The deciduous fruit industry in the Western Cape is a major source of employment in the region and an important earner of foreign exchange for the country. Its future, however, could come under threat over the very resource on which it depends – water.

A 1997 survey of Western Cape fruit producers found that few (about one in every five) used scientific irrigation tools or programmes and that there was a widespread tendency to over-irrigate. This results not only in wastage of water, but also in excessive consumption of electricity as well as leaching of fertilizers and pollution of groundwater with potential longer-term consequences. With the current water resources expected to reach near maximum utilisation by 2012 and priorities for the use of water, under the revised Water Law Principles, going to eco-logical and domestic needs, there is growing pressure on the agricultural sector to optimise its water use.

Moreover it has been established that the growth, productivity and quality of horticultural crops are closely linked to their water status, and therefore the management of water status is important to achieve optimal production and the high fruit quality demanded by local and overseas consumer markets.

IRRIGATION SCHEDULING

Improved irrigation scheduling, in which the timing and duration of irrigation is pre-determined, could offer a possible solution. The timing of irrigation can be determined by procedures based on measured soil and/or plant parameters. Alternatively both the depth of application and timing may be estimated by procedures based on a water budget. In turn, this requires estimation of the evapotranspiration (i.e. The loss of water from the soil and from the tree leaves). Direct measurement of this is not always feasible on a large scale and in such cases it can be estimated by mathematical models utilising meteorological, soil and crop-related data.

As the existence of an automated weather station network in the region supports the feasibility to use a real-time irrigation scheduling model, Theresa Volschenk and colleagues Johanna de Villiers and Odette Beukes of the Soil Science Division of ARC Infruitec-Nietvoorbij at Stellenbosch have undertaken an investigation of models for irrigation scheduling in Western Cape fruit orchards.

The ideal model for estimation of the water consumption of deciduous fruit trees should be able to predict accurately the water consumption for orchards of different crop and management combinations from daily meteorological data. Management variables include different combinations of planting density, tree training systems, summer pruning, clean cultivation, cover crops, mulching, ridging, terraces, wind breaks and crop density, while irrigation systems can result in wetting of either the full (e.g. flood, sprinkler) or part of the soil surface (e.g. micro, drip).

SWB MODEL

Against this background, the model selected for evaluation was the Soil Water Balance (SWB) model, which uses real time weather data along with crop and soil information, to assess the water flow in and between the soil, crops and surrounding atmosphere.

The SWB model combines an FAO-based crop factor model with a quasi-two dimensional cascading soil water balance model to predict crop water requirements on a daily time step for hedgerow tree crops from limited input data. The potential evapotranspiration (PET) is calculated from the internationally standardised FAO Penman-Monteith methodology, while the two components of the PET (potential evaporation and potential transpiration) are estimated using canopy cover. Above-ground energy is partitioned on a semi-empirical approach and a cascading soil water redistribution separates the wetted and non-wetted portion of the ground.

"The way in which this model simulates evaporation and transpiration has the possibility to address the wide array of management practices and irrigation methods employed in the deciduous fruit industry," Volschenk explains.

Input parameters to run the SWB model include crop planting date, latitude, altitude, maximum and minimum daily air temperatures, basal crop factors and duration of crop stages. The basal crop factor (K_{cb}) is defined as the ratio of crop evapotranspiration to the reference evapotranspiration (ET/ET_o) when the soil surface is dry but transpiration is occuring at the potential rate. The ET_o is the evapotranspiration from a reference surface, a hypothetical grass reference crop with specific characteristics, not short of water, and is calculated from weather data using the FAO Penman-Monteith equation. For the water balance component inputs include rainfall and irrigation amounts, the volumetric soil water content at field capacity and permanent wilting point and initial volumetric soil water content for each soil layer, as well as row spacing, wetted diameter, distance between emitters and the fraction of roots that are wetted.

No locally determined crop factors or K_{cb} values were available for deciduous fruit trees in the West-

De Rust Rosemary pear orchard.

Molteno Glen Packham's Triumph pear orchard

Grabouw Farms Golden delicious apple orchard.

(All photographs courtesy of ARC Infruitec-Nietvoorbij)

Left: Molteno Glen golden delicious apple orchard.

Right: Field tests: Tensiometers and neutron probes.

ern Cape and these had to be determined. The duration of crop stages under local conditions also had to be established.

EVALUATION

According to Volschenk, a two-pronged approach was taken to evaluate the SWB model. First it was used to assess if the transpiration coefficient (K_t), which is a measure of the crop transpiration only, could be used in place of the basal crop coefficient (which includes transpiration as well as a residual soil evaporation component) in combination with measured soil water deficit to calibrate the model. Secondly, it was used to perform simulations and fit SWB-predicted soil water deficit to measured soil water deficit from orchards until the best statistical fit was obtained.

A series of six sites were selected for study, comprising two different cultivars of apples and four of pears in the Elgin district, and three cultivars of peaches in the Robertson and Ashton areas.

Transpiration coefficients were determined for Golden Delicious apples and Neethling peaches and it was found that these could not necessarily be used interchangeably with the model-derived basal crop coefficients. According to the statistical output parameters and/or visual fit there was reasonable agreement between the SWB-predicted and measured soil water deficit for six of the eleven study plots where the fitting procedure was used.

DRAWBACKS

A drawback of the model was that it could underestimate evaporation grossly for warmer areas where the tree canopy fraction exceeds the irrigated soil fraction.

Moreover, attempts to estimate the basal crop coefficient from easily measurable orchard parameters – the tree width and lateral spacing – proved unsatisfactory. However it was found possible to estimate K_{cb} from the measured leaf area, leaf density or the fractional interception of solar radiation by the tree, all of which require specialised expertise and equipment to determine.

It was also found that full bearing trees of early and mid-season cultivars had higher water requirements than predicted from previously published crop factors and Class-A pan evaporation. Producers thus should consider the higher seasonal irrigation requirements of these trees when managing irrigation water. The crop coefficients determined for use with ET_o for apple, pear and peach trees in this research project could prove to be valuable in this regard.

Volschenk concludes that the use of a model such as SWB, which utilises a dual crop coefficient approach (i.e. models evaporation and transpiration separately), has the potential to address some of the variability present in irrigation of orchards and to improve water management. However, further research is required on various aspects, such as assessment of a simple and practical approach to determine K_{cb} values and extending the model to accommodate separate water balances for trees and cover crops under full surface irrigation conditions.

With regard to the practical application of the model trained professionals are needed to collect input data and assist farmers in using the model. In the case of basal crop coefficients not being available, these can be estimated for apple and peach orchards from the fractional interception and from the leaf area for pears.

Critical limitations to using the model are possible lateral water movement into orchards on slopes and soil variability. In such cases direct measurement of the soil water content may become important. "Where lateral water flow into orchards is not a concern, real time irrigation models that are verified through measurements could aid in improved water management and the saving of limited water resources" says Volschenk.