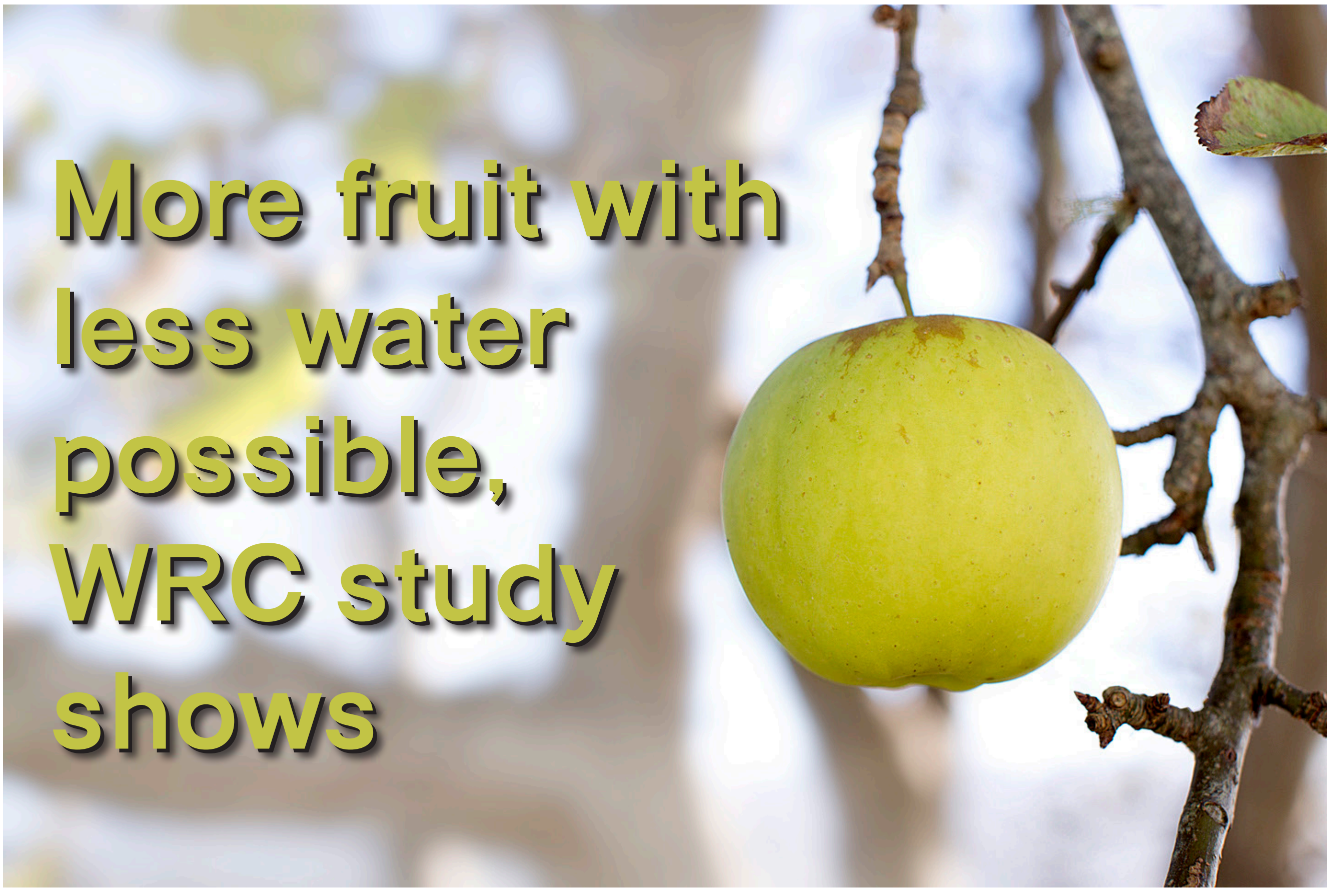
More fruit with less water possible, WRC study shows



Over 300 years South African fruit production has become a major contributor to the South African economy, not only in terms of job creation but also with regards to foreign exchange export earnings. With the costs of resources rising along with international competition, this irrigation-dependent sector is constantly requiring ways of raising efficiency. A recently completed Water Research Commission (WRC) study has applied various water use monitoring techniques in the field towards improving the water use efficiency of South Africa's fruit production. Article by Lani van Vuuren.

Covering an area of around 78 000 ha, deciduous fruit production is one of the largest agricultural sectors in South Africa. It is also a sector aimed at the export market, with more than 50% of fruit produced sold to overseas markets, mainly Europe.

Fruit is principally grown in the Western and Eastern Cape provinces where warm, dry summers and cold winters prevail. At last count, there were around 1 700 pome and stone fruit as well as table grape producers in South Africa, according to the Department of Agriculture, Forestry and Fisheries (DAFF).

Due to the country's naturally variable and semi-arid climate, nearly all fruit produced in South Africa is grown under irrigation, also making the sector a large water user. Yet, the exact water use of fruit production has not received much attention in South Africa to date.

Important knowledge in this regard has now been gathered through the seven-year project initiated

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by the WRC and led by CSIR and the University of Pretoria on the water use of economically important fruit trees and orchards. The team also worked closely with Citrus Research International.

According to WRC Executive Manager: Water Utilisation for Agriculture, Dr Gerhard Backeberg, the study was not only one of the most comprehensive on the subject ever undertaken in South Africa to date, but has ushered in a new research focus for the Commission. "To date, most research commissioned by the WRC has been on the water requirements of crops, either through measurement or modelling. In the process various agricultural models have been developed, such as SAPWAT and the soil-water-balance (SWB) model, to assist farmers with irrigation scheduling and improved water management."

Of late the lens has shifted wider to consider water use within the entire food value chain as well as to determine the water footprint of crops. "While the focus is still on water use of specific crops, it is now within an explicit framework or broader context," explains Dr Backeberg. "This improves understanding of water use in agriculture beyond the field or farm level."

Government has identified agriculture as an important contributor to rural development. The Irrigation Strategy for South Africa sets a target to increase the area under irrigation in the country. However, while we might in future have more crops in the field, it is unlikely that there will be additional water resources available to irrigate them.

This consequently necessitates significant increases in water use savings so that more crops can be produced with less water. Knowledge such as what is currently being obtained through WRC research will undoubtedly stand South African farmers in good stead in future.

NEED FOR IMPROVED WATER USE EFFICIENCY

According to Dr Mark Gush, Research Group Leader: Hydrosciences at the CSIR Natural Resources and the Environment, the research team set themselves the goal of better understanding water use along the entire production chain of selected fruit crops. The question was what data, measurements and information would be required to accurately quantify the water footprints of the fruit examined and how could this be used to improve water use efficiency?

Courtesy Mark Gush

The Koue Bokkeveld, one of the main fruit production areas in the country.

To come up with an answer, the team applied various water monitoring techniques on seven selected fruit farms. Dr Gush reports that farms were purposefully selected where best management practices were already being applied in terms of irrigation applications. Most of these farms make use of soil moisture measurements for irrigation scheduling.

Some farms were found to be at the forefront of scientific approaches and were using climatic data and existing crop coefficients to assist in scheduling irrigation, reports Dr Gush. "However, results from this project indicated that the existing crop coefficients being used differ significantly from those derived from the project measurements, and if applied should facilitate more accurate irrigation scheduling."

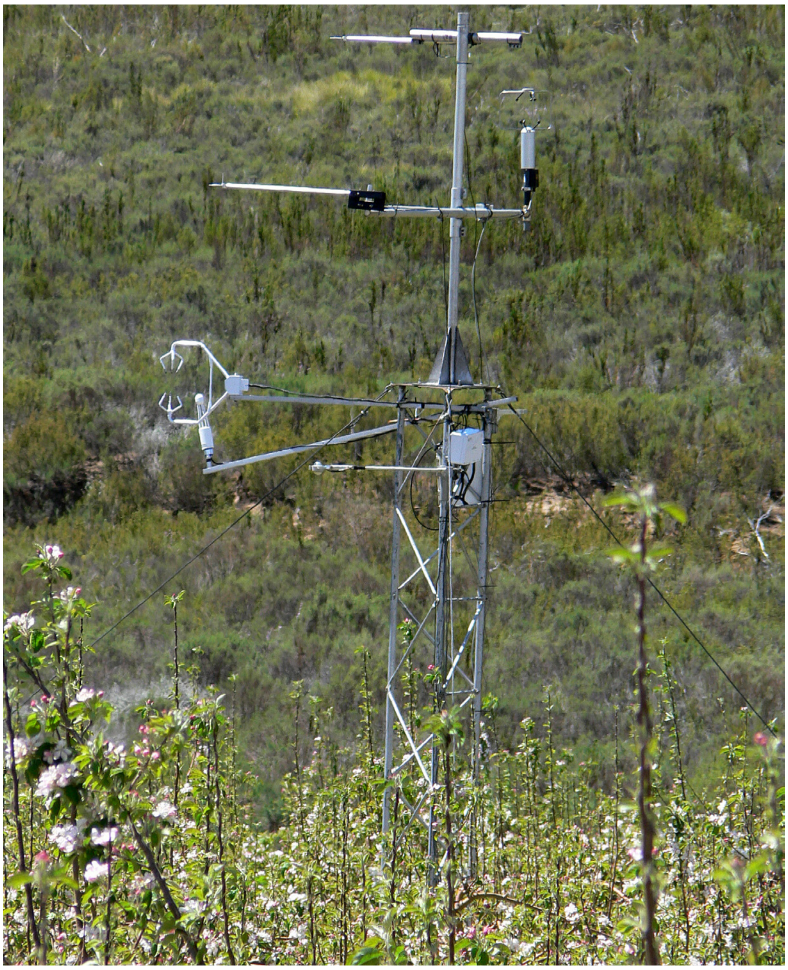
Dr Gush continues to say that the use of soil water measurements can also be misleading due to uncertainties about whether soil water is draining downwards, evaporating upwards or actually being used by the trees. "This is where actual tree water use measurements, as conducted by the research, were very beneficial."

While economic considerations are still top priority, there is no doubt that the importance of water to the fruit tree industry is increasingly being recognised, as well as the risks related to uncertainties about future water supply. "Water is a very strategic consideration in the industry, and is key to the sustainability and expansion of the sector. While there does seem to be more focus at present on how to secure more water for a farm (to allow expansion) as opposed to how to increase efficiencies (make do with less water), this is bound to change in the near future."

WATER USE VARIABLES

Determining how much water goes into growing an apple or a pear is not as easy as it sounds. The water use of a fruit tree is influenced by many factors. The first is the size and age of the tree, mainly due to differences in total leaf area. This changes most dramatically as the tree grows from a sapling, but becomes less of a factor once the canopy is fully developed and relatively constant in size, such as is the case in a mature orchard.

The second variable is the time of year or growth stage, as deciduous trees in particular undergo dramatic changes in leaf area through the year. Then there are the prevailing climatic conditions of the day, mainly the vapour pressure deficit of the air, net radiation and wind. Main drivers for these variables are solar radiation, temperature, humidity and wind speed.



Courtesy Mark Gush

The eddy covariance technique measures turbulent eddies of air above a vegetation canopy, which are important drivers of water vapour exchange (evapotranspiration) from the underlying vegetation.

Soil water content, soil texture, and soil depth also play a role as this determines how much water is available to the tree, and how easy it is for the tree to extract it. Access to soil water is also influenced by root distribution and depth which, in turn, may be influenced by soil nutrition (fertilisation).

Tree water use is also linked to tree health, as vigorous healthy trees will use more water than diseased trees or those growing in water-logged soil. However, they will also produce higher yields, thereby improving their productivity. The last factor to consider is that of management interventions, particularly pruning (which changes leaf area), mulching and obviously irrigation.

VARIETY OF WATER USE MONITORING TOOLS

So how did the team get around all of this variability? The project combined different methods to measure water use. This included techniques to obtain data on transpiration of trees through sap-flow measurements, orchard evapotranspiration rates, soil water balances and automatic weather station variables, such as rainfall, temperature, humidity, solar radiation and wind speed. The research team also determined irrigation timing and amounts from metered records at the sites or from direct measurements on the irrigation lines.

More specifically, the heat pulse velocity (HPV) technique was used to measure sap flow rates through the trees. This involved installation of probes in the stems of individual trees and allowed the team to calculate the transpiration of the trees (i.e. the volumes of water physically passing through the stem of the tree).

This sap flow data supplied by the HPV system quantified the volumes of water actually being taken up by individual trees, from the roots out through the leaves (as opposed to amounts of water simply being applied by irrigation). This is known as beneficial water use.

Furthermore, the team used the eddy covariance technique to measure the total evaporation of the orchard. This required installation of the system on a mast above the orchard. This instrumentation provided the team with data on the evaporation rates from the entire orchard, being inclusive of transpiration (tree only water use), soil evaporation, water use of the cover crop (working row vegetation), and the evaporation of any intercepted water on the leaves of the orchard (for example, from rainfall or irrigation).

Eddy covariance instrumentation was also established within the orchards.

Courtesy Mark Gush

Apart from these primary measurements the team also measured climatic variables with an automatic weather stations, soil moisture fluctuations at different positions and depths down the soil profile, irrigation applications and some physical characteristics of the orchard, for example leaf area index, tree size, sapwood depth and so on.

This comprehensive sampling strategy then formed the basis for modelling water use, allowing or enabling extrapolation beyond the locality where measurement were done, within specified 'boundaries' (for example fruit type, soil class and rainfall zone). The research determined water use of single trees and given the plant spacing and additional non-beneficial water use, also water use of the orchard as a whole.

Water use was quantified or estimated as evapotranspiration. Within the water balance approach, both these variables constitute consumptive water use, Dr Backeberg explains. "The big advantage is to distinguish beneficial water use from non-beneficial water use. By understanding and improving evapotranspiration within the tree rows and reducing evapotranspiration between the tree rows, beneficial water use is increased. This clearly contributes to increased efficiency and productivity of fruit production."

By reducing or at least limiting non-beneficial water use, water and cost savings are possible with the potential to improve the profitability of fruit farming. "The available research output can therefore be applied for more effective advisory and extension services to farmers in the fruit industry," notes Dr Backeberg.

CASE STUDY ON APPLE ORCHARD

One of the case studies was undertaken on a Cripps' Pink apple orchard in the Koue Bokkeveld region of the Western Cape. The 2.3 ha orchard features mature trees of an average 13 years of age and yields around 60 t/ha of apples a year. The long research period allowed the team to account for year to year differences in climatic and orchard conditions.

An important finding of this case study was the fact that water requirements of the apple trees declined dramatically towards the end of the growing season (from March onwards), but irrigation applications were not curtailed to a similar degree. This provides scope for water savings.

While comparing the water use of different fruit cultivars fell outside the scope of this study Dr Gush and his colleagues did make an interesting observation in the apple orchard case study. "In the apple orchard we found that the pollinator tree species (Hilleri), which comprised every eighth tree in the orchard used less than half the water of the primary (Cripp's Pink) variety." This raises a number of questions for future research studies, especially as to the performance of locally bred stone fruit cultivars compared to imported counterparts.

Another interesting finding of the study was that if the transpiration (i.e. tree only) water use values are considered, then results showed that for virtually all the case studies actual tree water use is less than what was previously thought. "It is important to bear in mind that this data represents only what is used by the trees themselves, and it is unrealistic to expect that irrigation applications could be so accurate as to provide exactly what the tree requires," qualified Dr Gush. "Inevitably, there is non-beneficial loss through drainage or evaporation, so allowance for this fact needs to be made."

Importantly, the research has yielded new insights into the patterns of water use exhibited by the various fruit tree species through the growing season, which could assist in scheduling irrigation more accurately.

The research team gained significant knowledge during the study, mostly associated with the volumes and patterns of water use by the various fruit tree species being monitoring. There is now a better understanding of these water use volumes and patterns, which are incorporated in the species-specific crop-coefficients derived from the observed data. These have indicated that the focus should be on maximising beneficial water use and minimising non-beneficial water use by accounting for seasonal patterns in tree water requirements, and endeavouring to deliver the right amount of water as close as possible to the root zone of the trees.

Dr Gush gives the following advice to fruit farmers looking to improve water use efficiency: "Use the latest and most accurate crop coefficients (preferably based on observed data) when planning irrigation schedules for the growing season. Maximise the use of rainfall during the growing season, and adjust irrigation applications accordingly. Avoid over-irrigation and water-logging, not only due to water use and electricity cost considerations, but also due to the detrimental impact on the health of the orchards. Ensure that water distribution and irrigation infrastructure is in good condition so as to minimise transmission losses."

ADDITIONAL STUDIES

The research team expressed their gratitude to the farmers and farm managers who participated so willingly in the study. All of the results of the study were shared with participating farmers and other stakeholders, mainly through specially organised information days. According to Dr Gush, these information sessions were useful not only in facilitating discussion on water issues, but also to illustrate the technologies employed by the project to determine water use of trees and orchards. "We also used the opportunity to highlight the potential for improvements in water use efficiency, mainly by reducing over-irrigation."

Based on the results of the study above, the WRC has initiated a further two projects on specific citrus and apple varieties. These studies are being undertaken in cooperation with Citrus Research International and HortGroScience.

- To obtain the reports, *The water use of selected fruit tree orchards (Volume 1): Review of available knowledge* (**Report No. 1770/1/14**) and *The water use of selected fruit tree orchards* (*Volume 2*): *Technical report on measurements and modelling* (**Report No. 1770/2/14**) contact Publications at Tel: +27 (0)12 330-0340; Fax: +27 (0)12 331-2565; Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy. ❑

Heat pulse velocity sap flow monitoring uses heat as a tracer of sap flow in the stems of woody plants – sap flow being synonymous with transpiration of water use.

Courtesy Mark Gush