component (T) of ET_c – a crop will transpire at the potential rate as long as water in the root zone is not a limiting factor (and therefore even when the soil surface is dry).

The second component of the equation ($K_e \times ET_o$) represents the evaporation component (E) of ET_c. Where the topsoil is wet following rain or irrigation, this component will be at a maximum. As the soil surface dries, the component will decrease until no practically measureable evaporation is taking place.

The need for the separate evaluation of soil evaporation and plant transpiration was identified in the 1980s and locally a calculation procedure was developed for the SAPWAT program based on work done by De Jager & Van Zyl (1987) and Strooisnijder (1987). The procedure had the advantage that it was independent of soil texture, and with the evaporation and transpiration being considered separately, it becomes possible to manipulate the basic crop factors to provide for ground cover, wetted area, frequency of irrigation, cover crops, tree crops, perennial crops and different irrigation systems. SAPWAT was the first program to apply this principle.

THE BASAL CROP COEFFICIENT, K_{CB}

Careful attention should be given to crop coefficient values, especially peak values. There is a tendency to accept the default crop factor curve as a given physiological characteristic of a crop, which is seldom the case. Unrealistic or incorrectly applied crop factors are one of the main causes of inaccurate estimates of irrigation requirements.

Changes in vegetation and ground cover mean that the crop coefficient varies during the growing period. The trends in K_{cb} during the growing period are represented in the crop coefficient curve. Only three values for K_{cb} are required to describe and construct the basal crop coefficient curve. After dividing the total growing season into the four general growth stages discussed in the previous article, the corresponding K_{cb} values can be selected and adjusted for the initial stage ($K_{cb\ ini}$), the mid-season stage ($K_{cb\ mid}$) and at the end of the late season stage ($K_{cb\ end}$). The result is the basal crop coefficient curve from which the daily values of Kcb can be easily obtained.

An example of determining daily values for K_{cb} from Allen et al (1998) is shown below.

CALCULATE THE BASAL CROP COEFFICIENT FOR DRY BEANS AT THE MIDDLE OF EACH OF THE FOUR GROWTH STAGES.

Initial stage (L_{ini} = 25 days), at day 12 of the growing period: $K_cb = K_{cb\ ini} = 0.15$

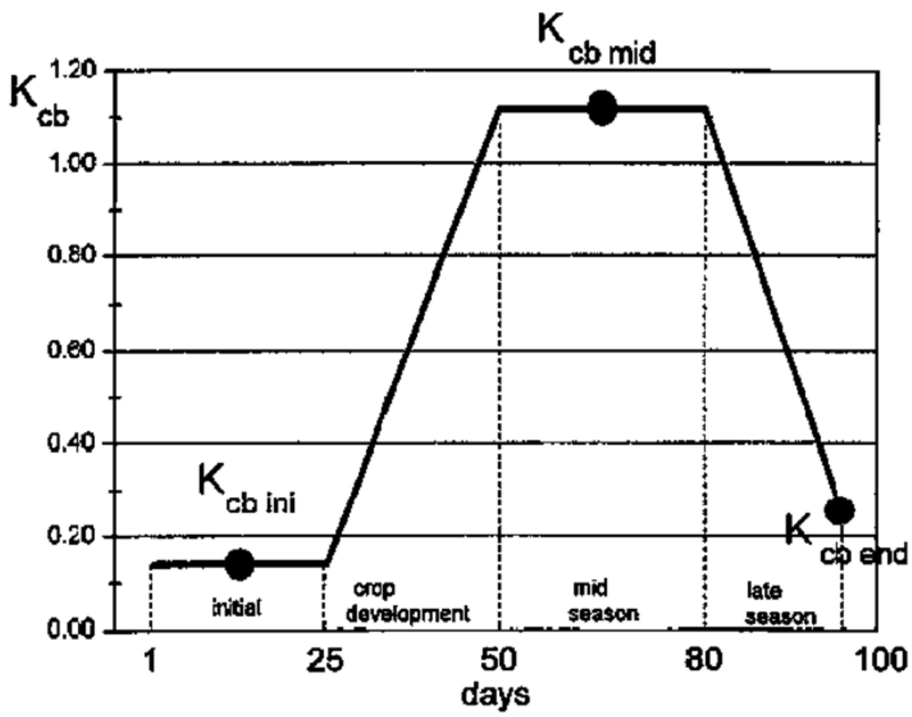
Crop development stage (L_{dev} = 25 days), at day (25 + 25/2 =) 37 of the growing period: $K_{cb} = 0.15 + [(37 - 25)/25]\ (1.14 - 0.15) = 0.63$

Mid-season stage (L_{mid} = 30 days), at day (25 + 25 + 30/2 =) 65 of the growing period: $K_{cb} = K_{cb\ mid} = 1.14$

Late season stage (L_{late} = 20 days), at day (25 + 25 + 30 + 20/2 =) 90 of the growing period: $K_{cb} = 1.14 + [(90 - (25 + 25 + 30))/20]\ (0.25 - 1.14) = 0.70$

The basal crop coefficients, K_{cb}, at days 12, 37, 65 and 90 of the growing period are 0.15, 0.63, 1.14 and 0.70 respectively.

FIGURE 1: Constructed basal crop coefficient (Kcb) curve for a dry bean crop using growth stage lengths of 25, 25, 30 and 20 days (Allen et al, 1998)



CROP COEFFICIENTS FOR LOCAL CONDITIONS

During the development of SAPWAT, specific attention was given to the development of locally relevant crop coefficients. As SAPWAT is not a crop growth model, an alternative solution was found by dividing South Africa into seven agro-climatic regions and developing default crop factors for each of these regions. Default planting date ranges for each region and crop is provided in the model but can be adjusted by the user for his/her specific requirements. Where the planting date has a noticeable influence on the growth stages, individual crop files were developed. Similarly, where noticeable differences between cultivars are found, these were included as separate crops.

Validation of the default values takes place continuously with the help of crop scientists, and is based on practices in the field and the experience of irrigation consultants. The crop coefficients can further be manipulated by the user to take into account ground cover, wetted area, frequency of irrigation, cover crops, tree crops, perennial crops and different irrigation systems as mentioned before.

In the latest version of the program, SAPWAT3, the seven agro-climatic regions for South Africa have been superseded by the change to the Köppen-Geiger approach to standardized climatic regions that is now more generally used.

In the next article, we will look at how to determine the soil evaporation coefficient (K_e) for different wetting events and ground covers, and the outcome of combining K_{cb} and K_e to determine crop evapotranspiration.

REFERENCES:

Allen, R.G., Pereira, L.S., Raes, D. and Smith, M. 1998. *Crop evapotranspiration: Guidelines for computing crop water requirements.* Irrigation and Drainage Paper nr 56. FAO, Rome, Italy.

De Jager, J.M. and Van Zyl, W.H. (1987). *Atmospheric evaporative demand and evaporation coefficient concepts.* Water SA, 15(2).

Stroosnijder, L. (1987). *Soil evaporation: test of a practical approach under semi-arid conditions.* Neth. J. of Agric-Sc.i

The information provided here was partially abstracted from the recently released Water Research Commission (WRC) report entitled "Integrating and Upgrading SAPWAT and PLANWAT to create a powerful and user-friendly irrigation water planning tool" (WRC report nr TT391/08) in collaboration with report main author Pieter van Heerden.

Copies of the report which include a copy of the SAPWAT3 program is available from the WRC at 012 3300340 or www.wrc.org.za.