Measuring and modelling the water use of fruit tree orchards in the Western Cape province of South Africa

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INTRODUCTION

There is increasing competition among the various sectors of the South African economy for limited water resources, and irrigated agriculture is estimated to use approximately 60% of available surface water (NWRS2, 2012). With a 90% dependence on irrigation, it is important that the fruit tree industry improves irrigation scheduling and efficiencies in both the summer and winter rainfall areas of South Africa, where water stress is increasing. It is a goal of the modern horticultural industry to use less water, without compromising fruit quality, size, yield and profits. Technological advances in sap flow and energy balance monitoring instrumentation allow for the quantification of exact amounts of water used for transpiration (individual tree water use) and total evaporation (orchard water use). This knowledge can aid on-farm water management planning, irrigation scheduling, and the development of decision support tools such as models for predicting water use by fruit tree orchards. In a project solicited and funded by the Water Research Commission (WRC, 2008), the CSIR is collaborating with the University of Pretoria to study the water-use of fruit tree orchards. The primary objectives are:

1. To measure the unstressed water use and ancillary variables of the most important sub-tropical and deciduous fruit trees/ orchard crops in winter and summer rainfall regions of South Africa
2. To develop comprehensive knowledge of their water use characteristics for application in fruit tree/orchard management
3. To develop, verify and validate the most appropriate crop water use model(s) for the selected species.

METHODS

Figure 1: Heat Pulse Velocity system used to measure sap flow (transpiration) in the apple orchard

Two years of detailed water use measurements were conducted in two Western Cape orchards. Sites comprised a 12-year old 'Cripps Pink' ('Pink Lady') apple (*Malus domestica*) orchard in the Koue Bokkeveld region near Ceres (S33° 12′ 03.57″; E19° 20′ 15.06″), and an eight-year old 'Alpine' nectarine (*Prunus persica*) orchard near Wolseley (S33° 25′ 0.59″ and E19° 14′ 44.84″). Sap flow (transpiration) was measured hourly for the entire period using the Heat Ratio Method (Burgess et al., 2001) of the Heat Pulse Velocity Technique (**Figure 1**). In addition, short-term seasonal measurements of total evaporation (ET) were taken periodically, using the open path Eddy Covariance energy balance technique (**Figure 2**). Mature, unstressed trees were selected on farms applying best management practices to ensure that peak water use rates were measured. These observations were combined with site-specific information on weather, irrigation volumes, soils and tree characteristics to calibrate and validate a dual-source model (total evaporation (ET) = transpiration + soil evaporation (modified version of Shuttleworth & Wallace, 1985)). Measured and modelled results were used to derive monthly FAO-56 type crop coefficients (Allen et al., 1998) for the two species.

RESULTS

Distinct seasonal trends in water use were observed for these two deciduous fruit tree species (**Figures 3 and 4**). The apple trees transpired just over 4 000 L/tree/year, while the nectarines used a more conservative 3 000 L/tree/year. Relative to planting density, this equated to 690 mm and 490 mm respectively. Basal (K_{cb}) and full (K_c) crop coefficients were derived for the two species (**Figures 5 and 6**) by combining the transpiration and ET results with daily reference evaporation (ET_o) data.

Figure 2: Open path Eddy Covariance system mounted on a lattice mast, and used to measure total evaporation in the nectarine orchard.

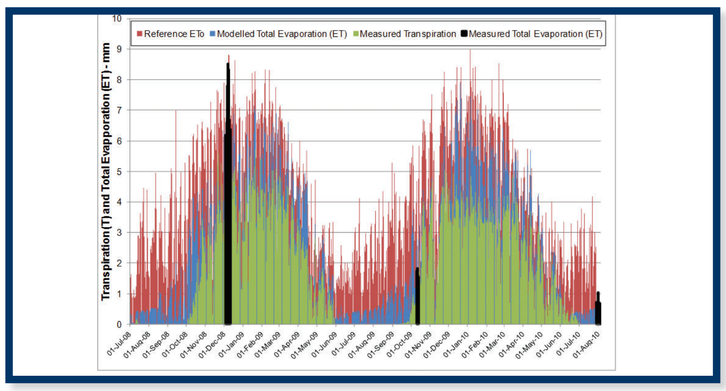

Figure 3: Daily variation in reference evaporation (FAO56 ET_o), observed and modelled total evaporation (ET), and transpiration (T) from July 2008 until June 2010 in a "Pink Lady" apple orchard near Ceres, Western Cape

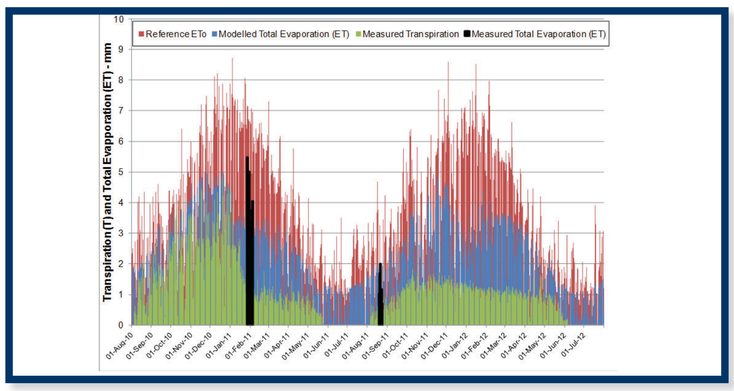

Figure 4: Daily variation in reference evaporation (FAO56 ET_o), observed and modelled total evaporation (ET), and transpiration (T) from August 2010 until July 2012 in an "Alpine" nectarine orchard near Wolseley, Western Cape

This project investigated the water use of irrigated fruit tree orchards as a means of facilitating more efficient and productive water use within the sector and reducing operating costs.

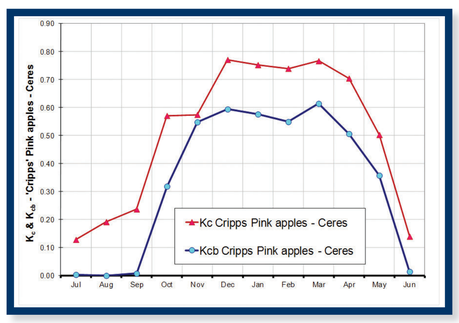

Figure 5: Basal (K_{cb}) and full (K_c) crop coefficients for 'Cripps Pink' apples at Ceres, Western Cape

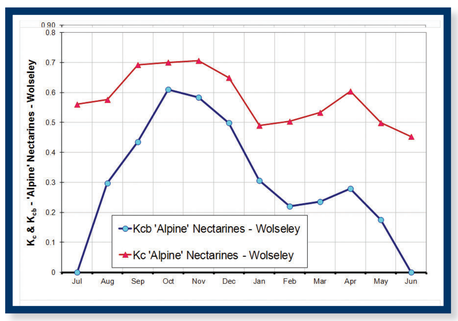

Figure 6: Basal (K_{cb}) and full (K_c) crop coefficients for 'Alpine' nectarines at Wolseley, Western Cape

CONCLUSIONS

South Africa's Draft National Water Resources Strategy (2012) calls for substantial water savings in agriculture, and has the implementation of water use efficiency as one of its core strategies. Implementation actions include registering water use to levy charges and authorising water use by issuing licences. Research on the water use of irrigated fruit tree orchards is one means of facilitating more efficient and productive use of water within the sector, and also reducing operating costs on farms. The data collected from this project has improved knowledge of fruit tree water use and refined crop water use models for the targeted species.

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