# A DATABASE OF CROP WATER USE COEFFICIENTS FOR IRRIGATION SCHEDULING OF SUGARCANE

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## Introduction

Effective irrigation scheduling is a prerequisite to optimising the use of expensive irrigation water for sugarcane production in South Africa. Current scheduling methods aim to maintain soil water content in the optimal range by (1) direct monitoring of soil water content, or (2) by estimating soil water content through the profit and loss approach. The latter requires an estimate of evapotranspiration from a reference cane crop (3 m tall, fully canopied and well watered - ETc). The Penman-Monteith equation to estimate ETc from weather data (McGlinchey and Inman-Bamber, 1996) is more accurate than A-pan estimates and has become widely accepted as the standard. It has also become widely available with the advent of automated weather data logging techniques (see e.g. Singels *et al*., 1999). An adjustment (named the crop coefficient, Kc) is required to calculate crop water use (ET) for partially canopied crops.

$$ET = Kc.ETc$$

Kc varies between zero (bare, dry soil) and one (fully canopied, well watered cane) and depends on the amount of canopy cover and the area of 'wet' ground surface. Kc fluctuates from day to day depending on factors such as crop cycle, variety, row spacing, rainfall and irrigation. Crop models such as Canesim (Singels *et al*., 1998) could be used to accurately calculate daily Kc. This technology has not been accepted widely by the industry because of its complexity. An alternative would be to provide period average values of the crop coefficient for a given scenario based on pre-run model simulations for numerous scenarios.

Reported here is progress with the development of a database of weekly coefficients for partially canopied crops for use with Penman-Monteith evapotranspiration estimates. The ultimate aim is to develop a decision support program (DSP) that will provide crop coefficient values for specific combinations of location, irrigation system and cycle, row spacing, starting month, variety and plant or ratoon crop.

## Methods

The Canesim model was run for numerous irrigated scenarios in order to calculate daily values of Kc for eight sites (Table 1), nine crop starting times (months of the milling season), four irrigation systems and different row spacings. A reference soil (clay content 25%, silt content 12%) and reference crop (ratoon NCo376) was used for this work. Initial soil water content was at capacity and irrigation was simulated to prevent any water stress. Weekly averages ($Kc_{avg}$) and standard errors were calculated.

With drip and sub-surface drip irrigation only partial wetting of the soil surface is achieved. The area of wetted ground surface was calculated after Thorburn *et al*. (2000) from emitter flow rate and air entry potential. Soil air entry potential was estimated from soil texture and bulk density (Campbell, 1985). For sub-surface drip it was assumed that the upward movement of the wetting front equalled the horizontal movement.

## Results and discussion

Examples of results are given in Figures 1 and 2 and Table 2 to illustrate trends. From these results it can be seen that:

- Crop cycle has a huge effect on $Kc_{avg}$ with crops at TenBosch reaching $Kc_{avg}$ = 80% at six weeks after a November start, and at 19 weeks after a May start. Kc is also affected significantly by locality especially in crops started in winter (Figure 1).

**Table 1. Selected meteorological stations within the major irrigated areas.**

| Irrigation Area | Station name (Latitude, longitude, altitude) | | Data record |
|---|---|---|---|
| Komatipoort | TenBosch | 25°22'S, 31°55'E, 200m | 1976 – 1995 |
| Malelane | Kaalrug | 25°40'S, 31°34'E, 284m | 1974 – 1997 |
| | Mhlati | 25°29'S, 31°31'E, 301m | 1969 – 1999 |
| Pongola | Pongola | 27°24'S, 31°35'E, 308m | 1968 – 2000 |
| Zululand-North | Entumeni | 28°54'S, 31°18'E, 587m | 1969 – 1992 |
| | Mtubatuba | 28°27'S, 32°13'E, 15m | 1968 – 1999 |
| | Mtunzini | 28°56'S, 31°42'E, 36m | 1967 – 2000 |
| | Nkwaleni | 28°44'S, 31°37'E,110m | 1980 – 1995 |

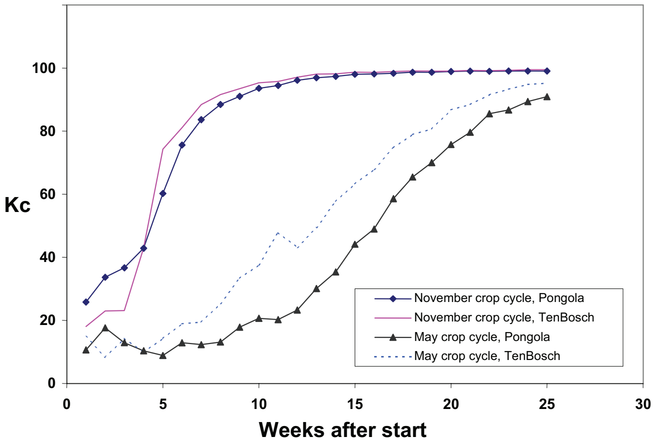


**Figure 1. The long-term average weekly crop coefficient (Kc in %) for different crop cycles for Pongola and TenBosch using surface drip, 1.5 m row spacing.**

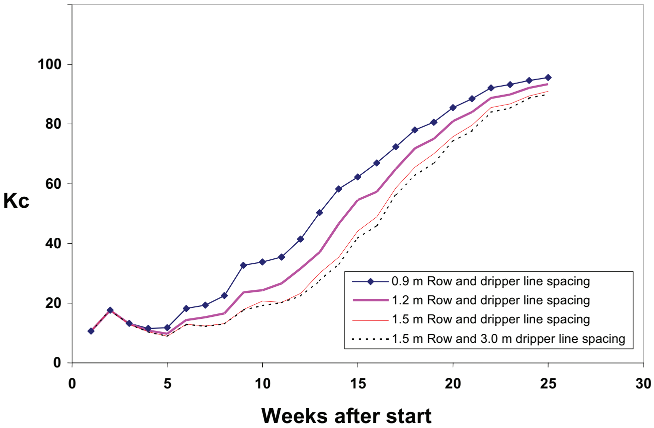


**Figure 2. The long-term average weekly crop coefficient (Kc in %) for different row and dripper line spacings for surface drip on a crop started in May at Pongola.**

- Irrigation system also has a huge effect, with flood and overhead irrigation having lower $Kc_{avg}$ values than drip irrigation because of the lower irrigation frequency and therefor lower evaporation from the soil. The Kc values for sub-surface drip are approximately 17% lower than surface drip because of less soil evaporation (Table 2).
- Row spacing in overhead and surface drip systems has a lesser but significant effect on $Kc_{avg}$. The 1.5 m spacing generally had $Kc_{avg}$ values 15 to 25% lower than the 1.2 m spacing (Table 2). A noteworthy result is the complete lack of $Kc_{avg}$ sensitivity to different dripper line spacings on the same cane row spacing (Figure 2).

Variability in $Kc_{avg}$ caused by variable wetting events (expressed as the standard deviation in Table 2) will decrease as the period of averaging increases, while the applicability of $Kc_{avg}$ to represent canopy induced change in Kc will decrease. An averaging period of longer than a week may be more appropriate and this will be investigated further. The effect of varieties, ratoon stage and irrigation cycle will also be included in the final database.

The database will be linked to a DSP to enable users to extract $Kc_{avg}$ values specific to their cropping situations (Figure 3). These could be applied to ETc estimates to estimate crop water use and schedule irrigation for individual fields according to the method of Culverwell *et al.* (1999). This method provides a much simpler alternative to practical irrigation scheduling than the use of crop models.


## Acknowledgements

The authors would like to thank Carel Bezuidenhout for his assistance with setting up model runs and processing the data.


**Table 2. Long-term weekly average and standard deviation (Std) of the crop coefficient at 15 weeks after a May crop start and 5 weeks after a November crop start at Pongola.**

| Irrigation system (amount per irrigation) | Cane row and dripper line spacing (m) | May crop cycle 15 weeks after start | | November crop cycle 5 weeks after start | |
|---|---|---|---|---|---|
| | | Average (%) | Std (%) | Average (%) | Std (%) |
| Flood (30 mm) | 1.5 | 23.8 | 17.5 | 51.6 | 18.7 |
| Overhead (25 mm) | 1.2 | 27.7 | 17.0 | 56.2 | 18.1 |
| | 1.5 | 21.3 | 15.6 | 51.1 | 19.2 |
| Surface drip (7 mm) | 0.9 | 62.2 | 17.2 | 75.4 | 13.8 |
| | 1.2 | 54.5 | 18.9 | 67.9 | 16.4 |
| | 1.5 | 44.1 | 20.3 | 60.2 | 18.1 |
| | 1.5 m cane row + 3.0 m dripper line | 41.7 | 19.6 | 59.7 | 17.8 |
| Sub-surface drip (7 mm) | 0.9 | 55.9 | 20.7 | 72.8 | 14.3 |
| | 1.2 | 44.9 | 23.4 | 64.7 | 17.0 |
| | 1.5 | 34.9 | 23.9 | 56.9 | 19.1 |
| | 0.9 m cane row + 1.8 m dripper line | 53.9 | 20.1 | 72.4 | 14.2 |

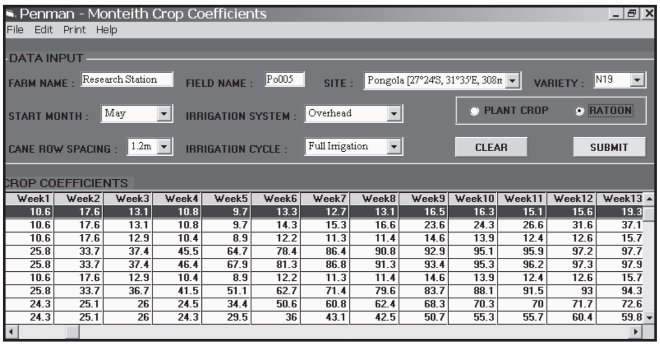


**Figure 3. Sample screen of the crop coefficient decision support program.**

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