DETERMINING IRRIGATION REQUIREMENTS WITH SAPWAT3

By Pieter van Heerden

SAPWAT3 is die jongste weergawe van die rekenaarprogram SAPWAT, wat oor die laaste 2 dekades met behulp van befondsing vanaf die Waternavorsingskommissie (WNK) ontwikkel is. Die program word gebruik om die waterbehoefte van gewasse te bereken deur middel van die Penman-Monteith vergelyking, gebasseer op historiese weerdata. Vyftig jaar se weerdata vir die hele Suid-Afrika asook data vir 144 lande in die res van die wêreld is ingesluit. Statistiese analises kan uitgevoer word vir verskillende omstandighede en gewasse, vir een landery of vir 'n hele watergebruikersvereniging, en resultate kan ook aan produksiebegrotings gekoppel word om die ekonomiese impak van waterbestuursbesluite te ondersoek.

Sapwat3 is essentially an improved version of Sapwat, the computer program that was first developed in the 1990s to succeed the "Green Book", and is the result of nearly 20 years of committed research funding from the Water Research Commission (WRC). It is a computer program that is extensively applied in South Africa as a procedure for the estimation of crop irrigation requirements by irrigation engineers, planners and agriculturalists.

REFERENCE EVAPOTRANSPIRATION

The calculation of crop water use through evapotranspiration is the first, essential element of any routine for estimating crop irrigation requirements; therefore Sapwat3 has as its core the procedures contained in the internationally accepted guideline for estimating irrigation requirements – the United Nation's Food and Agricultural Organisation Irrigation and Drainage Report no. 56 (FAO 56); which uses the Penman-Monteith equation as shown below:

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

Equation 1

where:

ET_0 = Reference evapotranspiration [mm day^{-1}]
R_n = net radiation at crop surface [MJ m^{-2} day^{-1}]
G = soil heat flux density [MJ m^{-2} day^{-1}]
T = mean daily air temperature at 2 m height [°C]
u_2 = wind speed at 2 m height [m s^{-1}]
e_s = saturation vapour pressure [kPa]
e_a = actual vapour pressure [kPa]
e_s-e_a = saturation vapour pressure deficit [kPa]
Δ = slope vapour pressure curve [kPa °C^{-1}]
γ = psychrometric constant [kPa °C^{-1}]

The ET_o value that is calculated with the Penman-Monteith equation represents so-called "short grass" reference evapotranspiration, which can be defined as the rate of evapotranspiration from a hypothetic crop which would closely resemble evapotranspiration from an extensive surface of green grass cover of uniform height, actively growing, completely shading the ground and not short of water. Previously, pan evaporation figures were used as reference, which, although still valid, has limited application in modern irrigation management and research.

WEATHER DATA

The Penman-Monteith equation is calculated using weather data records of solar radiation (sunshine), air temperature, humidity and wind, which together provide the energy input for calculating the reference evapotranspiration. Precipitation information is also required as part of the water balance equation.

Included in Sapwat3 is a comprehensive weather data base:

- The complete FAO CLIMWAT weather data set of 3262 weather stations from 144 countries.
- A derived weather station for each quaternary drainage region of South Africa which provides a comprehensive coverage of the country with 50 years of historical (1950-1999) daily weather data.

Crop development is linked to climate parameters, and for this purpose the internationally recognised Köppen-Geiger climatic system, which is based on temperature-rainfall combinations, is included in Sapwat3. The climate of a weather station is automatically reflected on selection.

CROP COEFFICIENTS

Sapwat3 utilises the FAO four-stage crop development curve procedure (see figure 1) for relating crop evapotranspiration (ET_c) to short grass reference evapotranspiration (ET_o) by applying a stage-specific crop coefficient (kc), which serves as an aggregation of the physical and physiological differences between crops and the reference condition.

Figure 1: Crop development stages and crop coefficients in SAPWAT3

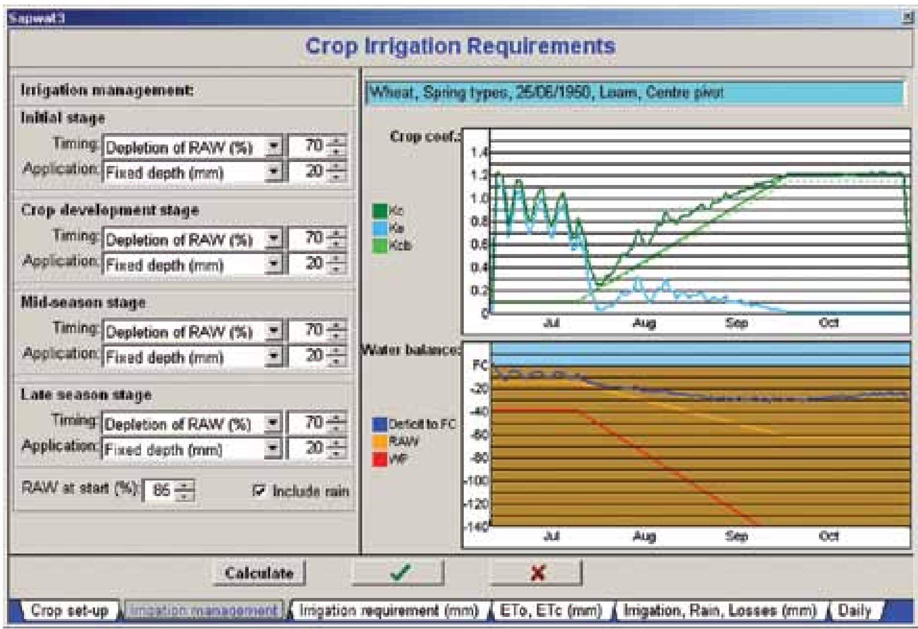
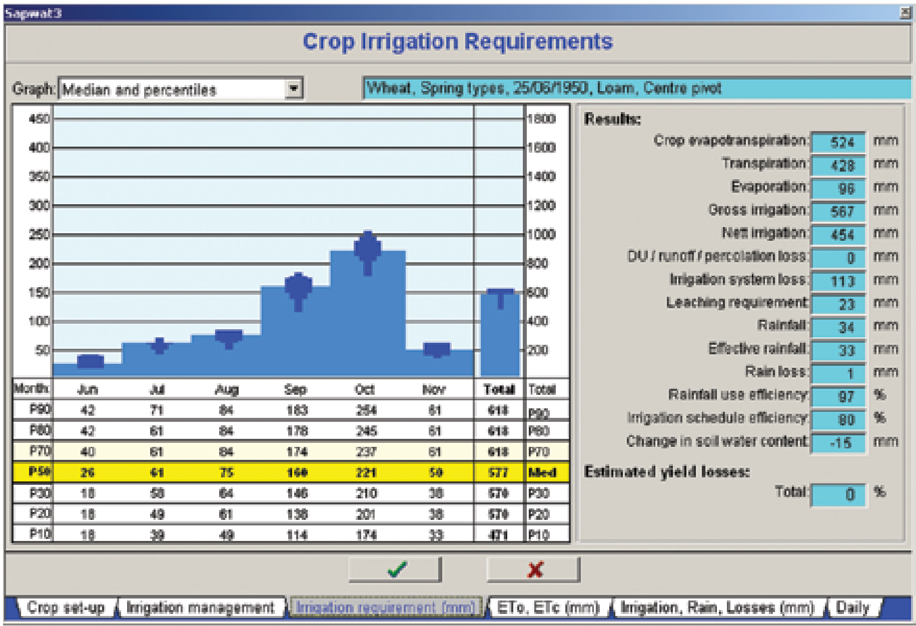


Figure 2: Screen output showing irrigation requirements in SAPWAT3



The relationship can be expressed by the equation $ET_c = k_e \times ET_o$

Typical values of expected average crop coefficients under a mild standard climatic condition, as well as correction factors for deviating climates and conditions, are published in FAO 56 and are applied in Sapwat3. Included in Sapwat3 are default stage length values for each of the crops and their options listed for each of the five climatic zones covering Southern Africa. Crop characteristics were reviewed with the help of experienced local crop scientists.

CROP EVAPOTRANSPIRATION

Sapwat3 makes use of the FAO 56 procedure that separates soil evaporation (represented by ke in Figure 1) from plant transpiration (kcb) and, therefore, conforms to the FAO 56 defaults that determine soil water characteristics and evaporation parameters. Furthermore, a statistical analysis is done on the results to show irrigation requirements for different levels of non-exceedence, giving the user the choice of designing for different levels of risk which would influence the capital and running cost of an irrigation system. Typical screen output can be seen in figure 2, with the median irrigation requirement in mm per month and summed for the season highlighted in yellow.

ADDITIONAL PROGRAM FUNCTIONS

Sapwat3 also includes methodologies for estimating crop irrigation requirements for non-standard situations, such as for saline soils and water, and water stress situations due to inadequate water supply.

Furthermore, the program can be applied for estimating the irrigation requirements for a single crop, for a field of multiple crops, for a single farm, for a group of farms (WUA), for a group of WUAs, for a WMA or for a river basin. Provision is made for printing comprehensive output tables, saving to file or exporting for further processing by spreadsheet applications.

Planning irrigation water use without considering the economic impact does not give enough of a picture on which to base future planning for crop production. A newly included enterprise budget module solves this problem.

Finally, Sapwat3 also includes a rainwater harvesting module aimed at small areas, typically small farms or household gardens. The 50 year daily weather records provided by the quaternary weather stations are particularly useful because a thorough understanding of the rainfall pattern is essential when assessing the viability and developing of suitable systems for rainwater harvesting for both irrigation and household requirements. This module calculates the required harvest area and storage required for a specific situation.

In all program functions, the user has full editing rights on all supporting data sets so that data can be added or edited to reflect local defaults, making it a useful tool for developing different "what if" scenarios.

PROGRAM AVAILABILITY

Sapwat3 is destined to be finalised during the last half of January 2009 and is expected to be available as from March 2009. It will appear as a Water Research Commission Report, because the WRC funded the development there-of.

NEXT ISSUE

In the next article in this series, we will be looking at different types of weather stations that can be used to collect the weather data needed in the Penman-Monteith equation. Practical guidelines for the selection, installation and use will be provided by a local supplier.