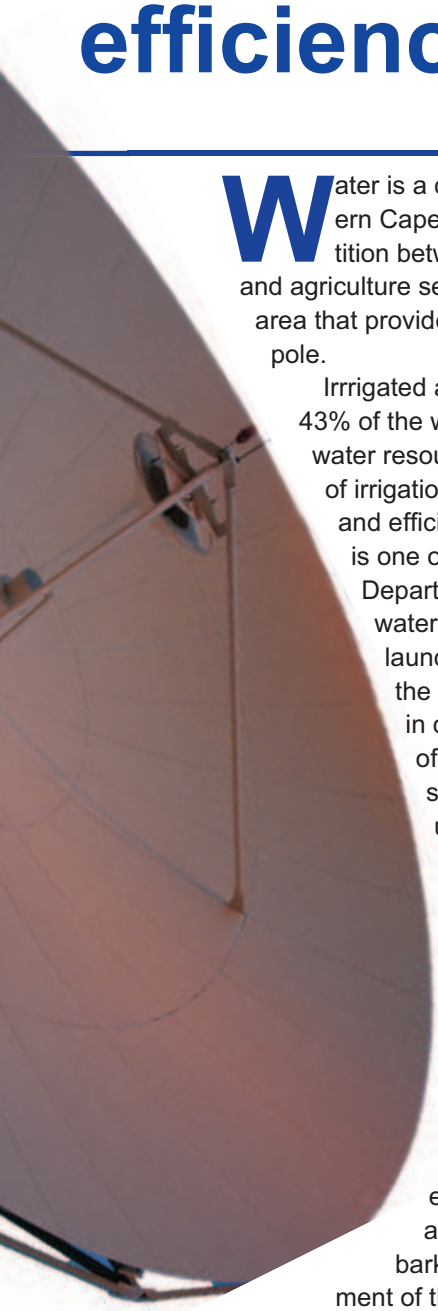
Satellite images show water use efficiency



Water is a critical resource in the Western Cape and there is strong competition between the urban, industrial and agriculture sectors within the catchment area that provide water to the Cape Metropole.

Irrrigated agriculture is responsible for 43% of the water usage from surface water resources and the efficient use of irrigation water is critical. Effective and efficient use of irrigation water is one of the top priorities of the Department of Agriculture and a water conservation project was launched in 1999 to determine the water use efficiency of crops in certain areas. Over a period of four years, this project resulted in an increase in water use efficiency (kg of fruit produced per cubic meter of water) of between 15 and 20%. This in-field monitoring however requires extensive personnel and financial resources and a more cost effective method to reach the same objectives had to be found.

The use of satellite imagery provided the opportunity and a pilot project was embarked upon with the appointment of the CSIR in Stellenbosch and Waterwatch in the Netherlands. The study aims at spatially estimating water use efficiency in table and wine grapes in Western Cape with remote sensing technology.

The Surface Balance Algorithm for Land (SEBAL) is used to estimate total evapotranspiration (ET) and water use efficiency for grapes in the Hex River Valley, Worcester, Franschhoek and Paarl areas for two growing seasons (September 2004 to April 2005; September 2005 to April 2006). SEBAL uses the simplified energy balance to the estimate total evapotranspiration (ET), biomass production, water deficit and soil moisture spatially. Land surface characteristics such as surface albedo (earth surface's reflectivity), leaf area index, the vegetation index and surface temperature are derived from satellite imagery. In addition to satellite images SEBAL requires meteorological data (wind speed, humidity, solar radiation and air temperature). Since SEBAL uses the energy balance, and not the water balance, no data on land cover, soil type or hydrological conditions are required.

Biomass, Harvest index and Yield calculation
Biomass production calculated by SEBAL can be defined as the total dry matter production by a plant (roots, stems, leaves and fruit.

The harvest index (HI) of grapes is the part of the biomass that is harvested. This index was found to be a function of water deficit in February and soil moisture content in November and December. The HI function for table grapes was developed in this study and is based on field measurements of yield of the Alphonse Lavalee cultivar grown in the Hex River Valley.

The harvest index (HI) of wine grapes were developed based on field measurements of yield from the Colombar grape cultivar grown in the Worcester area. It is dependent on the water deficit in February and the soil moisture content in November and December. The wine grape yield function needs to be improved to include more cultivars as very different management strategies are applied in the production of different wine grape cultivars.

The estimates of evapotranspiration and yield were used to calculate water use efficiency (WUE in kg of fruit per m^3) of table and wine grapes. Water use efficiency (or water productivity) is thus defined as the marketable crop yield per unit of actual total evapotranspiration.

Two ASTER images were acquired. These images have a spatial resolution of 15 x 15m per pixel and are therefore very suitable for orientation during the fieldwork and for vineyard mapping. Images of Landsat 5-TM and Landsat 7-ETM (30 X 30 m pixels) were obtained, one per month for the 2004/05 and 2005/06 irrigation season

We're serious about saving water .... are you?

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sustainable resource management and concentrate on poverty alleviation, capacity building and awareness. Area Wide Planning of large areas within the Western Cape is a holistic and pro-active planning tool to link the farm plans with area plans that reflect the future desired condition of the resources within the Province - see p. 12 for more information.

The campaign will run from September to December 2007 and will focus on the youth, as well as the farming and broader communities but the focus on resource conservation is a long term commitment for the Department and the various programmes and projects will continue long after the campaign has ended.

(September to April), to be used for the determination of the various parameters required.

A team from WaterWatch collected field data from 2 981 grape vineyards, of which 2 042 were table grape vineyards, 894 wine grape vineyards and 39 bush grape vineyards, to be use for field validation in the Hex River Valley, Worcester, Franschhoek, Paarl and Wellington.

To compute the spatially distributed ET (evapotranspiration) of grape yield and grape ET, it is necessary to have an estimate of air temperature, air humidity, wind speed, rain fall and solar radiation for every Landsat pixel. WaterWatch has developed the MeteoLook algorithm that interpolates point data on the basis of physiographical properties. The data of the 20 automatic ARC weather stations was used as calibration input to MeteoLook. The data of the 85 mechanic ARC stations and 17 SA Weather stations was used for validation of the MeteoLook results.

The following results were obtained through the project:

Water consumption of vineyards

The distribution and quantity of rain in a specific year play a meaningful role in the water consumption of crops. Low rainfall was recorded in the winter of 2004/05, resulting in limited availability of water for the irrigation season. More than average rain was however recorded in the following summer, which reduced the irrigation demand. During 2005/06 more rain fell during the winter but very little rain fell during the summer months, resulting in more water available from storage during the irrigation season and a higher irrigation demand due to the dry summer.

- Table grapes clearly consume more water than wine grapes.
- Wine grapes in both studied years consumed a conservative amount of water, with averages of 533 mm (2004/05) and 575 mm (2005/06). This reflect a 7,8% (43 mm) increase. Irrigation field measurements in Hex Valley agree with these results, showing irrigation supplies increase by 69 mm in the second season.
- Table grapes' water consumption however increased with 18% from 702 to 828 mm which is equivalent to an increment of 126 mm.
- What draws the attention is that not all farmers were able to increase their irrigation during the dry season (2005/06), resulting in more variation in table grapes' water consumption.
- One explanation for the lower increase in irrigation for wine grapes may be that over-irrigation in red wine grapes affects the quality of wine. For table grapes and white wine grapes however, extra irrigation mainly results in a higher yield.
- A good correlation exist between the accumulative monthly evapotranspiration in the fields calculated with SEBAL and evapotranspiration calculated with the soil water balance based on field measurements.

Water use efficiency

Water use efficiency was fairly similar in the two study seasons. Water use efficiency of table grapes decreases slightly from 3.8kg/m^3 on average to 3.7kg/m^3 in the

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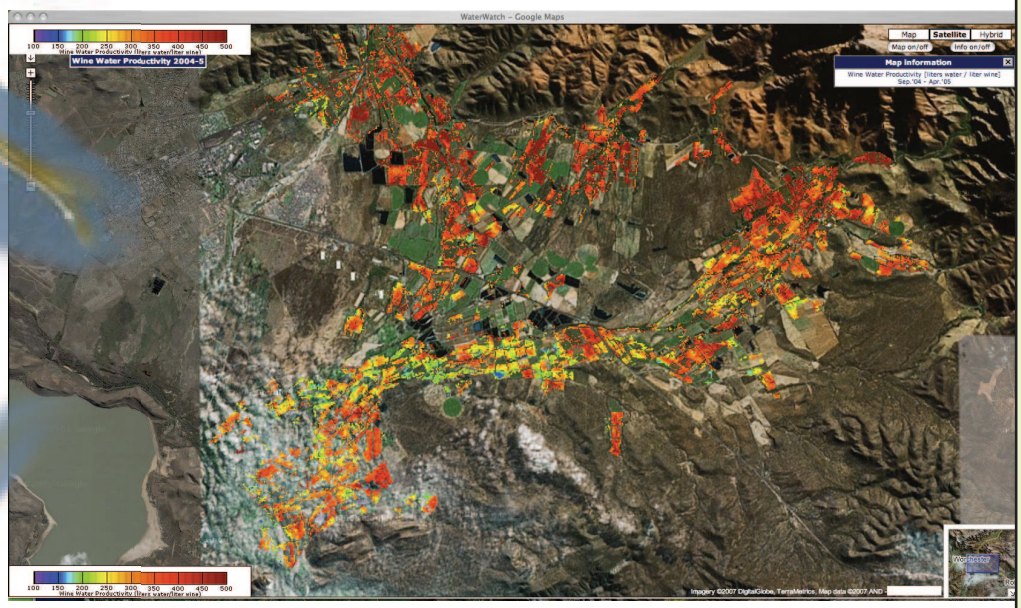

A satellite image from Google Earth and Waterwatch showing water use efficiency in the Worcester area.

second year, while the water use efficiency of wine grapes shows a small drop from 4.9 kg/m^3 to 4.5 kg/m^3 on average.

Water use efficiency in the Hex Valley in the second season is lower in most areas due to slightly lower yields and significantly higher water consumption. Especially in the downstream area, water use efficiency drops during the second year. In the more isolated table grape vineyards (in the southeast and east, most likely from farmers with their own water resources), water use efficiency remains preserved or even improves.

Many factors however play a role such as the variability of soil type, both in terms of physical and chemical properties.

Many conclusions can be reached from the project results but due to limited space, only a few will be highlighted.

- Water use efficiency of grapes in Western Cape is in general quite good, although it varied considerably between fields, regions and between years.
- The considerable spatial variation in WUE in the grape producing areas, suggest that WUE can be improved.
- Spatial estimates of WUE can be used to evaluate differences in management practices and suggest improvements.
- Water use efficiency is influenced by many factors. The availability of water per farm (access to ground water and storage capacity) and management of water in times of scarcity play an important role.
- The production objectives influence the water use efficiency. High quality red wine grapes require less water that high yielding vineyards producing grapes for the brandy industry.
- Variations in water use efficiencies in Hex Valley are very large. This can partly be contributed to the large number of cultivars grown.
- The varieties Dauphine, Thompson, Barlinka and Crimson have highest water use efficiencies, while the varieties Victoria and Flame have relatively low water use efficiencies.
- It seems that farmers with their own water resources at the outskirts of the area are able to manage their water resources better, resulting in higher water use efficiencies.

It is recommended that the study be extended to include the potato growing areas of the Sandveld, the grape producing areas of Vredendal and the citrus producing areas of Clanwilliam and Citrusdal.

Recommendations for further studies include incorporating more years to evaluate the influence of rainfall on water consumption, and to make inter-annual evaluation possible. It is necessary to study more than two years to better express temporal variability and the role of reliable water supplies.

It is also recommended to collect more spatially varied field data on yield in future studies. The wine yield model in this study was based on Worcester field data only, while yields are very different in Paarl area.

The datasets produced are highly relevant for the growers and their irrigation advisors. Combination of the remote sensing data with vineyard management expertise will create a good avenue for better explaining the causing factors of the strong variations in water use efficiency in both space and time. Grower associations could benefit from having geographically different values of yield (income), water (conservation) and water use efficiency (utilisation and sustainability). Targets could be established for improving fields with low water use efficiency, for better future control of the spatial variation in water use efficiency.