IRRIGATION WATER USE

In-depth study sheds light on irrigated farming areas, water use

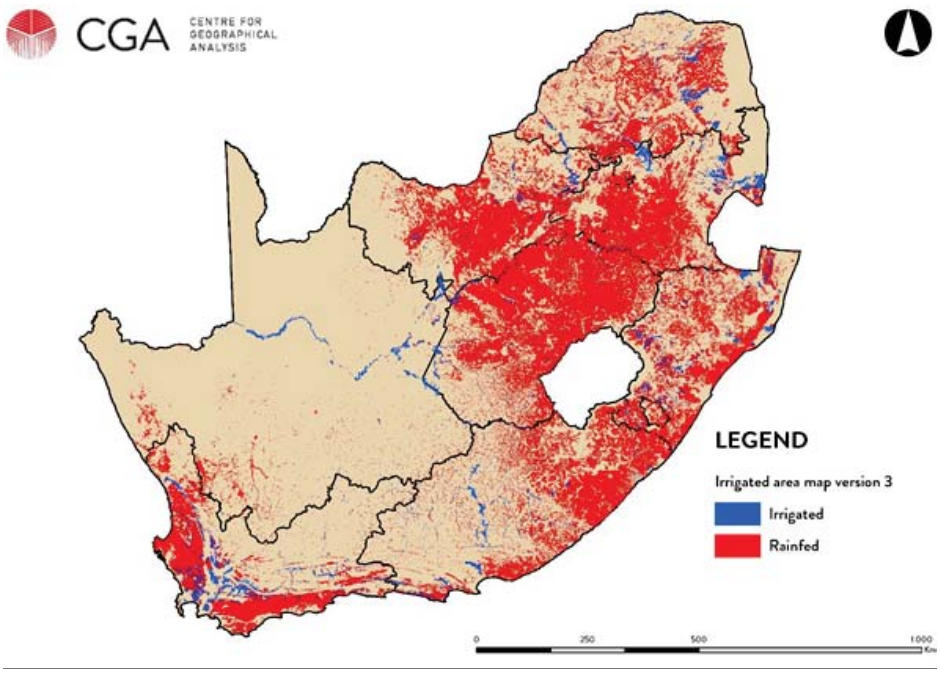
A research team used a novel approach to estimate the total area and water use associated with irrigated agriculture in South Africa. We take a closer look at their findings. Article by Jorisna Bonthuys.

Scientists forecast that farmers will need to double their current water use or produce more with the water available to meet rising food demands by 2050. Given that water has already been fully or over-allocated in many of our catchments, it will likely not be sustainable to expand the area under irrigated agriculture.

Key questions remain, however: Do we know how much water is needed for irrigation agriculture in South Africa? Can we tell which crops are more water efficient in terms of production? And, how can we ensure that we use our water resources sustainably considering future uncertainties?

A four-year-long research project, jointly funded by the Water Research Commission (WRC) and the Department of Agriculture, Forestry and Fisheries (DAFF), focused on these and other related questions. The research team, under the leadership of Prof Adriaan van Niekerk of Stellenbosch University (SU), conducted a study on consumptive water use and irrigation. Prof Van Niekerk is the director of the Centre for Geographical Analysis in SU's Department of Geography and Environmental Studies. The work was done in partnership with Dr Caren Jarmain, eLEAF, the Agricultural Research Council (ARC), GeoTerraImage, and other independent researchers.

The results of this study have now been published. This document, ***An Earth observation approach towards mapping irrigated areas and quantifying water use by irrigated crops in South Africa*** (**WRC Report No. TT 745/17**), forms part of



Map showing irrigated and rainfed areas in South Africa.

the earlier WRC and DAFF-funded project titled ***Wide-scale modelling of water use and water availability with Earth observation/satellite imagery*** (**WRC Project No. K5/2401**).

The context

Although irrigated agriculture uses a large proportion of South Africa's available water resources, the importance of this sector for the economy and food security is undisputed.

Agriculture and irrigation matters to our economy. The role of agriculture remains important despite its relatively small contribution to South Africa's gross domestic product (GDP). The direct contribution of agriculture to South Africa's GDP is estimated to be between 4% and 5.3%, while its indirect contribution to the GDP is estimated to be much higher at between 14% and 30%.

Irrigation supports 25-30% of our national agricultural production. It is estimated that irrigation is responsible for up to 90% of the production of high-value crops (including potatoes, vegetables and fruit) and 25-40% of the production of industrial crops (including sugarcane and cotton).

Planning for a sustainable agricultural future remains key given current and future water realities. South Africa's annual rainfall is 470 mm – 80% of this pours down in only five months of the year. With the added pressures of climate change, population growth and the decline in water quality, the need for improved assessments of the current water resources and land uses are critical.

About the research

While irrigated agriculture is certainly the main user of surface and groundwater resources in South Africa, the estimations of the area of irrigated crops are outdated and vary greatly. The volume of water used by irrigated agriculture has been estimated to be between 51% and 63% of total water available. The researchers developed methods that allowed them to map the area under irrigated agriculture, while also estimating the volume of water used. This was done by employing Earth observation, geographical information systems (GIS), energy balance modelling and machine learning techniques. These techniques enabled them to map irrigated agricultural areas and to model actual evapotranspiration (plant consumptive water use) at the national scale.

Essentially, water consumption by crops can be determined by estimating actual evapotranspiration from remote-sensing data, processed with complex algorithms. The model used, named ET Look and developed by eLEAF, splits the evapotranspiration into evaporation and transpiration data.

The scientists fed satellite, land cover and meteorological data into the ETLook model to produce daily outputs that were combined to generate 12 monthly evapotranspiration maps. These maps represent the consumptive water use across South Africa for the period from 1 August 2014 to 31 July 2015. The maps were aggregated into an annual evapotranspiration map, which represents a 'snapshot' of the consumptive water use by vegetation, expressed in mm/year, at a spatial resolution of 250 m.

A machine-learning analysis was performed on datasets derived from a range of medium- and high-resolution satellite images. Machine learning is a data analysis method that uses known data to automate analytical model building. It is essentially a predictive computer program that becomes better over time as it learns from successes and failures. The modelling was carried out in several climatic regions to account for rainfall variations and seasonal influences.

The resulting maps clearly show how water use by crops and

other types of vegetation vary across the country at different scales. It indicated that 1 334 562 ha or 1.1% of South Africa's land surface was actively irrigated during 2014/15. This constituted 10% of the total area under cultivation (including fallow areas) of the area used for agriculture in 2014/15.

It was found that the Western Cape contributes the most (269 476 ha), with Limpopo having the second largest area under irrigation (218 302 ha). Interestingly, the average water use per unit area in the Western Cape was substantially lower (5 874 m^3/ha) compared to Limpopo (8 841 m^3/ha), which resulted in the former using relatively less water in total.

These differences can be explained by crop types in summer and winter rainfall areas and whether irrigation is done on a permanent or supplementary basis. This analysis and refinement must be undertaken as part of follow-up studies to the baseline knowledge which has now been created with this study.

The national aggregation of evapotranspiration for all irrigated areas in 2014/15 showed that the total consumptive water use from irrigated agriculture in South Africa was 10 221 million m^3/yr. This compares well with previous estimates such as the 1997 ***Overview of Water Resource Availability and Utilisation in South Africa***, which estimated the water use by irrigated agriculture to be 10 740 million m^3/yr, and 7 836 million m^3/yr in 2000 (as part of the National Water Resources Strategy, with the latter based on a 98% assurance of supply).

The water use estimate for irrigated agriculture in 2014/15 was marginally lower than this estimate, despite the 44 430 ha increase under irrigation, implying either improved water use efficiencies or production of crops with lower water use requirements. However, differences in accuracies and methods between the 1997 estimations and the current study may also account for these dissimilarities.

This estimate of total consumptive water use is not to be confused with the volume of irrigation applied, which would likely be higher than the estimate. Ideally, the water applied should not exceed consumptive use (i.e. 100% efficiency), but in practice maximum irrigation application efficiencies are typically only as high as 90% for drip irrigation. More work is needed to investigate the relationship between water applied and water consumed and to improve water use efficiencies and reduce non-beneficial, non-consumptive losses.

Given that many cultivars and crops have been introduced to South Africa over the last two decades, the research unlocks a wealth of information for planning purposes, says Dr Caren Jarmain. Dr Jarmain, an independent researcher, is also a research associate at the SU's GCA, says this data will assist water managers to improve water resource management.

Of the crops assessed, citrus recorded the highest median evapotranspiration values with 911 mm/year and 678 mm/year in the summer and winter rainfall regions respectively. Wine grapes generally used less water, with rainfed vineyards in the winter rainfall region producing the lowest median evapotranspiration values (500 mm/year).

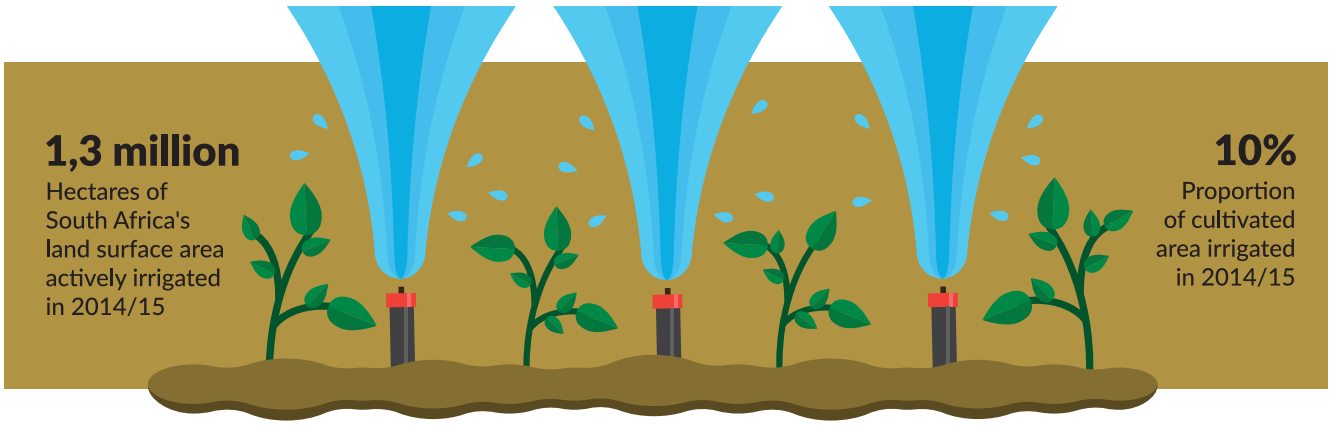
The crop-specific analyses also revealed that the evapotranspiration of irrigated crops is not disproportionate to those of rainfed crops. For instance, the evapotranspiration of irrigated wheat in the summer rainfall region was 737 mm/year, while the evapotranspiration of rainfed wheat in the same region was 611 mm/year, a difference of only 20%.

It should be noted that crop cultivation is highly dynamic and heavily influenced by climatic and market conditions in a particular season, the researchers point out. The estimation of 10 221 million m^3/year for the 2014/15 season should be seen as a snapshot of the total consumptive water use: it is expected that this estimate will fluctuate from year to year.

A water accounting framework was applied to seven secondary catchments throughout South Africa (selected based on characteristics such as population size, agricultural activities and proportion of irrigation). This was done to determine whether water resources are available for the extension of irrigated agriculture.

Using remotely sensed methods further enabled them to show how water accounting can be employed to determine water use and water availability over large catchments. Water accounting describes a catchment's hydrological processes, water flows, and their interaction with land use.

The Water Accounting Plus (WA+) framework was applied to seven secondary catchments throughout South Africa (selected based on characteristics such as population size, agricultural activities and proportion of irrigation). This was done to determine whether water resources are available for



the extension of irrigated agriculture. The WA+ framework is an international analytical framework used in the field of water resources.

The results showed that in the Mzimvubu, Kowie and the Breede River catchments, the water resources were likely enough to allow for more storage and productive use of (surface) water. This additional water could be used to meet their crop demand in summer or to store extra water in wetter years as insurance for drier years. Alternatively, this water could be used to support the expansion of the area under irrigation in the respective regions.

Research gains

How should these results then be interpreted? ***The Water Wheel*** approached members of the project's oversight reference group for their input.

The need for improved assessments of the current water resources and land is critical, says Dr Gerhard Backeberg, WRC's Executive Manager: Water Utilisation in Agriculture. Actions related to improved water use efficiency and irrigation expansion can only follow once this information is available, he points out. "This project and report have contributed recent and accurate information on water use by different irrigated crops over time (i.e. throughout the growing season) and space (i.e. in different geographical areas). Combining these datasets into a water accounting framework will improve understanding of the actual pressures on water resources with changes in land use, which will better inform water use for irrigated agriculture."

This information can now be factored into the design of irrigation systems, adds André Roux, water and drought specialist in the Department of the Premier of the Western Cape. "Being a water-scarce country, it was actually shocking that no accurate determination of the actual agricultural water use, which is a major water-use sector, was available," says Roux.

The research indicated the value of obtaining information about consumptive water use of various land uses for large areas on a cost-effective basis. "Twelve of the 19 water management areas in South Africa already face a water deficit," says Roux. "There is little room for increased surface water utilisation, although there is a clear need for irrigated agriculture to support crop production, food security, economic development and job creation."

According to Janse Rabie, who heads up AgriSA's Natural Resources Centre of Excellence, the study "represents a breakthrough by providing practical, high-value and relevant knowledge related to irrigated agriculture". "It could not have come at a more opportune time given the current deeply distressing vulnerability of South Africa's water resources," Rabie says. "Accurate information on the area and amount of water used by irrigated agriculture is imperative in informing policy and decision-making about the agricultural industry and – by implication – the state of South Africa's food security."

Rabie also considers the data "invaluable" for policy and legislative development. "It has clear implications for government's development targets and agriculture's contribution to the economy. It is imperative that government includes the results from the study in its present decision-making about water governance. However, the potential future application of the results creates an unprecedented advantage for the agricultural industry, which needs to be capitalised upon."

The study is unique in that it envisages a methodology that can be replicated for other periods. "It is imperative that the recommendations contained in the study be followed-through upon," Rabie says. "This includes that the irrigated area mapping procedure is automated and that funding for implementation of the procedure is prioritised; the irrigated area map is continuously updated; the consumptive water use of irrigated crops is revised on a continuous (seasonal) basis at national scale; and that a water accounting framework is applied on primary catchment level, preferably in all catchments."

Although the National Water Act (NWA of 1998) does not make provision for water conservation and demand management, the definition of water conservation makes these measures an essential component of water resource management. It also relates the effective and efficient use of water to the minimisation of water loss and wastage. "Demand management is not only about reducing water use; it is also about the economic valuation of a scarce resource in the context of irrigated agricultural crop production," Rabie elaborates.

Dr John Purchase, CEO of the Agricultural Business Chamber, says the Earth observation methodology and database developed during the project enables the water and agriculture sector to now far more accurately estimate water availability for agriculture. "One of the deficiencies in the current water legislation is that water allocation for irrigation and the management of that water allocation is not sufficiently dealt with," Purchase says. "Having the methodology and tools to deal with the matter should encourage legislators and government to include improved guidelines in this regard."

As South Africa's water resources become more constrained, the amount allocated to irrigation (~60% of total surface water use in South Africa) will come under far greater pressure. "This necessitates much improved overall management of especially our surface water, and you can only improve management if you can measure accurately," Purchase says. "The results will assist government (catchment management agencies) and water user associations with more realistic quota-setting to lawful users, and even assist in rooting out large-scale illegal water users."

The information allows DAFF to improve planning and estimates of potential agricultural production under irrigation. Purchase elaborates, "The National Planning Commission in its 2030 Vision (National Development Plan) advocates a 50% growth in irrigated agriculture area, but this will have to be achieved through water savings and water use efficiency as no 'new' water allocations will be able to be made to the agriculture sector, except for a couple of new capacity initiatives.

Backeberg concludes, "The study has closed a knowledge gap by using earth observation methods. This is at the forefront of international research practice."