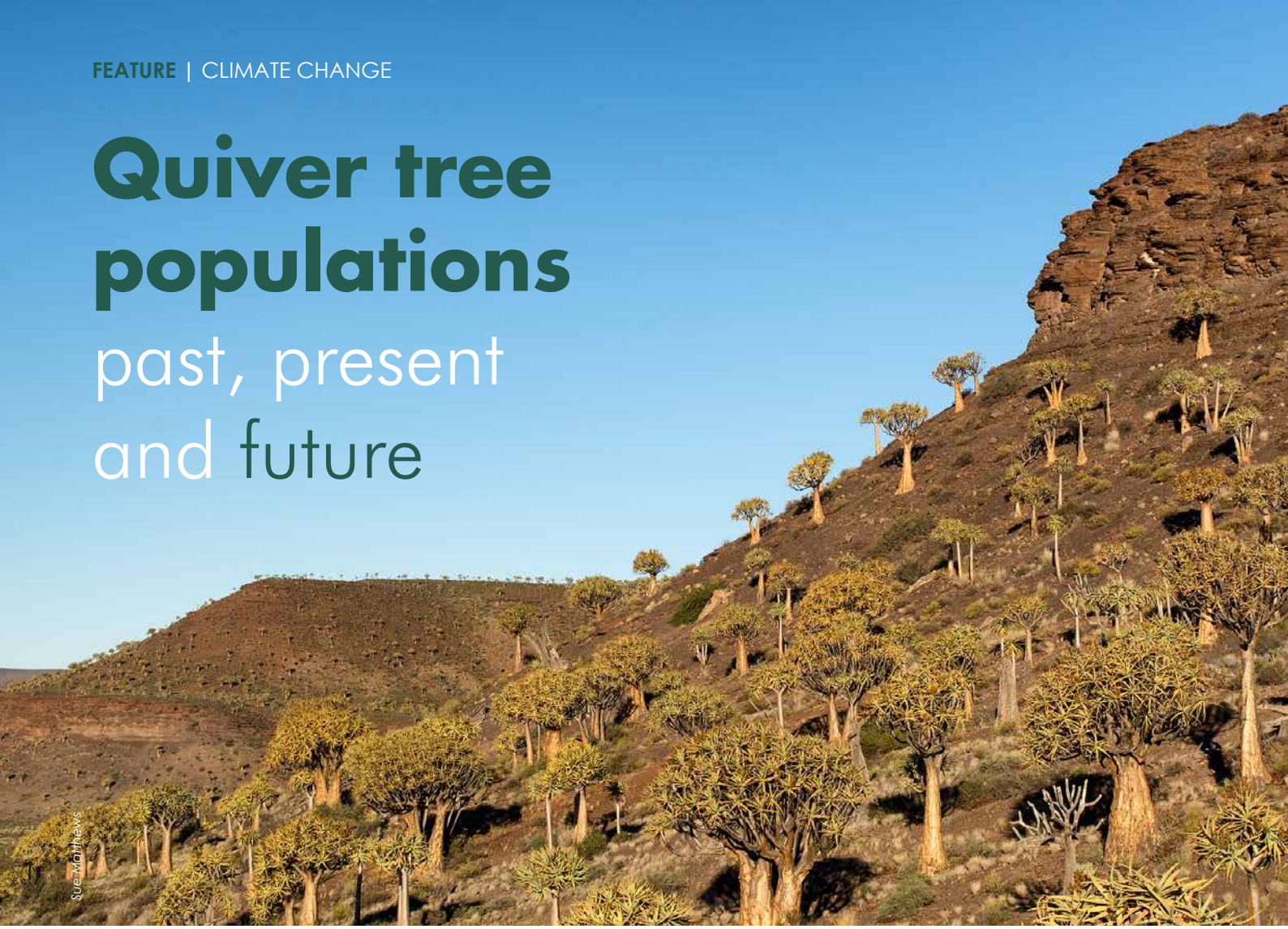
Quiver tree populations past, present and future



Going back 22 000 years into the past and projecting 50 years into the future, ecologists from Stellenbosch University simulated the palaeo- and future geographic range of the quiver tree, *Aloidendron dichotomum*, previously known as *Aloe dichotoma*. This iconic tree occurs in the arid landscapes of Namibia and South Africa's Northern Cape, and the ecologists hoped to understand how its past response to natural climate change could be used to predict its future response to anthropogenic, or human-induced, climate change.

Prof. Guy Midgley, head of the global change research group in SU's Department of Botany and Zoology, says research studies and observations worldwide have shown that biological systems and species are already responding to human-induced climate change.

"A common prediction for plants is that they will shift their geographic ranges in response to warming, either poleward or upward in elevation. The other options are on-site adaptation by genetic changes or changes in biology or behaviour," he explains.

In the case of long-lived trees, however, the adaptive options are limited, which could result in local extinctions. While trees may have been able to migrate or adapt to previous changes in the palaeo-climate that took place over thousands of years, they may not be able to do so fast enough to survive more rapid, human-induced climate change.

For example, over the past 10 000 years the surface air temperature in south-western Africa likely rose by 5°C during glacial to interglacial warming at the end of the Pleistocene. In contrast, according to the latest report from the Intergovernmental Panel on Climate Change (IPCC), surface air temperatures in Africa are projected to rise in excess of 5°C in the dry, subtropical areas in less than a century.

Over the past two decades, Midgley and his postgraduate students have been observing and documenting the response of quiver tree populations to climate change. In 2007 Wendy Foden – now the General Manager of SANParks' Cape Research Centre and an associate professor at Stellenbosch University – was able to show signs of a coming southward and upward shift, with individual trees dying off in the warmer parts of the range towards the equator and at lower elevations throughout the northern half of the range. Repeated observational studies over the years are needed to confirm the findings that such a range shift may be under way.

The latest study

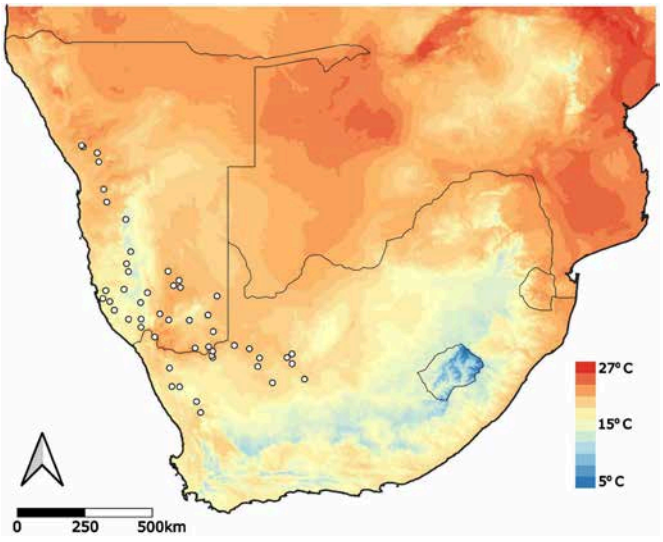
More recently, Midgley's postgraduate student Lara Brodie used species distribution modelling to reconstruct the

likely spatial extent of the quiver tree's range during glacial periods. She then used population genetic methods to test the results. The findings were published in the journal *Frontiers in Ecology and Evolution* in October 2021.

The models indicated that 22 000 years ago – in the time period known as the Last Glacial Maximum (LGM) because continental ice sheets were at their maximum extent – about two-thirds of the quiver tree's suitable habitat was around 650 km further north than the current range. As temperatures became more favourable, the trees started expanding their range polewards – in other words, to the south – at a rate of 0.4 km per decade. During the mid-Holocene, about 6 000 years ago, the available quiver tree range was more or less in the same location as the current range. This means that it took the species up to 18 000 years to migrate 650 km poleward.

This migration was indirectly confirmed by the results from the genetic population analyses. On average, the older northern populations support higher levels of genetic diversity than the more recently established populations in the southern and south-eastern regions. Biologists call this reduction in genetic variation brought about by a small subset of a population establishing a new colony the 'founder effect'.

The models predict that by 2070 quiver trees will have to shift 191 km eastwards in order to adapt to a changing climate. The models yielded different results for latitudinal shift, with two predicting a poleward range shift and the other a slight equatorward shift. Averaged out, the species would need to migrate 42 km in 70 years, which translates to 6 km per decade. This is roughly 15 times faster than what was expected of it 18 000 years ago.



The current geographic range of the quiver tree, superimposed on mean annual temperature. Previous research has shown that trees in the warmer areas have greater mortality than those in the cooler areas.

Sue Matthews

The quiver tree, also known as the kokerboom, is classified as vulnerable in the Red List of South African Plants. The English name refers to the fact that the San people used to make quivers in which to hold their arrows from the hollowed-out branches.

According to the researchers, the quiver tree will likely survive in the wild, but its geographic range would be much narrower. Populations in the south may struggle to adapt and survive due to lower levels of genetic variation, while those in the north will likely be lost as climatic conditions become unsuitable. To avoid losing the unique genetic diversity of the northern populations, the researchers recommend proactive conservation measures, such as safeguarding individuals in botanical gardens and implementing carefully considered assisted colonisation in suitable areas.

After decades of research, the iconic quiver tree still stands as a sentinel for human-induced climate change. The latest findings will not only inform conservation responses for this species, but potentially also for a wide range of others that occur only in this region.

- Brodie LP, Grey K-A, Bishop JM and Midgley GF (2021). Broadening predictive understanding of species' range responses to climate change: the case of *Aloidendron dichotomum*. *Front. Ecol. Evol.* 9:715702. *https://doi.org/10.3389/fevo.2021.715702*

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