CROP WATER USE

Water use study points to potential of bamboo in South Africa

Bamboo is a useful and sustainable crop. But is it a wise bet for our water-scarce country? A recently completed Water Research Commission (WRC)-funded project aimed to provides some answers. Matthew Hattingh reports.

Panda bears chew it up like rugby fans munching on ***droëwors***. Some of the world's first firearms were fashioned from it and it's the key material in a host of biodegradable consumer goods, from kitchen spatulas to toilet paper. Bamboo, with its relatively strong resistance to breaking, remains a mainstay of construction in the East. Around the globe, people are increasingly looking at cultivating this versatile member of the grass family.

In South Africa, there's growing interest in bamboo as a building material and a fuel source. South Africa's indigenous forests are few and far between. Heavy harvesting means there's little firewood to go around and erosion has depleted soils leaving them less able to store water to support life.

What if bamboo was cultivated at scale here, particularly on land already degraded by agriculture? It matures in six or seven years and produces new shoots at the base of the plant every year. Half a dozen stems can be harvested in a season from a single plant for perhaps decades without killing it, making bamboo a self-replenishing source of timber and firewood.

It certainly sounds promising, but at what cost to the country's scarce water resources? These and related questions were the subject of a recent report for the Water Research Commission (WRC), with the findings laying the groundwork for further research on bamboo's commercial cultivation. The report, ***Quantification of the evapotranspiration and streamflow reduction caused by bamboo species on water resources in South***

Africa (**WRC Report No. TT 875/22**) found the increase in stem diameter of bamboo under study was lower than for eucalyptus trees as well as that notorious alien invasive species, black wattle. On the plus side, bamboo proved nowhere near as thirsty. Nor, according to the literature, does it spread unchecked, provided the right species are planted. It is, however, hard to remove.

The report's authors, Colin Everson, Mxolisi Gumede, Terry Everson, Alistair Clulow and Richard Kunz, noted that the departments of Trade and Industry and Agriculture, Forestry and Fisheries and the Environment have been promoting bamboo planting to encourage rural development. They cited the Bamboo Association of South Africa which said 40 000 hectares had been earmarked for cultivation in KwaZulu-Natal and the Eastern Cape.

But before bamboo growing can begin on this scale, we need to know how much water it uses. There had been no research on the subject under South African conditions so the authors, representing the University of Kwazulu-Natal's Centre for Water Resources Research, set out to remedy this. Their aim was to determine annual and seasonal bamboo water-use figures to assist with water management, achieve an optimum crop yield and support applications for water-use licences.

The National Water Act lets the government declare farming, mining and other endeavours as "stream flow reduction activities", requiring approval and licensing. To date, for agriculture, this has applied only to commercial forestry plantations. The researchers wanted to learn if bamboo should join the list.

From September 2018 to February 2020, the team gathered data from two study sites with very different climates and conditions: Shooter's Hill farm, a few kilometres west of the Albert Fall Dam, north of Pietermaritzburg in KwaZulu-Natal; and at Kowie farm, near Bathurst in the Eastern Cape.

At least 15 different species have been planted on 10 ha at Shooters Hill and 330 ha of the 485 ha Kowie, said to be the country's first large-scale commercial bamboo farm.

The study focused on two varieties of the species ***Bambusa balcooa***, known as balcooa and beema. This is a clumping bamboo native to the Indian subcontinent and Indo-China that's not considered invasive – as opposed to species with long underground stems or runners that can worm great distances in search of water. It's also drought-resistant and easy to manage and its aerial stems are strong and are known to reach a useful 25 m in height.

In-depth growth studies were beyond the scope of the project, but pilot studies determined the increase in stem numbers and diameters. In KwaZulu-Natal, stem diameter increased by 0.2 mm and 0.12 mm a month for beema and balcooa respectively. The total number of beema stems was up by 18% and balcooa by 12.5%. These figures coincided with good rainfall – 2104.5 mm over 17 months.

Drought in the Eastern Cape may explain the lower growth figures recorded at Kowie (a mere 0.005 mm a month). The state of the soils at Kowie, impoverished by years of uninterrupted pineapple farming, may have been a factor too.

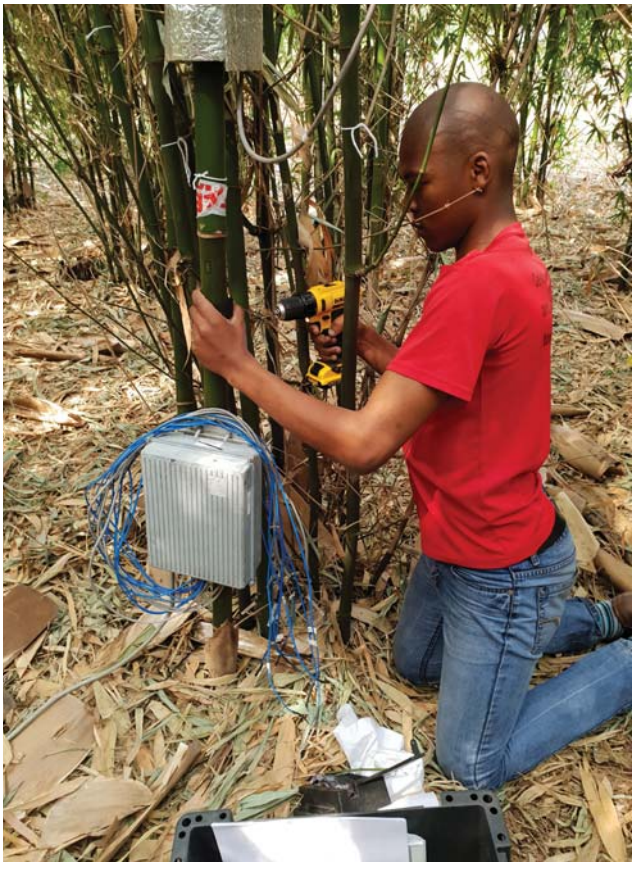
By contrast, the black wattle and eucalyptus at Shooter's Hill grew vigorously – by a monthly average of 3.0-4.0 mm and 5.4 mm respectively.

Back to water-use considerations. Plant water-use has two components: transpiration and evaporation. Evaporation happens when water changes to vapour from soil or plant surfaces. Transpiration refers to water lost to the atmosphere through leaves during photosynthesis. During this process plants turn the sun's energy into chemical energy, which is stored as sugars and starches. Collectively, the two are known as evapotranspiration.

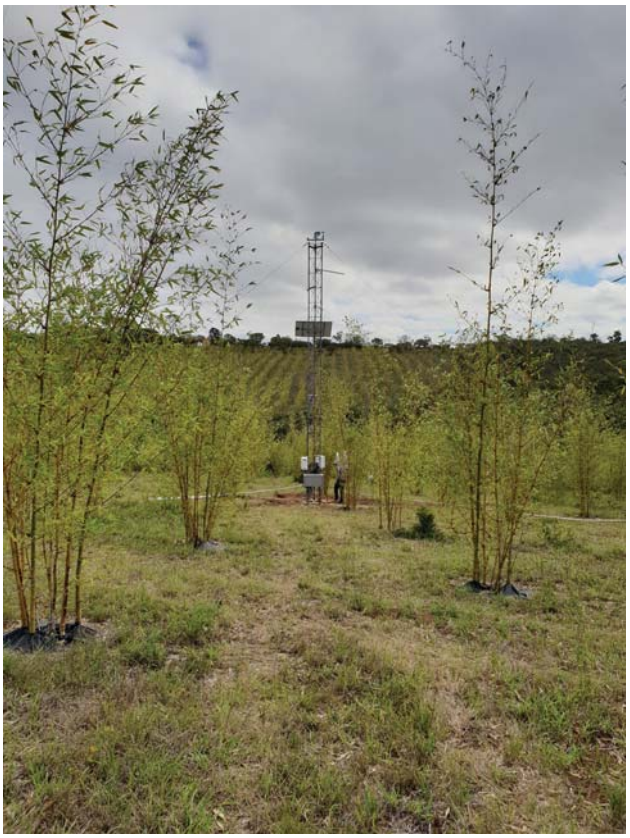
Indirect and direct methods can be used to measure evapotranspiration. Indirect methods include gathering and analysing microclimate data.

Vaporisation requires energy, which comes directly or indirectly from the sun. The amount of solar radiation available has a direct bearing on water-use. But air temperature, relative humidity, wind speed and rainfall play a big role and must be measured too. To this end, the team set up automatic weather stations at the study sites. They also studied soil structure and water content, which affects water flow to roots.

The equipment to do all this is costly and pains had to be taken to prevent theft. Some of these costs and complications can be avoided by directly measuring the flow of plant sap (which is



Study co-author and Master's student, Mxolisi Gumede, drills holes into a bamboo tree at Shooter's Hill farm prior to inserting hypodermic probes.



An old pineapple field planted with bamboo at Kowie farm in the Eastern Cape.

mainly water). The problem is, the technologies to do this were developed for dicotyledonous tree species. Would it work for bamboo, which is monocotyledonous?

> *"The data suggested that bamboo (a grass) was behaving in a similar manner to natural grassland, in that it is a conservative water user during winter."*

Dicotyledonous and monocotyledonous plants – the two main groups of flowering plants (incidentally, most bamboos flower once in their lifetime) – have several distinct features that aid in telling them apart. These include the way sap-carrying vascular bundles (xylem) are arranged in the stem. With dicots, the bundles form the sapwood around the centre heartwood of the stem. With monocots, which have hollow stems, the bundles are scattered near the stem's outside edge.

The team measured inner and outer diameters of beema and balcooa stems to determine average wall thicknesses for different stem diameters. Next, they used precision equipment to slice out tiny stem cross-sections for viewing under light and electron scanning microscopes.

With a better understanding of the structure and positioning of bamboo vascular bundles, including the depths at which these are found, the team was ready to try measuring sap flow. They used two techniques: heat pulse velocity and stem steady state.

For the heat pulse technique – which was used only in KwaZulu-Natal where stem walls were sufficiently thick – sets of hypodermic needles were inserted into stems to depths precisely determined during the measuring and microscope work. Each set included an electric heater needle and two needles wired to thermocouple probes up- and down-stream of the heater.

The heater needle was fired every 60 seconds, warming the sap. The difference between the voltage at the two thermocouples over time was recorded, with the heat acting as a tracer for sap flow.

The steady state technique involved strapping insulated collars around stems. These contained a continuous heat source and sensors before and after the source. The sensors recorded conductive heat losses.

Data from both techniques was logged and transmitted to the team's Pietermaritzburg offices where it was used to calculate sap velocity and from this to determine transpiration volumes for the KwaZulu-Natal and Eastern Cape bamboo. Heat pulse velocity and stem steady state techniques used on beema and balcooa in KwaZulu-Natal over three summer months gave similar results, so an average of the two methods was used.

Balcooa, a giant bamboo, was found to use twice as much water as beema, with summer being the thirstiest time – coinciding with higher rainfall and temperature figures. Beema water-use during what was a wet summer in KwaZulu-Natal averaged 2.0 ± 3.2 mm a day – about twice as much as the dry winter use of 1.0 ± 1.6 a day. For balcooa, a range of 3.8 ± 6.0 mm a day was recorded in summer and 2.0 ± 2.8 mm a day in the winter.

The result bears out the findings of the microscope work – that balcooa has nearly twice as many vascular bundles as beema. Seasonal climatic conditions were found to have a considerable influence on bamboo transpiration in KwaZulu-Natal.

"This data also suggested that bamboo (a grass) was behaving in a similar manner to natural grassland, in that it is a conservative water user during winter. The annual water use of balcooa and beema was 746 and 510mm, respectively," the report said.

By contrast, in the Eastern Cape, maximum daily evapotranspiration rates for balcooa averaged only 3 mm a day in the summer. Annual total evaporation was only 446 mm and 567 mm in 2019 and 2020, respectively – a period when the Eastern Cape suffered severe drought.

By way of comparison and to understand bamboo water-use in the context of changing land use, the team monitored eucalyptus and black wattle in KwaZulu-Natal. Natural grassland was included in the study too. It provided baseline or reference figures, used to estimate crop factors. These are things like crop height and surface roughness, reflection, ground cover and root characteristics, which result in different crops having different evapotranspiration levels.

A bamboo stem at Shooter's Hill farm with probes inserted to measure sap flow using the heat pulse velocity technique.

An automatic weather station installed at Shooter's Hill helped with measuring these factors. It also gave the researchers hourly and daily meteorological data which they used to interpret the effects of environmental changes on sap flow.

From January 2019 to December 2019, the heat pulse velocity technique recorded the highest water-use (1301.2 mm) in eucalyptus, followed by black wattle trees, with 911.4 mm. In the summer, also using direct techniques, peak eucalyptus water-use was found to be about 8 mm – "significantly higher than the daily bamboo water use (2–3.3 mm)". The average winter figure was about 3 mm. The maximum daily summer transpiration for black wattle was 5 mm and in winter, 3.5 mm.

Bringing together the automatic weather station and other data, and evapotranspiration figures for the reference crop, the researchers derived a crop coefficient for the bamboo in the study. A crop coefficient is a constant value which agronomists plug into formulas (such as the Penman-Monteith equation) to estimate the water-use of a particular crop in often widely differing growing conditions.

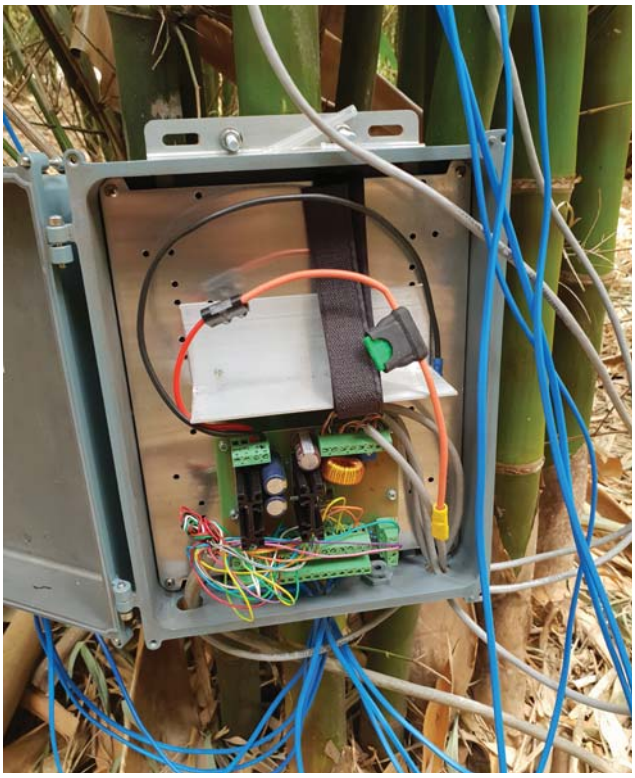
Once they had derived crop coefficients, the authors were able to estimate bamboo water-use across the country. They concluded that bamboo, particularly beema, was a "conservative water user" relative to natural vegetation, while balcooa could be declared a stream flow reduction activity in only 32 quinaries.

A little clarity here…

To aid research and planning, South Africa's catchment areas are subdivided into a five-level hierarchy, from primary at the largest scale, down to quinary at a very local level. In total, the country has 5 838 quinaries. The legislation deems an activity stream flow-reducing if its effect on runoff exceeds 10%.

The 32 quinaries are found in northern parts of the Northern Cape and North West, as well as the particularly arid parts of Limpopo. These are quinaries where rainfall ranges from 146 mm to 488 mm, making the commercial cultivation of bamboo a non-starter in any case. "Therefore, the commercial production of these two clumping bamboo species would be expected to have a minimal impact on stream flow," the report said, "...(it) is unlikely to be declared a potential stream flow reduction activity by the Department of Water and Sanitation."

The report called for further research on more mature bamboo including other species. "Since bamboo appears to be a conservative water user, research on the most suitable planting areas for the expansion of the industry should be undertaken to prevent failed investments in the bamboo industry," the authors said.



The project team collected data from a number of heat pulse velocity probes at Shooter's Hill.

To download the report, ***Quantification of the evapotranspiration and streamflow reduction caused by bamboo species on water resources in South Africa*** (**WRC Report No. TT 875/22**) visit: https://bit.ly/3AGusrE