AGRICULTURE AND CLIMATE CHANGE

Projected climate change threatening production of SA's unique tea

A research project that the Water Research Commission (WRC) funded on water use and yield of rooibos also investigated the potential impact of climate change. Article by Sue Matthews.

Media Club/Rodger Bosch

Coffee aficionados everywhere have likely been alarmed by news headlines over the past decade about the effect of climate change on coffee production. Will they still be able to get their regular 'fix' in future, and at what price? The headlines refer to findings from research done primarily on ***Coffea arabica***, which yields 60 – 70% of global coffee bean production. The species is grown in tropical highlands, and modelling studies have shown that areas suitable for its cultivation will decrease significantly by 2050 and shift to higher elevations. Fortunately, though, these areas are distributed over three continents. Brazil is currently the dominant producer, but Arabica coffee is grown in other South and Central American countries too, as well as in Asia and Africa – there is even very limited cultivation in South Africa.

By contrast, our country's world-renown tea, the caffeine-free rooibos, is produced only in a relatively small part of the fynbos biome in the Northern and Western Cape. Since production is based on forms of the leguminous shrub ***Aspalathus linearis*** that are endemic to the Cederberg mountains, the industry is centred in Clanwilliam, but the main growing area extends about 200 km from the vicinity of Nieuwoudtville in the north to Piketberg in the south, with some additional small-scale cultivation in the Cape Agulhas area of the Overberg. Two community cooperatives also harvest rooibos from the wild according to sustainability guidelines, and market it with fair-trade certification. Overall, annual production of rooibos over the past decade has fluctuated within the range of 10 000 to 20 000 tonnes.

The crop is harvested once per year, between January and April as conditions dictate, by cutting off thin branches bearing the soft leaves. Once transported to the processing factory, these are machine-cut into fine pieces, which are heaped in rows in the yard, dampened and then bruised by crushing or tumbling, before being left to ferment for about 12 hours. During this time a process of enzymatic oxidation takes place, turning the leaves from green to reddish-brown. Next, the rooibos is spread out in the sun to dry and then gathered up for sorting, grading and packaging, although many producers have a sterilisation step relying on steam pasteurisation too.

Green, unoxidised rooibos that has not undergone fermentation is also produced, and the polyphenol antioxidants and other properties of both forms are reputed to have a variety of health benefits. Apart from teas, rooibos extracts are used in other beverages, foods and skincare products made in South Africa and the more than 60 other countries around the world that currently import rooibos in leaf or powdered form.

In May last year, rooibos made history when it became the first African product to be granted Protected Designation of Origin (PDO) registration by the European Union (EU). Joining the likes of champagne, Parma ham and Stilton cheese on the list of foods and beverages with PDO status, the names rooibos and red bush can now only be used within the EU for products using rooibos leaves grown and processed within a defined area incorporating 15 municipalities in the Western Cape and Hantam Municipality in the Northern Cape.

Given this limited area of production and the fact that much of it is semi-arid, with very hot, dry summers, there have long been concerns about how the sector will be affected by climate change. Research has been ongoing over the past two decades, initially focusing on potential impacts on small-scale tea farmers from local communities, and ways of increasing their resilience. Emma Archer, then with the University of the Witwatersrand but now a professor at the University of Pretoria, was heavily involved in that work, and also led a study on climate change impacts on groundwater, which was commissioned by Cape Nature's Greater Cederberg Biodiversity Corridor (GCBC) project, the South African Rooibos Council and Potato South Africa – potatoes being another primary agricultural sector in the Sandveld.

Daleen Lötter was a co-author of the 2009 paper on the study, having been employed at the time as the GCBC conservation officer, based at Cape Nature's Porterville office. The research ignited her interest, and before long she took up a climate science post at the CSIR in Stellenbosch. She subsequently embarked on a PhD, co-supervised by Archer and awarded by the University of Cape Town in 2015, on the potential implications of climate change for rooibos production and distribution in the greater Cederberg region. The climate envelope modelling she conducted for her PhD suggested that rooibos would experience substantial range contraction, as well as south-eastward and upslope shifts. Lötter also conducted glasshouse and field experiments to assess the physiological response of rooibos seedlings to water limitation, and compared the seasonal variation in photosynthetic activity and nutrient cycling of wild and cultivated rooibos through isotope studies.

Lötter is now a senior climate researcher at the CSIR in Stellenbosch, and recently led a three-year, WRC-funded project that investigated the water use and yield of rooibos. The other members of the team – Sebinasi Dzikiti, Wasanga Mkhanzi and Sarel Haasbroek – have current or past associations with the CSIR, the University of the Western Cape or Stellenbosch University.

Since the main production area has a distinct rainfall gradient from the coastal regions to the central Cederberg, as well as widely varying air temperature, the project team selected two different study sites. The first year's fieldwork was conducted at a site near Porterville, approximately 150 km north of Cape Town, where the area's long-term average rainfall is just over 400 mm per year. In the second year the focus shifted further north to the Clanwilliam area, where rainfall averages less than 250 mm per year. Fortunately, the Agricultural Research Council had established weather stations within 5 km of these sites, so the project team was able to access hourly data on maximum and minimum air temperature, maximum and minimum relative humidity, wind speed and direction, rainfall and solar irradiance.

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Dr Daleen Lötter measuring leaf area index (LAI) in a rooibos field during overcast conditions.


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The rooibos crop is harvested in summer, typically hand-cut using a sickle.

Some of the more physically demanding fieldwork entailed digging pits more than a metre deep to collect samples down the soil profile for laboratory analysis, and to install soil moisture sensors at 20 cm depth intervals in the root zone of rooibos plants. The sensors monitored the volumetric soil water content at hourly intervals throughout the study period, while a rain gauge installed in the same field allowed rainfall to be quantified.

The project team also installed stem heat balance sap flow sensors on branches of three randomly selected rooibos plants, and these were moved to other plants once per month to avoid causing further stress over and above the hot ambient conditions the plants are naturally adapted to. Ten plants per field were labelled, and their growth monitored on a monthly basis. A leaf area meter was used to measure the leaf area index (m^2 of leaf area per m^2 of ground area), and canopy dimensions and plant height were also recorded. In addition, open path eddy covariance and surface renewal systems, comprised of a variety of sensors above and below ground, were installed in the rooibos fields for evapotranspiration measurements.

Having collected all their data in the first two years, the project team focused on data analysis, modelling and gap-filling in the third year of the study. They were able to model daily evapotranspiration by the rooibos crop using a simple combination Penman-Monteith equation, based on a big leaf approach in which the whole field is assumed to be a single uniform surface.

"The relationship between the measured cumulative evapotranspiration and biomass accumulation data through the season was used to develop the yield model," they explain in the final report. "The water-use model was calibrated using data collected from the Porterville site and validated with that from the Clanwilliam site. Lastly, the model was used to estimate changes in crop water requirements under the envisaged climate change scenarios for the key rooibos producing areas."

In her PhD, Lötter found that maximum temperatures in the Greater Cederberg region had increased by more than 2°C over the past half-century, most significantly during March, April and May, and there was strong evidence of localised changes in rainfall characteristics. Looking forward, other researchers have projected that average annual temperatures will rise 2–3°C by about 2050 in the Western Cape, and there will be drying across all seasons, with largest rainfall reductions occurring during June, July and August.

In the current study, simulation modelling for the period 1960 to 2100 – assuming the 'business as usual' RCP 8.5 greenhouse gas emission scenario – predicted an increase of 4–5°C in both the maximum and minimum air temperatures for the study area. In response to the inevitable increase in atmospheric evaporative demand, annual total evapotranspiration is expected to rise by 7–13%. Perhaps surprisingly, six coupled climate models, which were dynamically downscaled for the region by means of the conformal-cubic atmospheric model (CCAM), predicted that crop yield would increase by 8–15%. The project team note the possibility of higher increases in yield if the CO_2 enrichment of the atmosphere is taken into account.

Under the prevailing climate conditions, though, the field experiments indicated that transpiration declined with increasing soil water deficit. It peaked in mid-December at almost 1 mm/day – confirming the plant's very low water usage – and then decreased as the average soil water content in the root zone dropped below 4%, even though the canopy cover was still increasing before the crop was harvested in February.

Transpiration is known to be linearly and strongly correlated to crop yield, and the rooibos sector certainly endured substantially

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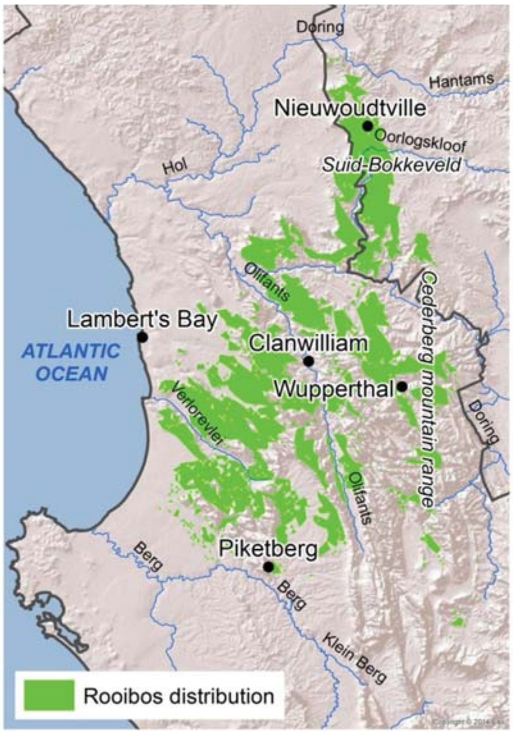

Rooibos production takes place primarily in mountainous and lowland areas of the West Coast, but there is limited cultivation in the Overberg as well.

lower yields during the Western Cape's severe drought between 2016 and 2018, when soil water deficits were high. Rooibos is a rainfed crop, and although some farmers have experimented with supplementary irrigation, it's understood that irrigation must cease at least a month before harvesting starts if the level and type of polyphenols in the final product are to be assured.

Importantly, the team's data showed that more than a third of the annual total evapotranspiration was consumed between September and November – the first three months of the growing season – but this was mostly evaporation of soil moisture after winter rains and transpiration by weeds, rather than water use by the rooibos crop itself. Weed and grass growth has become more of a problem in rooibos fields, especially newly planted ones, with the increasing adoption of conservation (no-till) farming methods, which minimise soil disturbance.

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Rooibos leaves following the processing stage with their distinctive red colour.

"Careful management of weeds and cover crops early in the season is critical to preserve the soil water reserve for later use," note the project team. Implementing other water demand management practices, such as green mulches between plant rows to limit water losses and contour ridges on sloping terrain to trap runoff, would also be appropriate adaptation strategies to cope with the expected dry conditions in future.

Asked to comment on the project, Managing Director of Rooibos Limited, Martin Bergh, said: "We in the rooibos sector are all aware of the threat of climate change, but we also understand that old-style farming has been detrimental to soil, so we need to improve our methods and hopefully preserve more moisture."

"Every one of these studies adds to a greater body of knowledge," he added. "This was the first to monitor evapotranspiration and energy balance of a rooibos crop from the beginning of the growing season until harvest, so that was novel, and although we knew that rooibos uses water very efficiently, the research has quantified it."

The report, ***Water-use and yield of rooibos tea** (**Aspalathus linearis**) **in the winter rainfall areas of South Africa*** (**WRC Report No. TT 878/22**), will be published later this year.

Recognising the traditional knowledge of SA's first nations

In mid-July it was announced that payment of just over R12,2 million had been made to the San and Khoi people of South Africa in accordance with the rooibos traditional knowledge benefit-sharing agreement. The agreement was signed by the South African Rooibos Council, the National Khoi-San Council and the Department of Environment, Forestry and Fisheries (DFFE) in November 2019, after nine years of negotiations.

In terms of the agreement, the San and the Khoi people will receive 1.5% of the farmgate price from the 10 rooibos industry processors. The payment represents the annual levy from the first year of farmgate purchases, and was deposited into the DFFE-administered Bioprospecting Trust Fund account before being transferred in equal amounts to two community trust accounts established by the South African San Council and the National Khoisan Council.

Rooibos leaves are green when harvested, but turn reddish brown as a result of enzymatic oxidation during the fermentation stage of processing.