# CROP WATER USE

## Trunk call: Why Jumbo's favourite goes the distance in a drier world

*Efforts to model water use by marula trees are bearing fruit (as it were), with an 'unexpected finding' underscoring its value in the face of climate change. Matthew Hattingh reports.*

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Animals can't get enough of marulas. Baboons binge on the golf ball-sized fruit of the ***Sclerocarya birrea*** tree. Giraffes gobble them down, fruit and leaves. Famously, it's a favourite of elephants, who eat the bark, branches and fruit. However, the popular story about fermented marula fruit rendering pachyderms ***poegaai*** doesn't seem to hold water.

This is not to doubt that once processed, it can have a potent kick. Thanks to the 29 different yeasts present in its skin, marula beers and liqueurs certainly do the trick. Of course, the pleasantly tangy fruit can simply be eaten and enjoyed fresh. Rich in vitamin C, marulas are a valuable source of food in many African countries. It's made into (non-alcoholic) juices, jams and jellies. Its seeds are snacked on or squeezed to extract oil.

Marulas are prized for their nutritional qualities and used in medicine — conventional and traditional — to treat everything from venereal disease to flagging sperm production.

The list goes on, but leaving aside its 101 uses, the truly marvellous thing about marulas is how little water the trees need. In frequently parched South Africa, where marulas are widespread, this is a vital consideration. Moreover, with climate change expected to reduce rainfall in places, the fruit offers an alternative to thirsty exotics, like apples and oranges, favoured by commercial growers.

However, a new Water Research Commission (WRC) report reminds us that despite its economic significance, most marulas are not cultivated, but grow wild, and that "very little detailed research has been done on how marula trees interact with the environment in their natural habitats". The report, ***Water use of marula (**Sclerocarya Birrea**) trees in various agro-ecological regions and postharvest utilisation of its fruit and byproducts*** (**WRC report no. 3195/1/25**) addresses this absence. Its authors, Shonisani Ramashia, Mpho Mashau, Tsietsi Kgatla, Masiza Mikasi, Mashudu Makhado and Sebinasi Dzikiti, of Venda and Stellenbosch universities, have taken a long, wide-ranging look at marulas. This included research into marula carbonated soft drinks, and processing marula peels so they can serve as a source of flour and a feed for livestock.

For our purposes though, we will limit ourselves here to the parts of the report that investigated how variations in the environment affected water use, tree growth and fruit yield. To this end, the team set out to gather data, gauging the productivity of marula trees at three study sites, each with different climates, especially rainfall, and soil types. These were at:

- The Namakgale Wastewater Treatment Works near Phalaborwa, in a hot part of the Lowveld in Limpopo, with average annual rainfall below 500 mm
- The Mafemane Secondary School in Thulamahashe, near Bushbuck Ridge, in a relatively rainy part of the Lowveld, Mpumalanga and
- A ZZ2 farm in Moeketsi, near Tzaneen, Limpopo, a medium-rainfall tropical to subtropical region.

We will return to the sites, but first, the report's headline findings: Good rains alone won't guarantee good marula harvests. The soils must be able to hold the water, and this has a strong bearing on whether trees will use water efficiently. Significantly,

*Project team member Mashudu Makhado installling the heat ratio sap flow method for measuring transpiration at the Phalabowa study site.*

Sheona Shackleton/CIFOR

*Women from a local community opening marula to separate the kernel for the oil and the pulp.*

the study suggested marulas were unlikely to use much more water under future climate change. The "unexpected finding" meant marulas could prove to be an "ideal alternative" fruit tree crop as growing conditions become harsher. More on this later, too.

As a central aim, the study sought to validate a species-specific transpiration model for marula proposed by Dr Sebinasi Dzikiti, a Stellenbosch University horticulture scientist, and colleagues in earlier research (see **WRC Report No. 2720/1/22**). Transpiration is the main source of water loss in plants. Water is drawn up from the roots, through the stems and leaves, and released into the atmosphere as vapour through tiny leaf pores, called stomata. In the case of marula trees, the stomata are on the underside of the leaf. Transpiration is a key process in plant biology. It allows plants to absorb nutrients from the soil and to perform photosynthesis, converting sunlight and carbon-dioxide into carbohydrates, a store of energy that fuels growth.

The model, based on the famous Penman-Monteith equation, is a simplification or abstraction of reality. It's used to predict water loss for a given area of vegetation from a limited set of data. Crudely put, if we gather site data on variables like temperature, humidity, air pressure, radiation, wind speed, and canopy size and plug these numbers into the equation, we should be able to calculate water use specifically for marula trees.

The team set out to do this between 2021 and 2024, gathering data at the different sites at different times and seasons so that these could be applied to the model. Then, to check whether it lived up to its promise as a predictor, the results were compared with actual sap flow data (which equates to transpiration) collected from four individual trees at each of the sites.

The team used the heat ratio method to measure sap flow. Four sets of temperature probes were stuck at different depths into the stems of each of the trees at their cardinal points. In each set, a central element delivered a pulse of heat, which was detected by the two temperature probes, equidistant upstream and downstream of the element. The probes were wired to data loggers and, at hourly intervals over two to three years, recorded flow, with the ratio of the temperature changes at the probes used to calculate sap velocity. Locating the sets at the cardinal

Mnqobi Zuma


*According to the study, marula trees are a potentially valuable indigenous crop as they are not expected to use more water in drier conditions caused by climate change.*

points and different depths helped average out variations in the sap wood and therefore velocity. It also allowed the researchers to calculate flow volume in litres an hour.

These measured transpiration figures were compared with the estimates from the marula-specific model, with climate data drawn from nearby weather stations. "The results show this model can satisfactorily predict the transpiration rate of marula trees under a range of growing conditions."

To deepen the research, the team recorded the leaf area index at the sites as well as the soil water content at various depths in the rootzone. They also kept tabs on the trees through the different seasons and growth cycles and reproductive events, including bud break, leaf emergence, flowering, fruit set, fruit development, fruit drop, leaf senescence (ageing and breakdown), and dormancy (temporary halts in growth). Yields at each site were recorded.

Leaf area index is the ratio of the size of the tree canopy to the ground beneath it. A higher index is consistent with higher water demand. Proprietary measuring devices were used to calculate the index, with measurements taken on instrumented trees to monitor for a correlation between the index and water usage.

The trees varied considerably in size from site to site, with those in relatively wet Thulamahashe having the biggest canopies. Phalaborwa and ZZ2 had similar leaf area indices, although the Phalaborwa trees were more spread out. In Thulamahashe, transpiration peaked at an average of 226 litres a tree per day, followed by Phalaborwa at 160 litres, with ZZ2 at 112 litres. However, once the authors adjusted the figures to account for canopy leaf area, the ZZ2 trees emerged with the highest transpiration per unit leaf area, peaking at 2.33 litres per square-metre of leaf area per day. This was followed by trees at Phalaborwa, which transpired 1.60 litres per square-metre per day. Trees in Thulamahashe recorded the least transpiration — 1.02 litres per square-metre a day.

The figures suggested rainfall was not the only factor that determined marula water use at a given site. "Rather it is more likely the combination of the amount of rainfall, its distribution and the soil type that determines the amount of water that is available to sustain the transpiration rates," said the report.

Soil moisture reflectometer probes were used to measure volumetric soil water content.

The report reminded readers that indigenous species such as marula can withstand long drought because of their extensive root systems, and with this in mind, the team put probes at various depths. Most of the fine root system appeared to be at depths of up to 60 cm, but the presence of roots from other surrounding plants sometimes frustrated accurate assessment, the study found.

In Thulamahashe, soil texture varied from loamy sand in the shallow depths to coarse sandy loam as it got deeper, with low stone content. The field capacity of the Thulamahashe soil varied between 12% and 15% at 100kPa. This is a measure of the maximum amount of water the soil can hold two or three days after rain and is expressed as a percentage of total soil volume and assumes the soil has a certain force (expressed as pressure) that resists the water's extraction. Sandy soils have the least capacity to retain water; clay soils the most, with loamy soils in between.

Samples collected at ZZ2 indicated predominantly sandy loam soils in the shallow layers and sandy clay in the deeper 30-60cm layers. Volumetric soil water content at 100kPa was between 13% and 15%. The soil was acidic. In Phalaborwa, samples were collected at 40-60cm because the shallower layers were rocky, making samples hard to extract. The soils were mostly sandy, with the volumetric water content at field capacity, at 100kPa, between 11% and 12% at 40-60cm. The soils were generally acidic and nutrient-poor.

Keeping tabs on crop yield proved challenging because the sites were far from the team's University of Venda base. Marulas are not plucked at harvest, but drop when mature and this can be hard to anticipate. With Thulamahashe, a four-hour drive away, the team faced frustrations in the study's first year. "By the time we arrived, nearly all the fruit had dropped, so we missed the yield," they said. The following year they wised up though, hiring a local who not only collected and weighed the fruit, but also changed the batteries of the sap flow system.

The study noted that the trees flowered and the fruit set significantly earlier in Thulamahashe than in Phalaborwa and Mooketsi, and the authors suggested higher rainfall as the reason. "Early fruit set and flowering may result in extended times for fruit development, which will increase fruit output and size," the report said. Similarly, higher temperatures and lower rainfall in Phalaborwa might explain longer leaf senescence and dormancy as trees skimped on energy and water.

Average annual transpiration of trees at Thulamahashe was 28 027 litres per tree, with an average yield of 28.9 kg/tree. At ZZ2, it was 23 690 litres with a much higher yield of 53.9 kg/tree; and at Phalaborwa, 25 336 litres, with an average yield of 23.4 kg/tree. The study defined water use efficiency as the ratio of yield produced per cubic metre of water transpired. Based on the above figures, the team arrived at ratios for the three sites of 1.03 for Thulamahashe, 2.27 for ZZ2 and 0.92 kg/m$^3$ for Phalaborwa.

The authors felt these values were "quite low" compared with those for exotic species, citing water use efficiencies of up to 18.0 kg/m$^3$ for apple trees in the Western Cape. Irrigation would likely make a big difference to yield, but this was by no means certain, as attempts to irrigate indigenous rooibos have demonstrated. More research was needed, said the report.

The findings on marulas and climate change were encouraging. The authors said warmer, drier conditions were expected to lead to a 10-12% increase in atmospheric evaporative demand in the Thulamahashe area for the period 1960 to 2099. However, the change in water use rates by marulas would probably be negligible: "Daily tree transpiration is projected to increase by less than 5%."

Why so? The authors reckon that although stomata would close more, reducing transpiration, the plant's assimilation of carbon-dioxide into carbohydrates by photosynthesis was likely to be less affected. So, the yield may well remain unchanged.
"This situation may even lead to increased water use efficiency by the marula... If confirmed, this is a very significant outcome of this study wherein marula trees can indeed be possible alternative tree crops under increasingly drier conditions."

To access the research report, ***Water use of marula (Sclerocarya birrea) trees in various agro-ecological regions and post-harvest utilisation of its fruit and byproducts*** (**WRC report no. 3195/1/25**), visit: https://bit.ly/40tYQ4M

*A traditional dish of corn and marula. Marula is prized for its nutritional qualities.*