



AUTHORS:

Michael D. Cheek^{1,2} 
Șerban Procheș² 

AFFILIATIONS:

¹South African National Biodiversity Institute, Durban, South Africa
²School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal, Durban, South Africa

CORRESPONDENCE TO:

Michael Cheek

EMAIL:

m.cheek@sanbi.org.za

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The value of arboreta in South Africa

Significance:

- Arboreta are documented, living collections of ligneous species cultivated for research, education and display.
- Arboreta are a valuable resource for the forestry industry as gene banks.
- Arboreta, together with botanic gardens, form a useful network of sentinel sites for plant pathogens and invasive species.
- A survey of the species composition and status of arboreta in South Africa would be an important contribution to our botanical knowledge.

Since antiquity, collections of living trees, or arboreta, have been established for diverse religious and aesthetic purposes.¹ Naturalists became increasingly aware of their scientific value as early as the 16th century², in particular as a living resource with which to study taxonomic questions that arose with the influx of species into Europe from botanical exploration³. The economic and scientific importance of introduced tree species was realised by many of the major landowners in the United Kingdom and from 1750 and 1850 many arboreta were established on private estates and in botanic gardens.⁴ During the 19th century, arboreta were increasingly used as acclimatisation trials for introduced tree species in Europe^{1,5,6}, America⁷, Australia⁸ and South Africa⁹. The first arboreta to be established in South Africa were Arderne Gardens in 1845¹⁰ followed by the Durban Botanic Gardens in 1851¹¹. Acclimatisation studies developed into a new research field during the 19th century and the term 'acclimatisation garden' became widely used by professional and amateur botanists.¹²

Defining an arboretum

Definitions of an arboretum vary from vague, such as a botanical tree garden¹³, to specific, for example, a comprehensive collection of arboreal species, varieties and forms, of both alien and indigenous species, that can be cultivated in one locality¹⁴. In some cases, such as the Morton Arboretum¹⁵, University of Wisconsin Arboretum¹⁶, the Holden Arboretum¹⁷, the Dawes Arboretum¹⁸ and Connecticut Arboretum¹⁹, the term is used as a synonym for a commons – a relatively large legally protected area (in the aforementioned cases 485, 1255, 728 and 182 hectares, respectively) that includes prairies, natural woodland, wetlands and landscaped areas, with some sections receiving little, if any, management. The optimum size of an arboretum is largely determined by its purpose, whether it is to address particular research questions or is intended for education and display.¹ Baas-Becking¹ differentiated between a forestry and dendrological arboretum, recommending a minimum of 50 hectares for the latter which would have wider research applications than strictly silviculture. This is a recommendation that will undoubtedly vary with the amount of land available. Hartley²⁰ observed that the renowned 19th-century Scottish botanist J.C. Loudon considered the ideal size of an arboretum that which allows sufficient space for each species to attain its full size and character.

Although he never defined an arboretum in his *Arboretum et Fruticetum Britannicum*, J.C. Loudon's concept of an arboretum is similar to that of a botanical garden except that it is specifically aimed at ligneous plants, displayed following a natural system.²⁰ In South Africa, the term arboretum is associated with the systematic cultivation of trees and shrubs for display and research purposes.²¹ While there is some overlap between the definition of an arboretum and a botanical garden (Supplementary table 1), we support a narrow arboretum definition as a documented or labelled collection of living, ligneous taxa, non-native or indigenous, cultivated for scientific research, educational and display purposes.

Arboreta in forestry

One of the most important stages in forestry plantation establishment is selecting appropriate species for a particular region or site conditions²² and arboretum experiments are the most practical way to facilitate this²³. The fact that different species or provenances require particular climatic and edaphic conditions to perform favourably, is known as the Genotype x Environment interaction.²⁴ Thus it is important that species are tested in the setting for which they are intended.²⁵ In this way, new genotypes could be selected for particular applications and new sites, either for commercial timber industry²⁶ or for reforestation of degraded land²⁷. Arboreta have been instrumental in selection studies for commercial timber species in South Africa and Tokai arboretum was the first to be established for this purpose (Supplementary table 2). Research into the performance and commercial suitability of kauri pines (*Agathis* species) was also done at Port Durnford arboretum (established in 1923), in KwaZulu-Natal, South Africa.²⁸ Whereas species selection trials are often a mixture of species, plant breeding programmes and provenance trials are often a series of ongoing trials²⁵ of a single species or cultivar where the goal is to select superior genotypes²⁹.

Arboreta in horticulture

Urban forests are valuable as amenity plantings and for improving the aesthetic value of municipal areas.³⁰ Urban plantings are increasingly used as a resource in detecting new plant pests and pathogens and investigating the potential effects of climate change.³¹ However, the selection of street trees is often based on what will grow at a site, the preferences of local people, and the availability of nursery stock.³² Arboreta are labelled, catalogued collections with information on their establishment date and often the origin of the species they contain, giving them greater value over and above the substantial plantings of trees in urban settings because tree selection is more often driven by research questions. Arboretum trials are useful in assessing species for various urban and industrial settings.³³ Selecting trees with the appropriate size and shape decreases the maintenance costs of both

the trees as well as the surrounding infrastructure.³⁴ To streamline the process of introducing new cultivars to horticulture in the USA, a National Arboretum introduction programme was started in 1971 to evaluate the performance of new cultivars.³⁵ The National Arboretum co-ordinates this evaluation programme but the growth and monitoring of plants is done at botanic gardens, arboreta, universities and nurseries that have signed a memorandum of understanding to be a co-operator in the programme, thereby converting established botanic gardens and arboreta into a network of test sites to determine the hardiness range of new cultivars.³⁵ Starting with Tokai arboretum, the Department of Forestry established a number of arboreta across South Africa which provided valuable information on the performance of tree species in the various climates. This information enabled the Department of Forestry to recommend tree species to farmers, municipalities and the public for amenity planting or particular applications such as windbreaks or soil stabilisation.³⁶

Arboreta as sentinel sites

The International Plant Sentinel Network functions as an early warning system through sharing information about new outbreaks of pests on alien collections in botanic gardens and arboreta.³⁷ Surveying introduced tree species in such collections has proven useful in detecting new insect introductions, as well as undescribed insect species that use the trees as refugia.³⁸ The International Plant Sentinel Network was started in 2013 and currently has 71 participating arboreta and botanic gardens, of which 7 are in South Africa: (1) Pretoria National Botanical Garden, (2) Free State National Botanical Garden, (3) KwaZulu-Natal Botanical Garden, (4) Harold Porter Botanical Garden, (5) Walter Sisulu National Botanic Garden, (6) Kirstenbosch Botanical Garden and (7) Stellenbosch University Botanical Garden.³⁹ In 2016, a Sentinel Plant Project was started by the South African National Biodiversity Institute in conjunction with the Forestry and Agricultural Biotechnology Institute (FABI); since then 53 pests have been detected from South African arboreta and botanical gardens.⁴⁰ The polyphagous shot hole borer beetle, and it is associated fungal symbiont *Fusarium euwallaceae*, was detected from such a survey at the KwaZulu-Natal Botanical Garden in 2017.⁴¹ The continued introduction of pests is likely to continue with continued trade and this is a significant threat to biodiversity across Africa.⁴²

Because arboreta contain introduced species, they can also act as point sources for future plant invasions. With a change in climate, new horticultural species will be introduced, providing potentially new invasive species.⁴³ The sharp increase in the numbers of botanic gardens and arboreta since 1950 suggests that they still have the potential to represent a pathway of plant invasions.⁴⁴ In addition, the rate of new plant introductions has increased steadily since the 19th century and shows no sign of decreasing.⁴⁵ The evaluation and development of tools for detecting and monitoring new plant invasions was highlighted by Van Kleunen et al.⁴⁶ among the important points in managing future horticultural invasions. Arboreta within South Africa represent a valuable resource for this purpose.

Arboreta in conservation

The role of arboreta and botanic gardens in botanical exploration continues; however, there is an increasing emphasis on their involvement in botanical research and the conservation of genetic resources.⁴⁷ Ex-situ conservation is the safeguarding of particular genotypes outside of their indigenous range and is useful when a threatened species has a very restricted indigenous range and arboreta and botanic gardens are currently the greatest contributors to ex-situ tree conservation.^{48,49}

An important question to be considered is the conservation value of the arboreta as gene banks, in particular, those containing unique and red-listed species. Accurate species inventories are an important foundation. It is nevertheless necessary to determine the genetic diversity represented in a collection itself.⁵⁰ Adaptation to a new environment occurs along with sexual reproduction and this could cause a gradual change in the genotype being conserved ex situ from the genetic composition of the populations in the indigenous range.^{51,52} Ideally, in-situ and ex-situ conservation should be combined for the conservation of a species to be most effective.⁵² Through additional infrastructure, such as climate-

controlled conservatories, arboreta can also expand their collections to include species that would otherwise not survive cultivation under the prevailing climate. The Princess of Wales Conservatory, at the Royal Botanic Gardens, Kew, houses many plant species from tropical regions such as the famous giant water lily *Victoria amazonica*.⁵³ In South Africa, Kirstenbosch Botanic Garden has successfully cultivated many bushveld plants from a subtropical climate (such as the baobab [*Adansonia digitata*]) in the Kirstenbosch Conservatory, despite being in a Fynbos biome with a Mediterranean climate.⁵⁴

The ex-situ conservation and silvicultural research on threatened species is the goal of the non-profit Central American and Mexican Coniferous Resources Co-operative (Camcore) focusing on four genera: *Pinus*, *Eucalyptus*, *Gmelina* and *Tectona*.⁵⁵ This initiative was started in 1980 and currently includes 29 forestry companies from 11 countries as active members.⁵⁵ Conservation is an obligation of membership of Camcore and each company is responsible for the well-being and maintenance of those species under its care.⁵⁶ South Africa has been part of the Camcore initiative since 1983, with six conservation parks containing 12 *Pinus* and 1 *Eucalyptus* species.⁵⁷ The research questions and projects of which arboreta are becoming a part, seem to be of an increasingly national and international nature over time (Supplementary table 2). Where arboreta were mainly used in the early 20th century to select suitable commercial or amenity planting species, in the late 20th and early 21st centuries, they have been effectively used in biosecurity research globally as well as in climate change research, such as the REINFFORCE network⁵⁸ across Europe.

Conclusion

Longstanding living collections of alien species have considerable research value for improving our understanding of pure and applied research problems.⁵⁹ The first assessment of South Africa's forestry arboreta was done by Poynton in 1957⁶⁰ followed by an unpublished survey by Poynton and Rycroft in 1986²¹. Arboreta represent an important resource for education, research, conservation and recreation and a survey of their current status would be an important step in using them for these purposes. Replacement cost theory is one way of placing a value on living plant collections. A complicating factor in this, is that living plant collections (as with herbarium collections) cannot be replaced, and the replacement value is more a measure of the investment made in establishing such collections.⁶¹ Alien tree species are of prime importance to forestry industries in the tropics⁶², and in the past there has been little in the way of procedures governing the movement of tropical tree germplasm between countries⁶³. The Nagoya Protocol on Access and Benefit Sharing that was launched in 2014⁶⁴ creates barriers to the exchange of biological material; those countries with existing collections of alien plant material will be at an increasing advantage over time⁶⁵.

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Competing interests

We have no competing interests to declare.

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