Journal of Botanic Gardens Conservation International

# BGjournal

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## Restoring damaged ecosystems:

### The role of botanic gardens and the Ecological Restoration Alliance

**New features in this issue:**

- Talking plants: an interview with a plant conservation champion
- Plant hunting tales from South Africa
- Featured gardens: focus on Malawi

BGCI

*Plants for the Planet*

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## IN THIS ISSUE...



**Cover Photo**: 12 year old restored forest at Brackenhurst Botanic Garden, Kenya. (Barney Wilczak/wilczakphotography.co.uk)

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United Nations Decade on Biodiversity

# EDITORIAL:
## ECOLOGICAL RESTORATION - THE ROLE OF BOTANIC GARDENS

Welcome to this edition of BGjournal, which focuses on the theory and practice of ecological restoration. You will also see some changes of a more general nature to the format of BGjournal in this edition. New, regular features include an image gallery, featuring the wonderful photography of Barney Wilczak, and a plant hunting story from Livhu Nkuna of the South African National Biodiversity Institute. Please let us have your feedback on these and any other ideas you might have about regular features that we might introduce.

This edition includes seven articles on ecological restoration, many of them from the Ecological Restoration Alliance of Botanic Gardens (ERA), a global consortium of botanic gardens actively engaged in restoration. BGCI provides the secretariat for ERA, the members of which have agreed to support efforts to scale up the restoration of damaged, degraded and destroyed ecosystems around the world, contributing to the Sustainable Development Goals and the United Nations' target to restore 15 per cent of the world's degraded ecosystems by 2020. ERA currently has 30 member botanic gardens carrying out ecological restoration projects in a diverse range of ecosystems and cultural contexts.

In this edition of BGjournal, we explore how gardens, big or small, can all contribute to ecological restoration. Indeed, some of the earliest pioneering work in restoration was initiated at botanic gardens (as described in the article from Chicago Botanic Garden on page 16).

In many cases, botanic gardens won't be carrying out landscape scale work themselves; instead, they will be supporting restoration efforts through baseline survey and inventory, provision of propagation protocols for individual species, reintroduction of threatened species (as illustrated by the article from the Botanic Garden Meise, page 24) or advice on how to store and germinate seeds (see the example on page 20 provided by Kings Park and Botanic Garden). Botanic gardens also play a key role in providing training (as shown in the article on page 28 that describes botanic garden contributions to forest restoration training in East Africa) and educating the public about the need for ecological restoration. Any botanic garden that grows or holds well-documented collections of native species has a contribution to make to ecological restoration.

BGCI's role is to grow these communities of practice; whether it is ecological restoration, or other related areas, such as red listing, seed conservation or science communication. It is essential that, as a professional community with unique skills and knowledge, we engage with society on solving the big environmental problems.

As we continue to transform and degrade ecosystems, the demand for ecological restoration services can only grow. We hope that this edition of BGjournal will encourage you to participate.

**Dr Paul Smith**
BGCI Secretary General

# FEATURES



*Images: Barney Wilczak*

# NEWS FROM BGCI

## BGCI'S INTERNATIONAL ADVISORY COUNCIL

On May 25th 2016, a meeting of BGCI's newly appointed International Advisory Council (IAC) was held at the Royal Botanic Gardens, Kew. This meeting was attended by 22 botanic garden directors and their deputies. The intention is that the IAC will become a global leadership forum for the botanic garden and arboretum sector, and this was reflected in the composition of the participants and in the agenda. This group will meet annually, and will have a strategic mandate. Key elements of the agenda this year were agreeing the Terms of Reference of the group, guiding BGCI's 5-year Business Plan, agreeing a peer-reviewed procedure for selecting Global Botanic Garden Congress venues, and discussing the establishment of a Global Botanic Garden Fund aimed at supporting plant conservation activities in smaller gardens. Significant progress was made on all of these items, and a range of other cross-cutting issues were discussed that this group could tackle.

## BGCI MEMBERSHIP BENEFITS

BGCI is presently reviewing and extending its membership offer to provide greater benefits to its membership. Under development is a new member's-only area of the BGCI website which will provide access to a range of new resources and services unavailable to non-members.

These will include:

- Advanced PlantSearch: greater access to PlantSearch records, allowing members to identify the location of species in *ex situ* collections. This will apply only to taxon records provided to PlantSearch under BGCI's new data sharing agreement and which have been flagged as 'not hidden' during the upload process.
- Access to on-line versions of BGjournal and Roots as soon as they are published.
- Training resources and the opportunity to apply for training courses.
- Examples and guidance for developing policy documents covering the various aspects of the work of botanic gardens.
- Access to BGCI's new botanic garden twinning programme.



## NEW BOTANIC GARDEN RESOURCES

**From idea to realisation**

The first chapters of BGCI's new Manual on planning, developing and managing botanic gardens are now available for download from the BGCI website. This comprehensive resource provides essential guidance for newly developing





institutions, as well as supporting established botanic gardens that may be seeking advice or information as part of a re-development or organisational review. Consisting of four main parts, the eight chapters of the Manual are being published in stages over the coming year, with Chapters 1 to 4 now available online. These chapters cover the planning, organization and operational essentials of establishing a botanic garden, as well as the development of a plant collections policy and the international policy environment in which botanic gardens operate.

Find out more about the Manual and download the chapters from the BGCI website: www.bgci.org/resources/2016-BGCI-botanic-garden-manual

**Training resources**

BGCI is developing a series of training resources for its members and the wider botanic garden community. The topics to be covered this year include The Nagoya Protocol on Access and Benefit Sharing (training modules already available on the BGCI website in English, French, Spanish and Chinese), The Convention on International Trade in Endangered Species (CITES), A Guide to Plant Biosecurity, Seed Conservation and Red Listing and Threat Assessments. These resources will be made available on the BGCI website as they are completed.
Visit www.bgci.org/resources/links/.

## DATABASES

BGCI is presently working on two new databases to support plant conservation action. These databases will be available for consultation via the BGCI website before the end of 2016.

**ThreatSearch** is a compiled list of plant species threat assessments using data from multiple information sources, including the IUCN Red List, National Red Lists, RBG Kew, various red list publications and journal articles. The list currently consists of more than 196,000 plant conservation assessments covering 108,000 plant species. The availability of ThreatSearch will mark considerable progress towards the achievement of Target 2 of the Global Strategy for Plant Conservation (GSPC): *"An assessment of the conservation status of all plant species, as far as possible to guide conservation action"*.

**GlobalTreeSearch** is being developed as the most comprehensive list of the world's tree species and their country level distributions. It presently includes 170,000 names of trees, which relate to 60,000 accepted species names.

GTA
GLOBAL TREE ASSESSMENT

GlobalTreeSearch is compiled from data from multiple information sources, including national checklists, journal articles and contributions from Global Tree Specialist Group (GTSG) members. This searchable tree list will also provide the backbone for the Global Tree Assessment, coordinated by BGCI and the IUCN/SSC GTSG, which aims to undertake conservation assessments for all of the world's tree species by 2020.

## NEW BGCI PROJECTS

BGCI is delighted to have secured funding to initiate a number of new plant conservation and education projects this year. We will be providing regular updates on the progress of these projects.

**Big Picnic: Big Questions – Engaging the public with responsible research and innovation on food security**
This EU-funded project will see the public across Europe and in Uganda sitting down with scientists, policy makers, industry and others to learn from each other and share ideas about food security, one of the most pressing challenges facing the planet. BGCI will co-ordinate an international partnership which includes botanic gardens, universities, a science shop, an institute for art, science and technology and an international NGO. Big Picnics will take place in 12 countries across Europe and one in Africa. More information is available on the BGCI website: www.bgci.org/news-and-events/news/1332/

**Save our Cedar! Conservation of Malawi's national tree**
Funded by UK's Darwin Initiative, this project will focus on the conservation of the Mulanje Cedar (*Widdringtonia whytei*), a critically endangered tree which occurs naturally only in the Mulanje Mountain Biosphere Reserve in Malawi. Working with Malawi's Forestry Department, the Mulanje Mountain Conservation Trust and local botanic gardens, BGCI will build an understanding of the propagation and cultivation needs of this species to enable it to be grown and sold by local people, generating alternative sustainable incomes. The project also aims to raise awareness of the Mulanje Cedar's importance, thus improving the conservation of this iconic species.

SAVE OUR CEDAR
MALAWI'S NATIONAL TREE


**Promoting the use of plant resources in research and development**
Also funded by the Darwin Initiative, this project will examine how access and benefit sharing (ABS) policies and legislation affect the use of plant resources for research and development. Through a pilot exercise in Ethiopia, BGCI will explore the chains of custody of plant resources from the 'owners' to the final 'users' of the materials. The project will attempt to identify key bottlenecks in the process and will make recommendations for simplified measures to facilitate plant-based research. Working in partnership with the Ethiopian Biodiversity Institute, the project will also help to build the capacity of botanic gardens and other collections holders to act as trusted intermediaries between the providers and users of plant resources.

**Conservation of threatened trees in Fiji**
The Kaidanren Nature Conservation Fund and the Japan Biodiversity Fund are supporting a new BGCI conservation project in Fiji. Here we will be working to identify the country's most endangered tree species, while at the same time, building capacity amongst local scientists to carry out further Red Listing and threat assessments. Working in partnership with a local NGO, NatureFiji-MareqetiViti (NFMV), BGCI will be also be helping to develop and implement Species Action Plans for the most endangered species. Seed conservation and the establishment of conservation collections in local botanic gardens will form an important part of the conservation work.

# INTERVIEW
# TALKING PLANTS

In the first interview of this new feature in BGjournal, BGCI talks to **Jože Bavcon**, Director of the Ljubljana University Botanic Garden and winner of the 2015 Marsh Award for International Plant Conservation.

We know you are passionate about plants, and particularly Slovenian native species, but what or who originally inspired your interest in plants?

From a very early age, plants were my toys. As a young child, my parents gave me a small patch of garden where I planted plants and watched them grow. I was particularly fond of cyclamen and snowdrops and by the time I started primary school, I already had a collection of more than 30 cyclamen growing in pots. Growing up on a farm, I loved to visit the dry hay meadows and collect plants and seed and watch them grow.

We know you have studied many different plant species, and published books on different plant families; but which species is your favourite and why?

My favourite plants have always been cyclamen and snowdrops. If I had to pick just one species, it would be *Cyclamen purpurascens*, a native to the alpine areas of central Europe and found widely distributed throughout Slovenia. Cyclamen have beautiful foliage year-round and under the right artificial conditions, can also be brought into bloom throughout the year as well.

The work of a botanic garden Director is very varied. However, is it possible to describe a typical day in your working life?

As the Director of a garden with a small budget and very few staff, the day-to-day work of the garden keeps me very busy. Activities in the garden have to be fitted in around scheduled meetings, which this year, with Ljubljana being the Green Capital of Europe, have been more demanding than usual. I tend to catch up on office work in the evenings and spend weekends going out in the field to collect seeds and plants. My family have learned that if they want to spend time with me, they have to join me on my field work. Luckily we all enjoy getting out into nature together. Working in the field is really my relaxation time. It is when I can think through problems and come up with solutions. I also find weeding a good activity to stimulate new ideas!

Many people talk about the lack of young people studying horticulture / botany today. What do you think we can do to inspire an interest in plants amongst the young?

This is a big problem in Slovenia today. Most of our young people want to work in computing or in the media. They have no interest in working outside. And even those people who do study botany or plant sciences, they learn more about the genetics of plants than about the plants themselves. They cannot recognise plants in the field and there are few people able to pass on this knowledge.

Nature is exciting to young children- they are fascinated by touch and smell; they ask questions and want to learn. However this interest needs to be encouraged and sustained as they get older. Unfortunately school regulations make it difficult for teachers to take children out into natural areas. In the garden we try to provide a safe environment where children can experience nature and we put a lot of emphasis on engaging the young.

Can you tell us what your plans are for the future of the garden?

I have many plans for the garden – but what we can achieve is always limited by the availability of funds and staff. We are hopeful that the City of Ljubljana will provide us with some additional land to expand the garden in the near future. In addition to this, we expand the reach of the garden by working in different sites across the city. This year Ljubljana is the Green Capital of Europe. This has provided us with many opportunities to work with the city authorities on 'greening' projects, which in turn helps to promote the garden and our expertise. We are particularly happy that many of these projects have involved the planting of native Slovenian plants in different places across the city. Wherever these are planted, we are able to add interpretation signs which provide information about the garden and its work. As a result, visitor numbers to the garden are increasing and our relationship with the city authorities is excellent.

In these days of economic crisis, many University botanic gardens in Europe are under threat of closure. How do you think botanic gardens can make themselves more relevant to universities, as well as meeting the needs of society today?

I believe that it is very important for university botanic gardens to demonstrate their value and to highlight the benefits the university gains from having such a garden. Providing education opportunities, carrying out conservation and research and being able to advise on city greening projects are some examples. They also need to take every opportunity to tell people about their work – in Ljubljana the garden is featured in a regular TV gardening show and we are frequently on the radio and in the papers. The greater the profile of the garden, the more it can provide a positive image for the University – so the garden can become the 'public face' of the University.

**Author:** Livhuwani Auldrean Nkuna

# PLANT HUNTING TALES
# THE QUEST FOR *ADENIA SPINOSA*

Adenia spinosa

Proper targeting and planning were key elements in finding a viable population from which a seed collection of *Adenia spinosa* was made in Limpopo Province, and of course the valuable knowledge of local people which greatly assisted our successful fieldwork.

## South African Flora

Although surrounded by the Indian Ocean to the east and the Atlantic Ocean to the west, South Africa is generally a dry land, largely composed of arid and semi-desert scrubland and grassland areas. The influence of the oceans and mountains, valleys and extensive plains means that plant and animal communities are extremely diverse.

The result is eight major South African biomes (ecological life zones which have distinct environmental conditions and related sets of plant and animal life). These are: Nama Karoo, Succulent Karoo, Fynbos, Forest, Thicket, Savanna, Grassland and Desert.

Approximately 10 per cent of the world's flora grows in South Africa, with the Cape Floristic Region holding 20 per cent of Africa's flora (although only 0.5 per cent of the land area of the continent). The South African National Biodiversity Institute (SANBI) manages a network of ten National Botanical Gardens covering the majority of South Africa's biomes. It is for this reason that the SANBI gardens are able to maintain such a wide variety of plant species as living collections.

## Threat status of South African flora

Although South Africa is one of the most botanically diverse countries in the world, many of its plant species face threats which are driving them towards extinction. Over 2,500 South African species (>10% of the total) have been assessed as Critically Endangered (CR), Critically Endangered with Possibility of becoming Extinct (CR PE), Endangered (EN) and Vulnerable (VU). Threats include habitat loss in sensitive environments due to development by government and the private sector to address the needs of an ever-growing population. There are also currently over 900 alien plant species in South Africa, of which more than 500 are invasive, out-competing and displacing indigenous species. Climate change is another major factor impacting on plant life in South Africa – we already have evidence of species disappearing due to changes in regional climatic conditions.

## SANBI's mission

The South African National Biodiversity Institute (SANBI) was established by the government to be the custodian of plant life in South Africa. The organization monitors and assesses the severity of threats to plants, develops conservation policies and plans, and makes recommendations to the government. To achieve its goals, SANBI forms and sustains collaborations and partnerships with relevant sectors of government, civil society and the private sector, including commercial and non-commercial organizations. The commercial sector offers SANBI opportunities (financial, time and space) to protect and rescue plants from areas demarcated for development, while the non-commercial or conservation organizations assist SANBI during conservation planning and implementation.

A. spinosa *found at Masequa farm, Mamvuka*

A. spinosa *seeds*

### SANBI's partnership with the Royal Botanic Gardens, Kew

For the past 15 years, SANBI has collaborated with the Millennium Seed Bank Partnership (MSBP) managed by the Royal Botanic Gardens, Kew, in London. The MSBP is an international programme seeking to collect and bank seed from species around the world. In South Africa, species are targeted for seed collection according to their red list categories, the most threatened having the highest priority. We also target species useful to humans, which face ever-increasing pressure from over-collection. SANBI has already made seed collections of over 4,000 species since the agreement with the MSBP in the year 2000. It is important to note however, that not all species produce seed that can be safely preserved under the orthodox seed banking conditions of the MSBP (–20 degrees Celsius).

### Targeting *Adenia spinosa* for seed collection

The MSBP team in South Africa targeted *Adenia spinosa* for seed collection for 14 years without success. Most of its habitats have become human settlements and in several areas only a single plant was found, without seed. The species is losing its natural habitat at an alarming rate. I remember seeing it in Tshikuwi village where I was born in the 1970s, but even there it has disappeared.

To identify the localities of *Adenia spinosa*, I began by gathering information at SANBI's National Herbarium (PRE) in Pretoria, where I also took pictures of herbarium specimens. The specimens were encouraging because they had flowers and fruits, and clear locality details were attached to them.

According to the literature, *A. spinosa* only occurs in the northern parts of Limpopo Province in South Africa, with some populations recorded in Botswana and southern Zimbabwe. One specimen in the herbarium was collected in 1982 from Wylliespoort, in the Soutpansberg mountains, on the road to Musina and Zimbabwe at Princess Farm. That farm is less than 3 km from my home village (Tshikuwi) in Nzhelele district.

### Spotting *Adenia spinosa* in the field

In the sandy, arid bushveld, across the mountain from Tshikuwi, still in Nzhelele district, a farm called Masequa was recently abandoned by the owners due to land claims against them. The local tribal authority at Mamvuka village claim the land belonged to their ancestors and it has now been returned to them by the South African government. The private farmers left in 2009 since when there has been no control over access, only a fence which is currently being destroyed by the local people in pursuit of edible wild fruits, medicinal plants, poles, firewood and hunting.

*A. spinosa* was reported to be here, growing alongside *Commiphora africana* and *C. mollis, C. marlothii, C. edulis, Sclerocarya birrea* subsp. *caffra, Boscia albitrunca* and many other species that were also mentioned on the herbarium specimen list.

I went to Mamvuka to search for *A. spinosa* and to see if there was a viable population. Spotting a healthy number of specimens on the Masequa farm (now belonging to the Mamvuka Venda tribe), I hurried to the tribal authority to seek permission to work on their land. They agreed – indeed the tribal authority was excited that there were people prepared to rescue important plants before development. A good working relationship meant the headman of the village was happy to allow local young people to assist the MSBP team. The tribal authority also set conditions to prevent future developments from destroying all the growing plants, and declared *Adenia spinosa* a flagship species of the village. SANBI, through its National Botanical Gardens (NBGs) and the MSBP in South Africa, will work with the community to identify plants that should be saved, according to age, usefulness, and scarcity. Unlike other *A. spinosa* populations like the one at Tshikuwi village, wiped out by human settlement, the population at Masequa farm still looks healthy. However, the plants growing on this land could soon be lost to building, arable farming, livestock grazing, sports grounds, or other human activities. It seems that approval was formerly given for human settlement and nobody can stop such developments from going ahead.

The SANBI NBGs, coordinated by the MSBP, will conduct a species rescue programme as soon as resources and time are available. Methodology will be according to species, so for example bulbous and similar herbs could be dug out for replanting at the relevant botanical garden. Such plants could then be used

**Taxonomic description of *Adenia spinosa***

- **Taxon:** *Adenia spinosa* Burtt Davy.
- **Family:** Passifloraceae (Granadilla family).
- **Stem:** The stem is shapeless succulent, thick and bulbous up to 1.5 metres in diameter. A tangled mass of thin branches arise from this stem.
- **Branches:** The branches are armed with blunt spines which may also function as tendrils for climbing.
- **Leaves:** The leaves are alternate, broadly ovate to elliptic with conspicuous venation, grey-green above, and paler below; margins entire or lobed.
- **Flowers and Fruits:** Flowers are unisexual on separate plants, axillary creamy yellow male flowers usually in denser clusters than female flowers. Fruits are oval segment capsules and yellowish-green in colour.
- **Distribution:** *Adenia spinosa* occurs in the northern parts of South Africa in Limpopo, Botswana and Zimbabwe, growing in scrubland or shrubland plant communities where the climatic conditions are often dry, hot and dominated by sparse grass, shrubs, herbs and geophytes.

during habitat restoration, species reintroduction, land rehabilitation, and other recovery programmes.

## Making a seed collection

We found about 150 plants of *A. spinosa* growing at Masequa Farm, of which around 40 per cent were in fruit, and I concluded it was worth collecting their seed. The seeds, checked using hand-lenses, were found to be in good shape for collection and conservation. I advised the local people about the method and containers suitable when collecting a fleshy fruit like this. Medium cotton bags were ideal, each collector having a bag in hand as they moved from one plant to the next. The fruit splits when pulled, so it was key to ensure the seeds did not fall out. It was perfect timing, as the seed was already beginning to disperse.

Local people participated throughout. They were happy to learn collection skills from the MSBP staff and were taught the importance of, and the way to make use of, a hand-lens when deciding whether to collect seeds from a particular specimen. The headman asked if I would return to explore the area with other colleagues from SANBI. The locals, with their new skills, have undertaken to report on any special plants producing seed in the area and to also make seed collections for the MSBP and the SANBI NBGs.

A very good quality seed collection was made from about 30 healthy plants. Local people also requested that the MSBP should share any information generated – knowledge such as propagation and germination protocols for the species, as well as its seed banking behaviour, so that they could grow these plants on their own premises if need be. There is a plan to go back to the village to conduct a workshop, teaching the Mamvuka people how *ex situ* conservation provides support to *in situ* conservation of plants. It became obvious that we need to work very closely with the locals, sharing information about plants that grow in their environment, and that the elders will in turn share with us any information about the known uses of such plants.

## Processing the seed collection

Back at SANBI, I submitted the herbarium specimen for verification of the collection at the National Herbarium, Pretoria. This specimen is a new botanical record of the locality and population where the seed was collected. The seeds needed to be cleaned immediately as they were still wet and could have gone mouldy if left for long inside the flesh. Having removed the fleshy materials, I placed the seeds in a container. Each seed was then washed in water gently but thoroughly, until the soft semi-slimy membrane around it was removed, and the seeds then placed in open trays in a dry room.

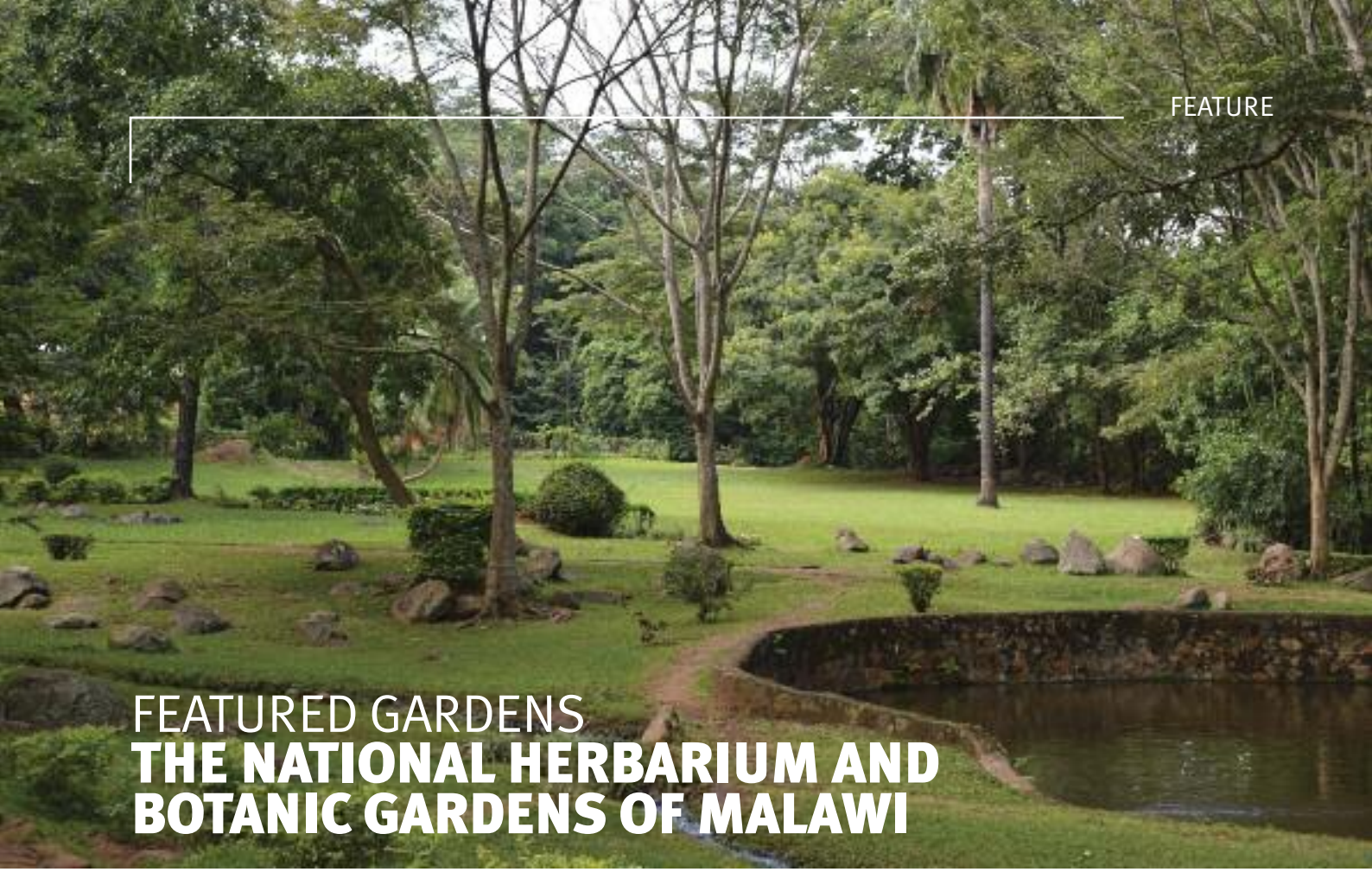
*Herbarium specimens, SANBI's National Herbarium*

*Aluwani Maano is one of the local people involved in seed collecting activities of* Adenia spinosa *at Mamvuka Village*

I can report that the seeds of *Adenia spinosa* collected at Mamvuka Village in the Limpopo Province have been sent to the UK for banking. Some seeds were donated to the Pretoria National Botanical Garden for propagation and plants will be kept there as living collections. As agreed with the local tribal authority, the MSBP will make more seed collections from the same population before the development of a new settlement begins. As a Gardens Conservation Manager at SANBI, I am currently in talks with the Garden's management regarding a major plant rescue programme for the area. The botanical gardens are willing to go and dig out plants that would be destroyed and grow them in the Gardens wherever possible. The Lowveld and the proposed Limpopo NBG are the most likely NBGs where these plants could be grown in suitable conditions.

As a footnote, there has been some evidence of damage to large stems of the Mamvuka *Adenia spinosa* plants that could have been caused by wild animals and I shall be working with the local people to determine the real cause. The species is not known to have medicinal uses, but the investigation should show whether the damage was done by animals or by medicinal collectors.

**Livhuwani Auldrean Nkuna is the Gardens Conservation Manager for SANBI National Botanical Gardens and is also responsible for managing the Millennium Seed Bank Partnership in South Africa.**



# FEATURED GARDENS
# THE NATIONAL HERBARIUM AND BOTANIC GARDENS OF MALAWI

The National Herbarium and Botanic Garden (NHBG) at Zomba was the first botanic garden to be established in Malawi. The NHBG has since established two more gardens in Lilongwe and Mzuzu, and all three botanic gardens are involved in *in situ* and *ex situ* conservation of rare and endangered plant species, e.g. *Widdringtonia whytei* (Mulanje Cedar) and *Khaya anthotheca* (Mbawa). They also offer recreational and educational services and propagate and sell a number of ornamental and indigenous plants.

*Inside the National Herbarium of Malawi. (BGCI)*

## Zomba Botanic Garden

Zomba Botanic Garden was founded by Alexander Whyte, Scottish explorer and botanist, between 1891 and 1895 and was originally the grounds of the British Consul's Residency (now the Government Hostel). The garden was established as an experimental area for newly introduced plants in order to promote agricultural enterprise. After Independence, the maintenance of the garden was entrusted to the Forestry Department until it was transferred to the National Herbarium and Botanic Garden (NHBG) in 1987.

The garden, which is located in the east of Zomba district, covers some 25 hectares and is situated at the foot of Zomba Mountain. The beautiful Mulunguzi River passes through the garden before flowing into Lake Chirwa, the second largest lake in Malawi, The boulder terrain in the northern part of the garden and the fish pond add beauty to the garden, while its tranquility is enhanced by the sounds of the numerous insects and birds the garden attracts.

## Plant collections

The garden's plant collection includes around 132 species, most of which are indigenous to Malawi. Some of the indigenous plants protected in the garden include *Khaya anthotheca, Parinari excelsa, Newtonia buchananii*, and many more. Zomba Botanic Garden also has a medicinal plant garden which

*Zacharia Magombo, Acting Director General of the National Herbarium and Botanic Gardens of Malawi. (BGCI)*

conserves some of the important species used by traditional healers. The collections include some of Malawi's rare and threatened plants such as *Encephalartos gratus* (Mulanje cycad), the rare and threatened but yet medicinally important plants such as *Dalbergia melanoxylon* and *Erythrophleum suaveolens*. The common plant families found in the garden include Caesalpinioideae, Cupressaceae, Euphorbiaceae, Mimosoideae and Myrtaceae.

### Key activities

The Garden's research programmes focus on the development of seed germination and propagation techniques for Malawian plants, especially those that are rare and threatened. Surveys of threatened species to be targeted for introduction to the garden are also conducted. The Garden has been involved in the conservation and rehabilitation of surrounding ecosystems such as the Chirunga Forest (in partnership with Chancellor College, University of Malawi), the rehabilitation of river banks such as the Likangala river and streams at Ulumba, as well as the establishment of medicinal gardens for traditional healers in Zomba and Mangochi districts (Southern Malawi), and Rumphi district (Northern Malawi). In terms of education and awareness-raising, the Garden works closely with a number of schools within the Municipality, at all levels from primary to tertiary level. As well as working with schools, the Garden has trained communities and traditional healers in nursery establishment and management.

### Lilongwe Botanic Garden

The Lilongwe Botanic Garden is situated in Lilongwe, Malawi's Capital City, in the Central Region of Malawi. The 118 hectare garden was established in 1989. The garden is conveniently located close to the seat of Malawi's Government (Capital Hill) and next to the Parliament Building. It is also close to the business district with its many hotels and restaurants. The Lilongwe Botanic Garden is an hour's drive away from the beautiful Lake Malawi in Salima district which makes it popular with holiday makers.

The Lilongwe Botanic Garden features national monuments commemorating those who died during the First World War and national freedom fighters. The garden also houses the beautiful statue of the first Head of State, Dr. Hastings Kamuzu Banda.

### Plant collections

As a newly designated site for a botanic garden, the collections largely feature indigenous plants with a few exotics. The vegetation type in the Garden is mostly *Piliostigma/Combretum/Acacia* mixed woodland. The common species include *Afzelia quanzensis*, *Acacia polyacantha*, *Albizia* spp., *Combretum* spp., *Dalbergia* spp., *Lonchocarpus capassa* and *Ximenia caffra* etc. Apart from the indigenous tree species, Lilongwe Botanic Garden also features an Aloe garden.

### Key activities

Lilongwe Botanic Garden has been involved in the reforestation of Dzalanyama Forest Reserve (catchment area for the Lilongwe river) through the provision of seedlings, in the conservation of Ngala ya pakamwa mountain with communities in Lilongwe as well as the establishment of medicinal plant gardens for Traditional Healers Associations in Lilongwe and Kasungu districts.

The Garden is also very much involved in educational programmes with a number of schools around Lilongwe, at tertiary, secondary and primary levels. As a result of this, the Garden has become an important hub for environmental education in the city.

### Mzuzu Botanic Garden

The 554.6 hectare Mzuzu Botanic Garden is situated in Mzuzu City in the Northern Region of Malawi. The garden was established in 1989 on a site that was gazetted in 1948 as Kaning'ina Forest Reserve, primarily as a catchment area of the Lunyangwa River.

### Plant collections

The plants of Mzuzu Botanic Garden are 90% indigenous species. Some of the plants being protected in the garden include the rare and endangered plant species *Aloe duckeri, Aloe swynnertonii, Ozoroa reticulata* ssp. *foveolata, Croton megalobotrys* and *Darbergia melanoxylon*.

### Key activities

The Mzuzu Botanic Garden has become a centre of attraction for education in relation to conservation, environmental and other plant science research as evidenced by frequent visits by members of academic institutions such as Mzuzu University and other foreign universities.

*Bridge crossing the Mulunguzi River in Zomba Botanic Garden. (BGCI)*

# ARTICLES



*Images: Barney Wilczak*


**Author:** Paul Smith

# BOTANIC GARDENS AND ECOLOGICAL RESTORATION: AN INTRODUCTION

Given the obvious need for restoration, instead of 'Why do restoration?', the question becomes 'How do we do restoration?', and this is where the botanic garden sector comes in.

*Images: Barney Wilczak*

ERA ecological restoration alliance of botanic gardens

The question of whether botanic gardens, foresters, conservationists and other land managers need to repair habitats is no longer asked. Humans have transformed 50% of the terrestrial landscape, converting biologically diverse habitats into crop production, pastoral fields and urban centres. In doing so, we have inadvertently disrupted, and in some cases destroyed, the functionality of whole ecosystems, leading to significant problems of water scarcity, erosion, loss of pollinators, loss of biodiversity and the emergence of new pests and diseases. This is widely recognized by policymakers and society with the result that large amounts of funding are available for afforestation and restoration, whether it is in the catchment forests of Kenya, the deserts of the Sahel or the rainforests of Southeast Asia.

There is also recognition that the planting of monocultures of the past is ineffective because without diversity there is no resilience. Millions of hectares of forest monocultures around the world are affected by emerging pests and diseases, resulting from climate change and human-assisted pathogen mobility.

Given the obvious need for restoration, instead of 'Why do restoration?', the question becomes 'How do we do restoration?', and this is where the botanic garden sector comes in. As a professional community, we manage at least one third of known plant diversity in our living collections – more by far than any other sector. The crop community manages a few dozen species at most and the forestry sector a few hundred species. What these sectors do well, however, is manage plant diversity on a grand scale and with a full understanding of the importance of infraspecific diversity. Clearly we can learn from each other.

In recognition of the unique contribution that botanic gardens can make to ecological restoration, the Ecological Restoration Alliance of Botanic Gardens (ERA) was formed four years ago. ERA is a global consortium of botanic gardens actively engaged in ecological restoration, the members of which have agreed to support efforts to scale up the restoration of damaged, degraded and destroyed ecosystems around the world, contributing to the Sustainable Development Goals and the United Nations' target to restore 15 per cent of the world's degraded ecosystems by 2020. ERA is coordinated by BGCI and currently has 30 member botanic gardens carrying out ecological restoration projects in a diverse range of ecosystems and cultural contexts.

One of the key objectives of ERA is to work in collaboration with other sectors to carry out ecological restoration, and in May, I attended an excellent conference organized by the USDA Forest Service, entitled 'Banking on the future: gene conservation of forest trees'. This meeting was convened in order for the botanic garden community to meet and discuss common areas of interest with foresters. Habitat restoration was a strong common theme.

It is not only the professional communities that are asking the How? question. Broader society is also looking for assistance. In March of this year, BGCI, on behalf of ERA, signed a Memorandum of Understanding with the UNESCO Man and Biosphere (MAB) Reserve programme. Under this MoU, ERA will help to train and advise Biosphere Reserve managers in how to go about restoring degraded landscapes, a significant enough problem for ecological restoration to be written into UNESCO MAB's new 10 year action plan.

That there is demand for our skills there is no doubt, but how are we, the botanic garden community, going to respond? ERA's mission is very clear. It is *'to mobilize botanic gardens, arboreta and seed banks to carry out science-based ecological restoration by marshalling their expertise, networks, and resources to help achieve the restoration outcomes needed for human well-being and a sustainable future for life on Earth.'* This mission translates into five main goals (see box).

## ERA GOALS

1. Work with local partners to set up, maintain and document a series of long term, sustainable, exemplar restoration projects in diverse biophysical, political, and cultural contexts around the globe that provide training and demonstrate the value of a carefully designed, science-driven approach to sustainable ecological restoration.
2. Improve the quality and volume of science-based ecological restoration practice by deploying scientific and horticultural skills to applied work on the ground.
3. Conduct ecological restoration research, to develop an enhanced knowledge base for restoration and identify and inform best practice.
4. Disseminate research and lessons learnt from projects.
5. Build expertise and restoration capacity through collaborations between botanic gardens, large and small, as well as with partners in local communities, professional societies, academia, industry, government, NGOs and international bodies.

So, how are we doing? A recent audit of ERA activities indicates that significant progress and momentum have been generated by the Alliance over the past 5 years (see box below).

This scale of activity is encouraging but represents the contributions of just 30 gardens. As ERA continues to gather momentum, we look forward to welcoming more members to the Alliance.

## ERA PORTFOLIO

**30** participating gardens and arboreta

**148** restoration projects in a diverse range of habitats and cultural contexts

**537** specialists engaged in restoration activities

Restoration sites at scales ranging from **0.1** hectare to **50,000** km$^2$

**US$158** million of project funding leveraged in the past 5 years

For more information about the work of ERA member gardens, please visit our website:

**www.erabg.org**

If your garden is interested in joining ERA, please contact

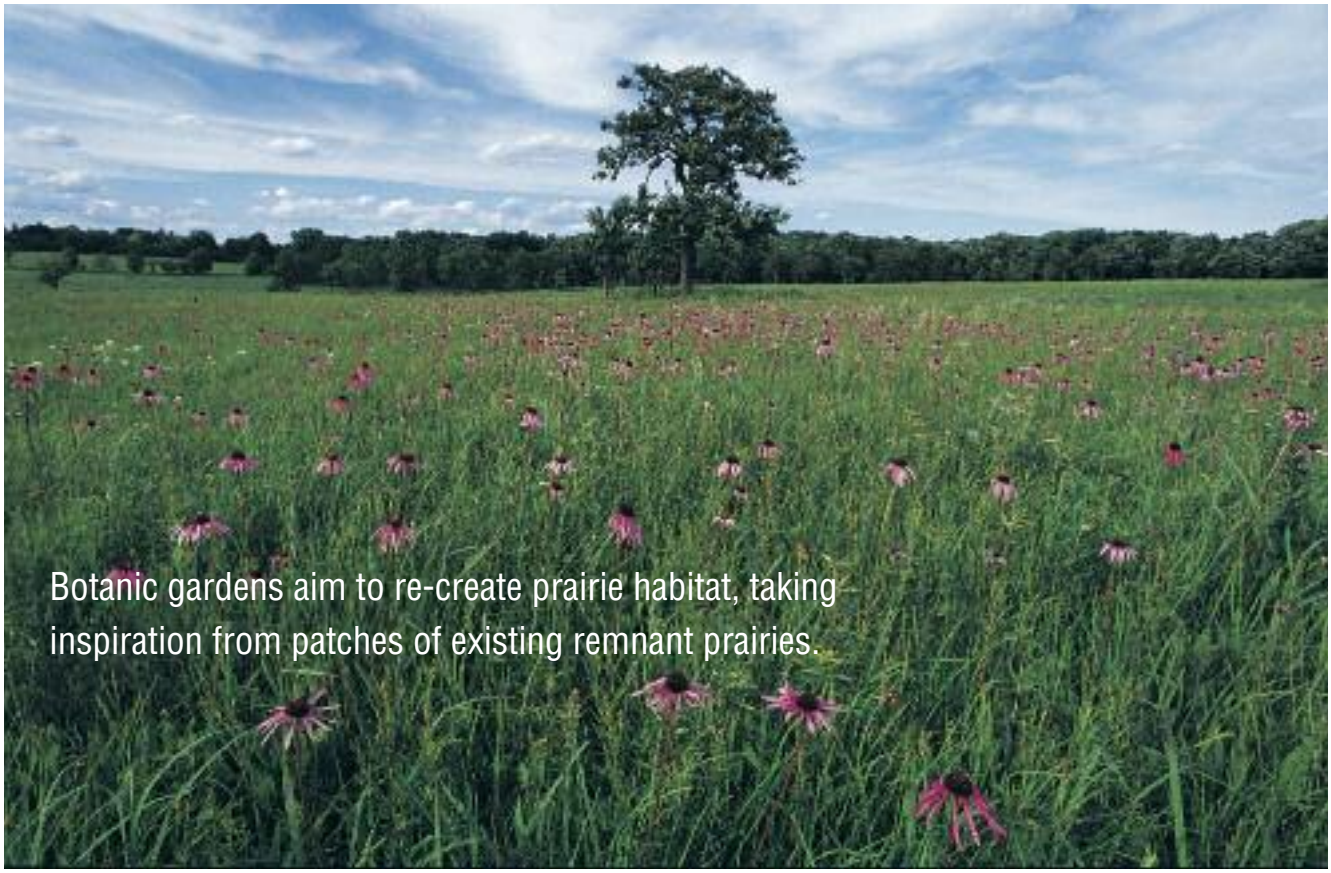
**erabg@bgci.org**

To tell us more about the ecological restoration work carried out by your institution, and enable us to better quantify the contribution of botanic gardens to ecological restoration globally please complete this short online survey:

**https://www.surveymonkey.co.uk/r/ERA_Survey_2016**
(active to end of October 2016).

**Author:** Rebecca S. Barak and Evelyn W. Williams

# INCORPORATING HISTORY TO IMPROVE PRAIRIE RESTORATIONS




*Schulenberg Prairie at the Morton Arboretum, one of the oldest restored prairies in the Midwest United States, was started in 1962. The prairie is a wonderful example of a high diversity prairie. (The Morton Arboretum)*

## Introduction

Every year more than a million visitors to the Chicago Botanic Garden walk through impressive, well-designed gardens with manicured landscapes featuring beautiful horticultural plants. But beyond the structured formal gardens, visitors are able to experience a piece of the historical Midwestern landscape: the Suzanne S. Dixon Prairie, a 15 acre mosaic of prairie communities including tallgrass, wet, gravel hill, and sand prairies interwoven with oak savannas and wetlands. Dixon Prairie packs multiple habitat types into those acres, including a gravel prairie, a wet prairie, and an oak savanna, demonstrating the range of grassland habitats native to the Midwestern United States. But Dixon isn't remnant habitat that was passed over by farm fields and urban development; it is a created prairie.

In 1980 the Chicago Botanic Garden established the prairie, hauling in gravel, sand, and topsoil to recreate the appropriate soils for these prairie communities and, over the years, planting thousands of plugs of prairie species. Today, the Dixon prairie is one of the highlights for visitors to Chicago Botanic Garden.

## Botanic gardens and prairie restoration

Botanic gardens in the Midwestern United States have a long history of research and practice for prairie restoration. Curtis Prairie, the earliest documented prairie restoration, was established in 1935 on post-agricultural land at the University of Wisconsin Arboretum using plant materials gleaned from intact remnant prairies (Cottam and Wilson, 1966). In 1962 the Schulenberg Prairie was initiated at the Morton Arboretum in Lisle, Illinois, by painstakingly planting individual forb and grass plants (Bowles *et al*., 2012). Many

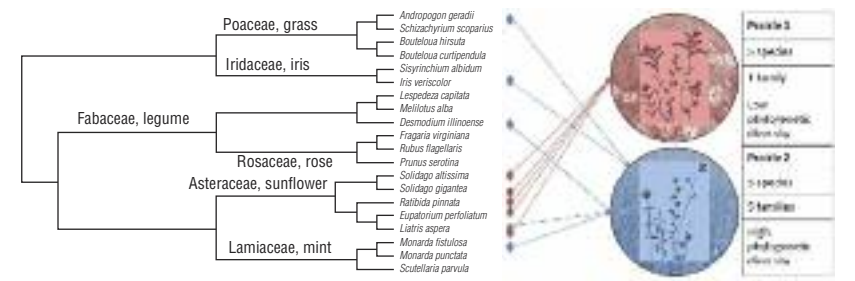



*Fig. 1 – Based on the species present, a prairie can have high or low phylogenetic distance even with the same number of species. Each prairie here has five species, but prairie 2 has species across the tree – species from families like Poaceae, Asteraceae, Fabaceae. Prairie 1 has low phylogenetic diversity because all five species are closely related, from the same family.*

of the restoration and management methods used today to restore diverse prairies, such as prescribed fire and soil inoculation, were developed though research and management at botanic gardens (Cottam and Wilson, 1966; Bowles *et al*., 2012). By sustaining restorations far beyond the time of any one researcher or practitioner, botanic gardens have helped to write the history of what it means to restore a prairie.

But restoration is not easy. At Dixon prairie, Chicago Botanic Garden managers and researchers continue to refine their management practices. For example, Chicago Botanic Garden has had difficulty establishing certain desired plant species because of site conditions. In addition, exotic invasive species from the surrounding urban/suburban landscape present a persistent challenge despite continued efforts on the part of staff members. Dixon Prairie, like all prairie restorations, requires constant maintenance, as well as ongoing research to achieve restoration goals.

Botanic gardens are particularly suited to carrying out ecological restoration as they have access to the necessary resources, expertise and infrastructure, and both researchers and practitioners are housed within the same organization. This structure allows for cutting-edge, interdisciplinary scientific research to solve applied problems in restoration.

## Creating diverse and functional prairies

We, as researchers from the Chicago Botanic Garden, along with collaborators at the University of Minnesota, and the Morton Arboretum are investigating the role of different measures of plant diversity in meeting restoration goals. Our project team also includes additional researchers, professionals, students, landowners and other stakeholders in prairie restoration. Our goal is to create diverse and functional prairies to meet restoration objectives. We investigate how manipulating different facets of plant diversity may increase ecosystem functioning at restored sites. Researchers studying the relationship between biodiversity and ecosystem function have quantified biodiversity as species richness - a count of species present in the community (Fig. 1). While species richness is informative for understanding many ecosystem properties, it is neutral with respect to differences between species: each species counts equally, no matter its identity. Our research focuses on the utility of phylogenetic diversity in ecological restoration. Phylogenetic diversity quantifies the evolutionary distance between species in a community, combining ecology with evolutionary biology (Webb *et al*., 2002; Cavender-Bares *et al*., 2009). This measure allows us to calculate how much of the evolutionary "tree of life" is captured by a given plant community.

## Incorporating multiple facets of biodiversity

As a simple example, consider two prairie plots that have the same richness of five species (Fig. 1). All five species in the first prairie are from the Asteraceae (aster family), while species from the second are from a range of families including Poaceae (grass), Fabaceae (legumes), and Lamiaceae (mints). Greater evolutionary history, or phylogenetic diversity, is represented by the plant community at the second prairie, because it includes species that are more distantly related. Not only will these two prairies look different, but they might function differently as well. Closely related species tend to have similar traits, whether it's floral characteristics,

*Restorations at botanic gardens like the Dixon Prairie at Chicago Botanic Garden allow visitors of all ages to experience historic landscapes. (Robin Carlson)*

*The Suzanne S. Dixon prairie at the Chicago Botanic Garden, initiated in 1980. (Robin Carlson)*

root architecture, or tissue nutrient content concentrations, because they evolved more recently from a common ancestor. By assessing the processes that mediate phylogenetic diversity at restored prairies, as well as the effects of phylogenetic diversity on key ecosystem function, our group is using evolutionary history to improve our understanding of community and restoration ecology.

> *"We are testing the relationships between phylogenetic diversity, functional diversity and ecosystem function."*

How might an understanding of phylogenetic diversity contribute to restoration? Previous research has found compelling evidence that high species richness has positive impacts on restoration outcomes like productivity (Tilman *et al*., 1997) and invasion resistance (Naeem *et al*., 2000). But in many studies, phylogenetic diversity is a stronger predictor of ecosystem function than species richness, or even functional (trait) diversity (Cadotte, Cardinale and Oakley, 2008). Communities with higher plant phylogenetic diversity are more productive both above and below ground (Cadotte, 2013), are more stable (Cadotte, Dinnage and Tilman, 2012), more resistant to invasion by exotic species (Gerhold *et al*., 2011), and support a greater diversity of pollinators and other arthropods (Dinnage *et al*., 2012). Phylogenetic diversity helps explain ecosystem function because it accounts for the trait diversity we can see (height, habit) and the diversity we can't see, or don't think to measure. We are testing the relationships between phylogenetic diversity, functional diversity, and ecosystem function through ongoing research in established restored prairies, greenhouse competition trials, and restoration field experiments.

To understand the role of phylogenetic diversity in restoration outcomes, we first set out to quantify the phylogenetic diversity in existing restored prairies in the Chicago area. We surveyed the plant community and measured soil conditions at 19 restored prairies. Where possible, we also gathered background information about the site including the original planting mix and the dates of major restoration and management activities. We also classified every species we found at each site as native, exotic, or invasive in order to determine whether diverse prairies are in fact more invasion-resistant. Ongoing experiments include a greenhouse and field experiment to tease out the mechanisms behind the effects of phylogenetic diversity on invasion and competition, and to determine how phylogenetic and functional diversity interact to influence ecosystem function.

## Preliminary results

Though our research is in the early stages, a few preliminary results point to a role for phylogenetic considerations in ecological restoration. When we examine the number of exotic species in our plots from each site, we see that plots with high species richness and phylogenetic diversity also have fewer invasive exotics. These findings agree with previous research on the importance of diversity, specifically phylogenetic diversity, in improving a restoration's ability to resist invasion (Gerhold *et al*., 2011; Li *et al*., 2015). But our results also reveal areas for future work. For example, a phylogenetically diverse seed mix doesn't always result in a phylogenetically diverse prairie, because some species do not establish, a pattern also found by Barber *et al*. (2016). It's likely that site conditions and ongoing management interact with seed mix diversity to influence phylogenetic diversity of a site (Larkin *et al*., 2015). As we continue our work, we will use

our research findings to develop phylogenetic tools for restoration practitioners to use at the planning stage (Hipp *et al*., 2015).

## Natural connections

Prairie restorations provide ecosystem services and help conserve native species, but also have an important role in building connections between people and nature. A final and significant benefit of botanic gardens participating in ecological restoration is the natural connection between restoration activities and science communication practiced at botanic gardens. For example, as part of our collaboration, we have partnered with the Morton Arboretum and a local high school to develop a student research module. Students became 'citizen scientists' and developed research projects related to prairie restoration and phylogenetic diversity; over 100 students have participated in this program to date. We also work with the Chicago Botanic Garden's Science Careers Continuum to involve students of all ages, including volunteers, high school interns, and undergraduate and graduate students, in our research in the field and the lab. Through mentoring, outreach and education, botanic gardens can help garner support for restoration activities and educate restoration scientists and practitioners of the future. At Chicago Botanic Garden, this dedication to restoration means that even the youngest visitors have the opportunity to hike through history in the Dixon prairie.

## Acknowledgements

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# THE RESTORATION SEED BANK INITIATIVE – A FOCUS ON BIODIVERSE RESTORATION IN THE SEMI-ARID PILBARA OF WESTERN AUSTRALIA

*The Pilbara is a highly weathered ancient landscape that contains some of the oldest dated rocks in the world (>3 billion years). It is also a landscape dominated by unique hummock-forming grasses (*Triodia *spp.) which have proven to be quite difficult to germinate on demand due to complex seed dormancy. (Shane Turner)*

Sufficient and timely supplies of seeds of wild plant species are required to support ecological restoration projects

*Location of the Pilbara bioregion (hatched area) in the northwest of Western Australia.*

## Introduction

All over the world seeds of wild plant species are at the heart of landscape-scale restoration. However, poor seed quality and low establishment success can frustrate attempts to re-instate biodiverse plant communities (Merritt & Dixon, 2011; James *et al*. 2013). With the growing recognition of the importance of landscape-scale ecological restoration in biodiversity protection comes an increasing demand for biological and technical knowledge of seeds and how to use them their effectively. The Botanic Gardens and Parks Authority (BGPA) who administer and manage Kings Park and Botanic Garden and Bold Park on behalf of the people of Western Australia, leads a number of research projects aimed at improving restoration techniques and technologies using seeds.

One of the largest of these projects, the Restoration Seed Bank Initiative (RSB) (http://www.plants.uwa.edu.au/research/restoration-seedbank-initiative), is a five year multidisciplinary research project that crystallizes an ambitious vision for the restoration of mine-impacted landscapes in the Pilbara region of Western Australia. The RSB unites the expertise and resources of BGPA, The University of Western Australia (UWA), and BHP Billiton Iron Ore to develop the science, knowledge, and technical skills required to achieve cost-effective and scalable environmental restoration. The RSB is not just about scientific endeavor, but also linking applied science with sustainable development, local communities, mining companies, and government in a collegial partnership to provide tangible environmental, social and economic benefits.

The Pilbara biogeographical region of Western Australia is a biologically unique, ancient, and highly distinctive landscape. Around 1,800 plant species occur in this semi-arid zone, of which 15% are endemic (Erickson & Merritt, 2016). The region is also a major area of

*A small section of the Mt Whaleback pit near Newman in Western Australia which is one of the largest iron ore pits in the world. (Shane Turner)*

resource development (Ye, 2008) with more than 90% of Australia's iron ore extracted and exported from the Pilbara. The disturbance footprint of established and emerging iron mine operations in the Pilbara is in the order of at least 230,000 hectares (EPA, 2013). Ecological restoration at this scale creates unique challenges, not the least of which is seed supply. Current seeding rates used for restoration in this region average 5 - 7 kg/ha, meaning that at least 700 tonnes of wild-sourced native seed is needed to restore the 120,000 hectares of disturbed land currently required to be rehabilitated (EPA, 2014). Add to this the significant variation in the purity and viability of wild-collected seeds, as well as difficulties created by substandard seed storage conditions and lack of information regarding seed germination requirements, and seed science clearly becomes central to optimizing restoration practices (James *et al*., 2013; Merritt, Golos & Erickson, 2016).

Enter the RSB initiative; part of a long-term partnership between the BGPA and BHP Billiton Iron Ore. The RSB is built around four core research programs: 1) Seed Bank Management and Curation; 2) Seed Storage; 3) Seed Capability and Enablement; and 4) Growing Medium. The focus of the project is to deliver the science needed for cost-effective restoration of biodiverse native plant communities, thus reducing the impacts of mining on the environment. It is envisioned that the restoration template developed over the next few years will in time be transferable to other regions of Australia, as well as internationally.

*"Good seed bank management underpins successful restoration efforts as high quality seeds are critical for ongoing restoration programs."*

### Program 1 - Seed Bank Management and Curation

This program aims to develop the framework, facilities, and handling processes to curate seeds from all current and future BHP Billiton Iron Ore seed holdings. This will be done in a way that supports ongoing research and technology development to promote biodiverse restoration in a cost effective manner.

An important activity of the seed bank is the ongoing training of mine site environmental staff and other land managers in seed curation and database management, with a particular focus on seed quality assessment and correct seed handling and storage.

### Program 2 - Seed Storage

The storage of seeds represents the most efficient method of appropriating large amounts of genetically representative germplasm for undertaking large-scale restoration. Seed banking also allows restoration practitioners to take advantage of years when seasonal conditions are good and seed production is abundant, thereby providing a resource for restoration activities during poor seasons. This program is examining seed storage behavior and longevity to ensure seed quality, enhance seed usability and, where beneficial, store seeds in a manner that promotes dormancy loss. Maintaining seed under optimal storage conditions ensures that seeds retrieved from storage will produce healthy, vigorous seedlings that have the best chance of *in situ* growth and development once sown.

*Preliminary* in situ *trial investigating the potential of seed orcharding approaches to increase seed production and seed quality. (Todd Erickson)*

*BHPBIO restoration site on a waste rock dump several years after the completion of restoration work showing above average recovery and regeneration. This site was seeded using up to date science-based seeding techniques utilising seeds stored according to "best practice" approaches developed by the RSB research team. (Brad Stokes)*

### Program 3 - Seed Capability and Enablement

As one of the largest programs in the RSB, the Seed Capability & Enablement program is focused on enhancing seed germination and seedling establishment. Up to 70% of native species produce seeds with some form of dormancy (Erickson, Merritt & Turner, 2016). Therefore, a key task of this program is to characterise seed dormancy types, resolve germination requirements, and understand how and when to apply germination stimulants such as smoke (Erickson *et al*., 2016). Seed dormancy is not the only challenge, however. Once the problems relating to seed dormancy and germination have been solved, it is by no means assured that seeds will perform in the field as required. Under current restoration approaches seedling establishment *in situ* is commonly less than 10%, even when germination of >90% can be achieved in the laboratory. Therefore, innovative new seed enhancement technologies are being explored and adapted for use on wild seeds - seed priming, seed coating and pelleting (Guzzomi *et al*. 2016; Madsen *et al*. 2016; Merritt, Golos & Erickson, 2016) to promote seedling stress tolerance and enhance germination and emergence rates. The final component of this program is centred on evaluating the potential of seed orchards to supplement seed collection strategies from wild populations. Seed orchards are horticulturally-managed stands of genetically diverse mother plants maintained for the mass production of high quality seeds. Demonstration seed orchards are currently being set up and assessed to understand the impact of growing conditions on commercial-scale seed production and consequently the feasibility of high-intensity seed orcharding for a range of priority species, particularly endemic native grasses.

*The seed bank of BHP Billiton Iron Ore contains seeds for use in mine site restoration. The room is maintained at 15°C and 15% relative humidity. (Brad Stokes)*

### Program 4 – Growing Medium

The Growing Medium program aims to develop growth media that will optimise the establishment of native plants following mining. At mine sites it is common for there to be a significant deficit of original topsoil due to the mining methods employed. With the abundance of mining waste material, this program is examining ways of utilising blends of different substrate types for restoration. Growth media must provide suitable conditions for seed germination, emergence, and successive growth – factors influenced by soil physical, chemical and biological properties (Muñoz-Rojas *et al*., 2016a; Muñoz-Rojas *et al*., 2016b). As moisture is the key limiting resource for germination in the Pilbara, the emergence of selected species under different temperature and rainfall conditions is a particular focus (Muñoz-Rojas *et al*., 2016c). A major component of the program centres on seedling emergence trials at a purpose-built, 1200 $m^2$ rain-out shelter at the Mount Whaleback mine site of BHP Billiton Iron Ore. This rain-out shelter is a first for environmental rehabilitation research in Australia, and provides for a greatly enhanced capacity to perform research trials under carefully simulated natural environmental conditions in the Pilbara. These field trials will test new technologies being developed to improve plant performance under various rainfall conditions and soil-type scenarios.

### Conclusion

The research programs of the RSB have been designed with the challenges associated with landscape-scale restoration in mind. The challenges being faced by restoration practitioners to re-instate biodiverse native plant communities cannot be solved by individual institutions alone, but rather require multi-disciplinary teams with a long-term commitment and vision, and a critical mass of staff and funding.

*Recently sown seed pellets scattered across the soil surface. Right – recently germinated* Triodia *spp. seedling emerging from a pellet several weeks after surface sowing. (Todd Erickson)*

There is a strong focus on collaboration and outreach to ensure the knowledge generated is accessible to the mining sector, land management groups, and the restoration community in general. Whilst the focus is on the Pilbara region of Western Australia, the ultimate goal is to provide generic principles for enhancing seed-based restoration in other equally diverse ecosystems (Kildisheva *et al*., 2016).

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*Left - the recently completed RSB controlled environment facility (CEF) situated in proximity to active restoration sites. This shelter will test different restoration soil types (using up to 64 plots) and watering regimes (up to 4) that will reflect current soils available for restoration purposes as well as likely rainfall patterns seeds and seedlings may naturally experience - from extreme drought right through to above average rainfall conditions. Right –* in situ *emergence of Pilbara species after several weeks incubation in the CEF. (Todd Erickson)*

*RSB research staff involved in extension work with a group of mine environmental managers discussing seed management and restoration issues. (Todd Erickson)*


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# **RESCUING CRITICALLY ENDANGERED SPECIES IN BELGIUM -** AN AMBITIOUS REINTRODUCTION PROGRAM OF THE BOTANIC GARDEN MEISE

*In addition to seed collection, young leaf material has been sampled in each source population (and target population, in case of reinforcement) for genetic analyses.*

*Plant vigour prior to transplantation was estimated by measuring rosette diameter or leaf length and width (as shown here for* Dianthus deltoides*). Differences in plant size were detected between seed source populations (Godefroid* et al.*, 2016).*

## Introduction

In Europe semi-natural grassland habitats and their characteristic species are considered as highly threatened (Pedro Silva *et al*., 2008). Southern Belgium is an important area for the conservation of semi-natural grassland types listed in the annexes of the Habitats Directive. There is an urgent need to preserve, restore and manage these few remaining, often degraded, habitat patches. This task includes genetic rescue of populations of critically endangered plant species that, without intervention, would not naturally regenerate because of restricted seed dispersal abilities and the absence of a persistent seed bank in the soil. In the framework of the EU LIFE project 'Herbages' (LIFE11 NAT/BE/001060), the Botanic Garden Meise, as a centre of excellence in *ex situ* conservation and plant propagation, has implemented population translocations into the wild for four critically endangered plant species (*Dianthus deltoides, Helichrysum arenarium, Arnica montana* and *Campanula glomerata*). The aim is to increase the effective size of the remaining populations (by reinforcement) and to restore extinct populations (by reintroduction) in order to improve connectivity in the landscape.

## A four-step approach

We first undertook a review of past and existing reintroduction projects worldwide (Godefroid & Vanderborght, 2011). This exercise helped to identify several factors that positively influence plant reintroduction outcomes (Godefroid *et a*l., 2011). It also revealed shortcomings of common experimental designs that jeopardize the success of plant reintroductions. With this knowledge in mind, we started to prepare reintroductions using a four-step

*After testing several propagation methods and visiting our colleagues of the LIFE project 'Arnikawiesen' in Luxembourg, we have developed an adequate protocol to produce 2,100 healthy plants of* Arnica montana *that were transplanted at the age of two months in three populations of 700 individuals each.*

approach (Godefroid *et al*., 2016): 1) the selection and profiling of the target species; 2) the source population selection and seed collection; 3) the development of propagation protocols; and 4) the assessment of plant fitness of the populations used as seed source before planting out.

## Species profiling is essential before implementing plant reintroductions

A detailed profile of each species has been produced in order to properly evaluate the species' biotic and abiotic needs, its basic biology and interspecific relationships (Godefroid *et al*., 2016). We compiled information for the following aspects:

- conservation status in Belgium and in the surrounding countries;
- ecological requirements (e.g. habitat type, soil pH and trophic level);
- morphological traits (e.g. life form, plant height, leaf arrangement, root depth);
- reproductive biology (breeding system, dicliny, dichogamy, phenology, and pollination);
- propagation ability (e.g. clonality, lateral spread); seed bank type; establishment strategy; aggregation; persistence; seed dispersal capacity; ploidy; mycorrhizae;
- interactions with predators and herbivores; diseases;
- seed germination requirements;
- cultivation methods (soil requirements, timing);
- possible causes of decline;
- (un)favourable ecological management practices.

## A careful selection of potential seed sources

The selection of the potential populations that may serve as sources for seeds was based on the following criteria: 1) a similar habitat to the translocation sites; 2) a size preferably of more than 50 flowering individuals, and 3) a location as close as possible to the translocation sites. For each species, seeds were collected following the recommendations of ENSCONET (2009). Quality assessment of harvested seeds of *A. montana* showed a positive relationship between flowering population size and seed weight and germination rate, the non-germinated seeds corresponding to empty (aborted) seeds (Godefroid *et al*., 2016). Germination rate in *D. deltoides* was positively correlated with population size (Godefroid *et al*., 2016).

These findings show that if local seed sources only consist of small remnant populations, seed quality may not be optimal. Therefore, population size can be a valuable criterion for selecting seed source populations. We recommend to use seeds from the largest possible source populations in order to optimize the quality of the source material used in plant reintroductions. Practitioners should also examine seed quality of source populations before undertaking reintroductions. Seed weight might be used as an estimation of seed quality. This is essential as seed size is known to affect long-lasting differences in fitness among offspring (Halpern, 2005).

## Producing quality plant material requires identifying the most appropriate propagation method

Preliminary tests using different kinds of growing medium were conducted in the seed laboratory and the nursery of the botanic garden. They provided valuable information for optimizing plant propagation protocols. The choice of growing medium strongly influenced the germination rate of the target species (Godefroid *et al*., 2016). For some species (e.g. *C. glomerata* and *A. montana*), changing the soil texture (e.g. by adding sand) increased germination rate by a factor of two. Such preliminary tests therefore provide valuable information for not wasting seeds, since reintroductions concern rare species where the seed amount that can be collected is limited. It also helps to know how many seeds need to be sown in order to obtain the required number of plants. The results also show that each species responds differently to a given growing medium, confirming that there is no universal protocol and that comparative trials using different kinds of substrate are necessary to optimise propagation protocols.

## Pre-translocation plant fitness as an indicator of genetic diversity

In order to detect possible effects of the seed source population on plant development, we carried out morphometric measures (vegetative plant size) on the produced plants (between 2,000 and 3,000 individuals per target species): rosette diameter for *A. montana, H. arenarium* and *C. glomerata*, and the length and width of the longest leaf for *D. deltoides*. These measurements were performed one month and one week before transplantation (when plants were 4 and 7 weeks old, respectively).

Differences in pre-translocation plant fitness were detected between seed source populations, which might reflect genetic diversity and maternal effects (Godefroid *et al*., 2016). As the translocated plants should retain as much genetic diversity as possible to ensure a high adaptive potential and improve establishment success, multisource reintroductions can be recommended.

### More than 9,000 plants reintroduced in 17 populations

For each species, a population of 500 to 700 young individuals was transplanted into three to six sites. Once *in situ* these plants (which are permanently labelled) were precisely mapped to facilitate their long-term monitoring. Transplants were positioned at an equidistance of 30 or 50 cm (depending on the species), and each translocated population consists of a mixture of plants from different origins arranged in order to maximize pollen exchanges between different origins.

### Long-term monitoring of the transplants is necessary

Long-term monitoring is necessary because initially high survival rates can be followed by reversals over time (Fahselt, 2007; Hutchings, 2010). A demographic survey (e.g. survival, floral production, reproductive success, and population extension by clonal propagation or seedling recruitment) is recorded yearly in the field. Seeds produced by translocated plants are collected on a subsample and germinated to estimate the offspring's fitness (measure of germination rate, chlorosis, and vegetative growth). Genetic diversity is estimated using molecular markers.

*Prior to transplantation, the target areas were 'cleaned' to avoid competition and to maximize the chances of transplant survival. Precise mapping of the permanently labeled individuals was carried out at the time of planting in order to facilitate long-term monitoring.*

*A total of 2000 plants of* Helichrysum arenarium *were transplanted for reinforcement into one site and for reintroduction into three sites, which were 1 km apart in order to promote gene flow between populations. Five months after transplantation, more than 40% of the individuals were already flowering, with a survival rate of 98%.*

### Box 1. A country whose flora is among the most endangered in the world

Belgium is one of the most populated countries in the world. As a consequence, about 40% of its flora is endangered and 8% has already disappeared (Delescaille & Saintenoy-Simon, 2006; Van Landuyt *et al*., 2006). The situation is particularly critical for species that are characteristic of very localized and seriously threatened habitats, such as wet depressions on peat soil, oligotrophic ponds or xeric sand calcareous grasslands.

Any shrinking of these habitats affects the status of all characteristic species. Barely 9% of the Belgian habitats of European interest are in favourable conservation status; 17% are in inadequate status, 73% are in bad status and 1% are of unknown status (Peeters, 2014). Restoring habitats and endangered species in Belgium is more essential than ever and it has become one of the core businesses of the Botanic Garden Meise.

### Encouraging results

The first results are beyond our expectations: over 90% reintroduced individuals survived the transplantation stress, and the flowering rate (> 30% on average) is impressive, sometimes just a few months after transplantation. We have also observed the presence of seedlings, and clonal propagation, indicating a potential for population expansion. Monitoring of reintroduced populations will continue for 10 years as only a long-term monitoring will tell what their future will be in the long run.

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*Plant fitness is monitored throughout the year. Special emphasis is put on floral display (number of flowering stalks and of flowers/flower heads per stalk) and on reproductive success, through the sampling of closed ripe fruits or flower heads in order to estimate seed production and quality (aborted and viable seeds).*


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### Box 2. One of the few LIFE projects involving a botanical garden

The LIFE project 'Herbages' (LIFE11 NAT/BE/001060) started in 2013 in Southern Belgium, coordinated by Natagora, a Belgian nature conservation NGO. The Botanic Garden Meise is one of the partners, together with the Walloon Directorate-General for Agriculture, Natural Resources and Environment. The project runs until 2019 and aims at improving the conservation status of 400 hectares of priority grasslands in 26 Natura 2000 sites. LIFE funds are used to restore 11 grassland types, including six priority habitats, among which xeric sand calcareous grasslands (6120*), semi-natural dry grasslands on calcareous substrates (6210*) and species-rich Nardus grasslands (6230*). The restoration of these habitats involves land purchase, ecological management (deforestation, scraping the top soil, seeding, fencing, and grazing by sheep or goats), and implementation of ecological corridors and stepping-stones. Another important aspect of the project is to prevent the extinction of the habitats' characteristic species, especially those that are most vulnerable to fragmentation, by population reinforcements/ reintroductions after the restoration of their habitat. The project also has a significant socio-economic dimension, by providing work to small local companies (forestry, environmental management, agricultural). Moreover, the restored habitats will subsequently be leased to local farmers who will ensure ecological management of the sites.


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# ENHANCING TREE CONSERVATION AND FOREST RESTORATION IN EAST AFRICA

BGCI is helping botanic gardens in Kenya and Uganda to act as demonstration, training and material supply hubs for forest restoration.

*Restored indigenous forest at Brackenhurst Botanic Garden, 2013. (Barney Wilczak)*

## Introduction

Africa experienced a net loss of 3.4 million hectares of forest annually for the period 2000-2010. Despite a steep rise in the number of forest management plans in place across Africa within that timeframe, and a small increase in the area of protected forest (FAO, 2010), a high reliance on wood as a fuel source, continued forest conversion to agriculture and development and selective extraction of valuable medicinal and timber species, continue to put pressure on Africa's forests and forest resources.

Recent forest restoration commitments from African countries, including the AFR100[1] and Bonn Challenge[2] pledges, as well commitments to the Aichi Biodiversity Targets[3], United Nations Convention to Combat Desertification (UNCCD) and the United Nations Framework Convention on Climate Change (UNFCCC), as well as national policies and targets, are beginning to drive action. However capacity for restoration across the continent is low.

## Lack of planting material of indigenous species

Availability of appropriate planting material is also a current bottleneck. Tree seed centres across Africa, often associated with national forestry research institutes, have traditionally focused on commercial timbers, many of which are exotic. These centres do not hold the material required for large scale indigenous forest restoration.



Eucalyptus *plantation on the site of Brackenhurst Botanic Garden before restoration commenced, c. 2000. (Barney Wilczak)*

In 2011, BGCI undertook a survey of indigenous and endangered trees held in botanic garden collections in East Africa, which found that these institutions hold an important source of planting material (BGCI, 2011). Though botanic garden collections are not exhaustive, in many countries they represent the best available source of planting material for the restoration of individual threatened tree species and wider forest restoration projects.

Recognising this, and that botanic gardens also have good knowledge on how to propagate native species,



[1] AFR100 (African Forest Landscape Restoration Initiative): A pan-African, country-led effort to restore 100 million hectares of degraded and deforested landscapes by 2030.
[2] The Bonn Challenge is a global aspiration to restore 150 million hectares of the world's deforested and degraded lands by 2020 and 350 million hectares by 2030.
[3] The Aichi Biodiversity Targets provide the framework for the Convention on Biological Diversity's Strategic Plan for Biodiversity 2011-2020.

BGCI launched a programme to support African botanic gardens to scale up their contribution to tree conservation and forest restoration. *Enhancing Tree Conservation and Forest Restoration in Africa* initially supported the activities of two botanic gardens: Tooro Botanical Garden in Uganda and Brackenhurst Botanic Garden in Kenya, both members of the Ecological Restoration Alliance of Botanic Gardens (ERA). Since 2012, the programme has expanded and we now have active collaborations with botanic gardens in six countries.

## Enhancing tree conservation and forest restoration in Uganda

Tooro Botanical Garden (TBG) is situated in Fort Portal in Western Uganda on a Central Forest Reserve owned by the National Forestry Authority (NFA) and leased to TBG. In 2012, BGCI provided support to TBG to enable the garden to expand their tree conservation and forest restoration activities. TBG has brought three new sites under forest restoration: one is an extension of the TBG site within the Central Forest Reserve, and the other two are Local Forest Reserves managed by the District Government, situated just outside Fort Portal. All sites have a similar history; they were initially designated as reserves for forest conservation, but changes in management regimes led to forests being felled and replaced with eucalyptus plantations, which were subsequently felled for timber. The degraded reserves were then left largely bare, with some encroachment for farming.

*Many of the indigenous tree species propagated in the nursery at Tooro Botanical Garden have medicinal properties, including the African Tulip Tree,* Spathodea campanulata. *(BGCI)*

The restoration sites were demarcated according to maps of the original forest reserves and remaining eucalyptus stumps were removed. Seeds and wildings were collected from remaining forest fragments closest to the forest reserves, the main source being Kibale National Park located approximately 30 km to the east. Seeds were propagated and wildings raised in the TBG nursery. Propagation methods and results were recorded. When seedlings had reached around 30 cm in height, they were planted out at the start of the rainy season, to maximise survival rates. Across the 3 sites, 16 hectares have been brought under restoration.

## Community engagement

When initial plantings took place, neighbouring communities allowed their goats to graze on recently planted sites, which resulted in high seedling mortality. A plan was developed with the communities allowing them to intercrop the seedlings with leguminous vegetables. Goats were kept out to protect both vegetables and trees, and community members became custodians of the restoration plots.

A large number of seedlings were also stolen from initial plantings. Popular species were identified by TBG (mostly medicinal and timber species) and seedlings of these species were provided free of charge to the communities. This took pressure off the replanted reserves, and indigenous species are now surviving well in local homesteads.

*Top: Three year old indigenous forest restoration plot within Tooro Botanical Garden, 2016. (BGCI) Above: Plot cleared for forest restoration within Tooro Botanical Garden, 2013. (BGCI)*

Four years into the project, many trees have reached heights and crown widths of >2 m so intercropping with vegetables is becoming less viable as harvesting can damage the tree roots. Alternative options that provide benefit to communities but do not involve cutting down planted trees are being proposed, including bee hives and planting shade-tolerant medicinal or edible plants beneath the canopy. The next steps will be led by communities. Information about the ecosystem services provided by restoration is being developed in local languages and consultation will remain a key part of this project to ensure its long-term success.

## Species focus

The restoration plots include a wide mix of indigenous species, the highest being 68 species on the site within TBG. Some rare and highly utilised species have been incorporated into the plots,

including *Prunus africana* and *Warburgia ugandensis*. All species were also planted in the TBG arboretum and since 2012 the number of tree species in the arboretum has increased from 19 to 126.

Survival rates and growth rates (height, crown width and root collar diameter) are recorded for a sample of each species in all restoration sites after each rainy season. This has enabled identification of top performing indigenous species, as well as management requirements for different species. For example, hardwoods such as *Entandrophragma utile* were trialled in initial plantings but low survival rates demonstrated that these species require partial shade. In the fourth year of the project these species have been planted under the newly formed canopy and initial survival rates are encouraging.

*The indigenous tree nursery at Tooro Botanical Garden. (BGCI)*

## Scaling up across Uganda

The 6.5 hectares of restored plot within TBG provides demonstration of the techniques and benefits of forest restoration. Top performing indigenous species are being promoted to customers at the TBG nursery. Propagation protocols have been developed for 8 indigenous species, and information on planting and care requirements is disseminated to customers and NGOs. TBG is now recognised by the National Forestry Authority as Uganda's leading supplier of indigenous tree seedlings. In addition, TBG has planted stands of indigenous trees of known provenance around the garden. Funds are being sought to establish a restoration seed bank at TBG to enable them to act as a seed supplier in future, supporting the restoration of forest reserves and other degraded forest areas across Uganda.

## Enhancing tree conservation and forest restoration in Kenya

Brackenhurst Botanic Garden is situated in Tigoni, 25 km from Nairobi in the Kenyan highlands. The garden was established in 2000 and is bringing 40 hectares of former exotic tree plantations under indigenous forest restoration. The restored forest includes nearly 1,500 species of East African plants. The number of birds visiting the site has quadrupled since restoration began. Colobus monkeys are resident in the forest after being absent for sixty years, and people from neighbouring communities harvest soap spinach (*Basella alba*) and other indigenous vegetables from the restored forest. Since 2012, with BGCI support, Brackenhurst has brought an additional 6 hectares under forest restoration, and more than 15 additional rare species have been collected and incorporated into restoration plots. A monitoring programme has been initiated to record the results of restoration work.

*Indigenous trees are grown from seed and wildlings in the Tooro Botanical Garden nursery. (BGCI)*

## Species focus

Since 2012, growth and survival rates have been recorded on a sample of 5,000 trees across the Brackenhurst site. This has enabled identification of 14 top performing species that are now being promoted to other restoration practitioners in Kenya, including *Croton macrostachys, C. megalocarpus, Rauvolffia caffra* and *Vitex keniensis* (Shaw, *et al*., 2015). Propagation protocols have been developed for these and 41 other indigenous species. Protocols are currently being tested in the nursery and will be published by the end of the year.

The older forest plots at Brackenhurst provide a site for carrying out restoration trials for rare forest species. For example, in 2013 seed from *Embelia keniensis*, a woody climber currently estimated to have only 5 mature individuals remaining in the wild, was collected and propagated. 50 individuals have now been planted in the Brackenhurst forest. Seed will be collected from these individuals and a supply of material propagated to restore the population in the original collecting site.

In the past year, additional threatened endemic trees were collected during seed collecting trips to Kasigau and Taita Hills including; *Syzygium micklethwaitii* subsp. *micklethwaitii* (Vulnerable); *Polyscias stuhlmannii* (Endangered); *Psychotria taitensis* (Vulnerable), *Memecylon teitense* (Vulnerable), and *Psychotria petitii* (Vulnerable). Propagation and restoration trials will now be carried out for these species.

| | Since 2012 |
|---|---|
| Number of threatened tree species planted in restoration sites | >30 |
| Number of trees planted in restoration sites | 85,000 |
| Number of trees provided to local communities free of charge | 46,000 |
| Number of trees sold to farmers, NGOs, government or private | 118,000 |
| Area under forest restoration (ha) | 28 ha |
| Average survival rate of top performing species in restoration plots | 96.5% |
| Average canopy width of top performing species in restoration plots | 3m |
| Matched funding secured by BGCI for tree conservation and forest restoration across Africa | c. £400,000 |

## Scaling up across Kenya

The forest restoration plots of differing ages at Brackenhurst provide a unique opportunity for demonstrating the timescale and benefits of forest restoration. In March 2016, BGCI and ERA held a 5 day training course at Brackenhurst for 25 participants from East African botanic gardens, NGOs and government representatives carrying out tree planting and forest restoration programmes. Training was provided by BGCI, Brackenhurst, Multiplant International Medicinal Conservation, the Royal Botanic Garden of Jordan (an ERA member), and the Forest Restoration Research Unit, Chiang Mai, Thailand. Participants learnt how to plan forest restoration effectively, carry out a rapid site assessment before restoration, propagate indigenous trees from seeds and cuttings and best practice for tree planting.

The course also fostered partnerships: the training at Brackenhurst led to seedlings and advice being provided to a forest restoration project in the foothills of Mount Kenya run by the Mount Kenya Trust, and funding applications have been developed with other participant organisations to enable botanic gardens to provide support on species selection and planting. All participants were trained to adopt the same monitoring approach so species performance can be monitored across Kenya.

*Participants of the ERA forest restoration training course held at Brackenhurst Botanic Garden, March 2016.*

## Scaling up across Africa

These two projects provide excellent sites for demonstrating the value of indigenous forest restoration and involving botanic garden knowledge in ecological restoration.

Since 2012, BGCI has identified other African botanic gardens actively involved in forest restoration and raised c. £400,000 to work with botanic gardens in Ethiopia, Nigeria, Tanzania and Malawi to build capacity for tree conservation, support survey and collecting trips for threatened tree species and carry out restoration.

BGCI is promoting the role of African botanic gardens in forest restoration and continues to provide training, support and raise funds to enable more botanic gardens across Africa to act as demonstration, training and material supply hubs for forest restoration.

*Species identification session during the forest restoration training workshop held at Brackenhurst Botanic Garden, March 2016. (BGCI)*

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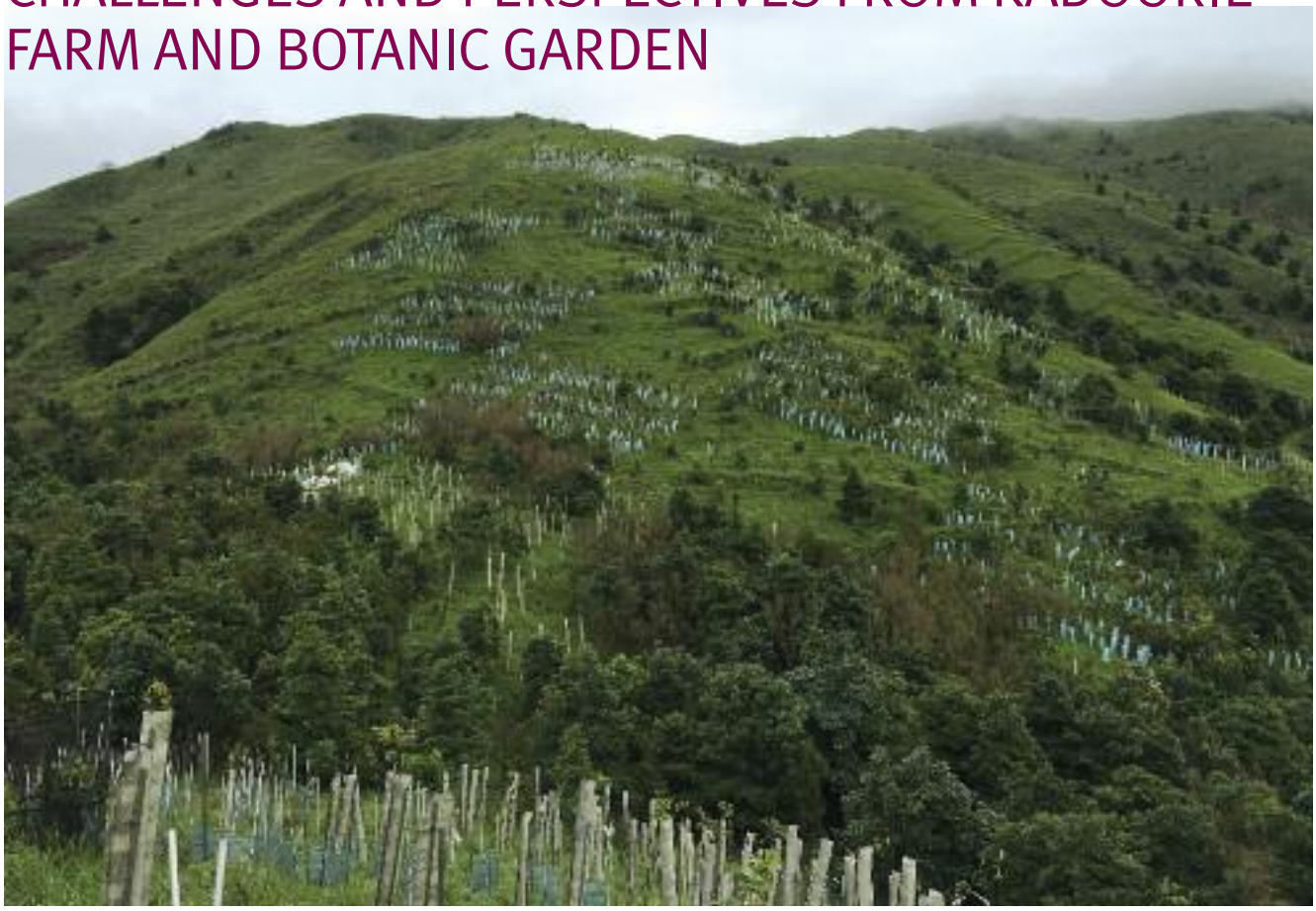
# RESTORING HONG KONG'S MONTANE FOREST

## CHALLENGES AND PERSPECTIVES FROM KADOORIE FARM AND BOTANIC GARDEN



*Core area of the restoration site showing the 20 x 20 m planting grid.*

### Introduction

With 7.2 million residents in 1,104 km$^2$, Hong Kong is one the most crowded places on Earth. Despite decades of urbanisation, 48% of Hong Kong's territory has been designated as country parks to protect the environment and to provide an escape from urban life for city dwellers. Geographically the city lies at the eastern coast of the Pearl River delta in Guangdong Province, South China. Its monsoon-influenced seasonal climate is marginal tropical to subtropical, with an annual mean temperature of 23°C. The wet season lasts from April to October, with an annual mean precipitation of 2,400 mm, although some of the highest mountain peaks can receive up to 3,300 mm rainfall each year (Hong Kong Observatory, 2016).

### Ecosystem and species composition around Hong Kong

Hong Kong's primary forests were destroyed centuries ago and have not recovered since, due to continued disturbance by humans, mainly by fire. All megafauna to the size of large rodents such as flying squirrels have disappeared together with the forest (Dudgeon & Corlett, 2011). The number of extinct species is hard to assess since their disappearance pre-dates specimen collections, but it has probably been in the hundreds. Only small patches of forest, most of them less than 5 hectares in size, have been preserved by villagers for cultural reasons. These so called "feng shui" woods", survived the destruction and remained, together with isolated shrubs and trees in rocky ravines, the only seed source of the local flora (Abbas *et al*., 2016).

Feng shui woods, some of them more than 400 years old, contain only parts of the original forest species composition, mostly made out of tropical and a few subtropical plant families such as Sapindaceae, Euphorbiaceae, Myrtaceae, Elaeocarpaceae, Lauraceae, Verbenaceae, Myrsinaceae, Fabaceae, Annonaceae, Arecaceae and Rubiaceae. Local people have used the feng shui woods as forest gardens for centuries, altering the original forest structure and species composition by removing unwanted plants, felling trees for wood and artificially enriching the forest with edible and medicinal plants (Dudgeon & Corlett, 2011). Despite being modified over centuries these forests harbour an incredible diversity of plants, often hundreds of species per hectare resulting altogether in a remarkable flora of 2,175 native Hong

Kong plant species, of which more than 400 are woody species (Chu & Xing, 1997; AFCD, 2012). The feng shui woods constitute very nice examples of traditional agroforestry systems once common throughout South China.

Only a few patches of high quality feng shui woods remain, mostly restricted to lowland areas, near villages, whereas most of Hong Kong's natural landscapes are now covered by secondary grasslands and forests of different successional stages mostly established after World War II. Grasslands are species poor and dominated by *Imperata cylindrica, Ischaemum aristatum* var. *glaucum, Neyraudia reynaudiana, Miscanthus floridulus* and pioneer shrubs such as *Rhodomyrtus tomentosa* and *Baeckea frutescens*.

The species composition of young forests is also relatively species poor, usually dominated by early successional species such as *Machilus chekiangensis, Mallotus paniculatus, Syzygium hancei, Gordonia axillaris, Itea chinensis, Castanopsis fissa* and *Acronychia pendunculata*.

Recent studies have shown that the oldest patches of secondary forest, which are around 70 years old, can harbour 174 species in 20 hectares, still consisting of mainly early and mid-successional species. There is no evidence that climax trees, which are still found scattered in feng shui woods, are able to recolonize the secondary forest (KFBG unpubl. data). Probably the lack of suitable dispersal agents and unfavourable microclimatic conditions limit the number of species able to recruit in secondary vegetation (Weir & Corlett, 2006).

## Natural re-establishment and early reforestation efforts

Generally the natural re-establishment of forest is a very slow process and follows the successional model, whereby grassland is replaced by shrubland and shrubland finally by forest. This process can take between 20 to hundreds of years in Hong Kong and certain exposed places with badly eroded soil seem incapable of recovery (Zhuang & Corlett, 1997). Therefore from some 150 years ago when Hong Kong became a British colony, early attempts were made to reforest the "barren rock" Hong Kong (Corlett, 1999).

Originally only exotic trees were planted, whereas in the last decades more native species were added to the planted species mix. Results were heterogeneous, with some hardy exotic species such as *Acacia* ssp. or *Eucalyptus* ssp. growing better than native species.

## Botanic garden-led restoration

Kadoorie Farm and Botanic Garden (KFBG) started to experiment with afforestation 60 years ago, when a barren hillside was selected as the garden's location along a stream, which never dried out in the seasonal climate. In the early days mainly agriculture and orchards were established and along the stream, trees were planted and the forest was allowed to recover. When conservation became one of the focus areas of KFBG in the 1990's an ecological restoration program was established by setting up a native tree nursery as a key facility. In collaboration with Hong Kong University (HKU) experiments were conducted to understand factors that limit the establishment and survival of native trees in grass- and shrublands. Much knowledge was gained about dispersal, recruitment, survival and growth rates of planted and naturally established tree species. Planting trials with native trees were successful and results have been published over the last two decades (see publications by Richard Corlett and Billy Hau).

Building on the experience gained and the fact that it seemed impossible that the forest would recover naturally, in 2013 we started an ambitious restoration project on the upper slopes of KFBG's

*Above: Tree guard protecting* Quercus edithiae *(Fagaceae) a rare climax tree in South China. Below: Liberation thinning and arboricultural pruning of lower branches will help the tree* Lithocarpus corneus *(Fagaceae) to reach it's maximum height and prevents slow growing species being outperformed by fast growing species.*

premises called: "*Ecological restoration of the original montane forest of Hong Kong*". The experience gained can, and hopefully will, be used for projects elsewhere in the South China Region.

We started with surveying remote ravines in Hong Kong to assess the candidate species for restoration but also comparisons were made with more mature forests in other parts of South China. Forest monitoring plots were established to better understand natural patterns of succession, including a 20 hectare forest dynamics plot in collaboration with HKU in Hong Kong's only nature reserve. Unfortunately, we were not able to identify any remaining primary or mature template forest with similar species composition and climatic conditions to our restoration site, but we could estimate by comparison with similar vegetation types in the region that the original plant community would have had at least 150 woody species per hectare.

## Monitoring and research

In order to be able to monitor the project from the first planted tree throughout the evolution of the forest, a 20 x 20 m grid was established over the total project area of 10 hectares. Every planted tree and also every existing shrub and tree was identified and tagged with a unique number. Not all plots were planted as some act as monitoring plots for natural succession. Two automatic weather stations permanently monitor the climatic conditions remotely, allowing us to link growth and survival rates to climatic patterns.

*A spacing of less than 1 m between the planted trees, was not sufficient to prevent a multi-trunked stem in* Syzygium hancei *(Myrtaceae) in a 15 years old restoration plot.*

One of the key questions we are asking is whether it is possible to shortcut natural succession and avoid the shrub and early tree stages of succession by planting climax trees at the beginning of the ecological restoration process. To address this we established a series of experiments to overcome factors that reduce survival and growth rates of climax trees in an open grassland environment, such as strong wind, wind desiccation, strong sunshine, herbivory, competition by grasses for nutrients and water, soil erosion etc.

The experiments included the use of different types of tree guards, different types of weeding mats, different types of fertilizers, soil amendments with compost and biochar and different weeding regimes. It was clear from the beginning that many of the questions which needed addressing were applied and mostly related to good horticulture rather than ecology. Early on we made the observation that protecting the trees with tree guards was very beneficial and allowed us to plant smaller seedlings, thus reducing the risk of curled roots and reducing the nursery time and amount of soil in the root ball. Tree guards also significantly helped to overcome many of the limiting climatic factors mentioned above and survival rates were drastically increased compared to zero controls without tree guards.

In order to test the effect of treatments we planted 20 different species in a mixture of pioneer and climax trees and shrubs in plots replicated at a high frequency over the restoration site. To avoid low diversity plantings, it is important to thin the trees once the initial treatment questions have been answered. This is normally done after 3-4 years. The thinned trees are used for mulching and as erosion barriers along the contour lines. The gaps are filled up with additional species of trees and shrubs to increase the overall species diversity. Before planting, the height and basal diameter of all trees are measured and a census of each plot is conducted after the first 2 years and after that every 5 years.

All the 20 x 20 m grid cells are alternately planted, always leaving one cell empty. Once the trees in the neighbouring plots have grown up to a least 4-5 meters in height, the climatic conditions inside the empty plots are more favourable for rare and shade tolerant species. First results are very promising and we have already established more than a hundred different woody species in the core area of the restoration site.

## Lessons learnt and looking ahead

The experiments and strict monitoring regime in place allows us to gather a large amount of information across a relatively small area and make recommendations for future projects. For example, we have learnt that good arboriculture is needed early on to make sure that rare climax trees grow straight, don't branch too early and are free of competition so they are not outperformed in the stem exclusion phase of succession by overly vigorous pioneer trees. We tested whether very close planting can overcome these problems but unfortunately without success.

Although little is still known about how plant species coexist and interact with each other in this particular ecosystem, our restoration experiments allow us to compare natural succession initiated by a limited species pool caused by massive deforestation in the past with succession initiated by an artificially increased species pool. This provides us with a unique opportunity to test hypotheses on community assembly, species coexistence, habitat preferences and environmental filtering in a phylogenetic, functional and ecological framework.

These experiments are still on-going and we plan to publish a series of scientific articles in the coming years to share the knowledge gained and guide restoration projects elsewhere.

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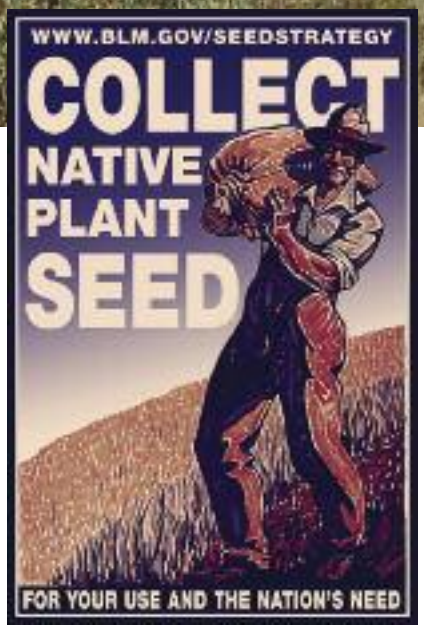
# NATIVE SEEDS FOR ECOLOGICAL RESTORATION

The US National Seed Strategy for Restoration and Rehabilitation aims to have the right seed in the right place at the right time.




*Sandberg bluegrass* - Poa secunda *being collected in Wyoming. (BLM WY932A, Seeds of Success)*

Ecological restoration is a global imperative and botanic gardens have essential roles to play in supporting global restoration targets. Important activities include the collection, storage and propagation of appropriate plant materials. Botanic gardens are uniquely placed to manage and supply the diversity of plants that are required at a local to global scale for ecological restoration action.

## Using native species

In the US, restoring degraded plant communities using native plants of appropriate provenance is a requirement of national policies relating to climate change, land management for pollinators and the restoration of fire-damaged sagebrush communities. Increasingly the need to build ecological resilience in response to extreme weather events is being recognised at the policy level together with the need for emergency preparedness. Native seed is essential to meet the national policies and plans for building ecological resilience. The right seed, often of common so-called "workhorse species" needs to be available in sufficient quantity for use at the right time and in the right place.

## The National Seed Strategy

In response to the need for appropriate native seed for landscape level restoration, the National Seed Strategy for Restoration and Rehabilitation was launched in the US in August 2015. This over-arching Strategy was developed by 12 federal agencies and over 300 non-federal co-operators of the Plant Conservation Alliance including commercial seed producers, plant nurseries and botanic gardens. The National Seed Strategy responds to a national shortage of native seed in the US, recognising the challenges of obtaining and delivering adequate quantities of seed to meet restoration needs which are often difficult to predict.

The National Seed Strategy has been designed to build on existing initiatives including the Seeds of Success (SOS) programme led by the Bureau of Land Management (BLM). The BLM is the largest federal land manager in the US, and purchases an average of 1.4 million kg of seed each year for restoration. Since 2001, SOS has made more than 16,000 native seed collections representing over 5,000 taxa.

*Basindaisy* - Platyschkuhria integrifolia *(BLM WY932A, Seeds of Success)*

The emphasis is on collecting orthodox seed for restoration needs particularly of species most threatened by climate change and species representative of key ecological communities. Material from SOS collections is seed banked and also made available for research and for plant development by commercial seed producers. The goal of SOS is to bank seed of 14,000 native taxa, approximately 75 percent of the US flora. For more widespread species, genetic variability will be represented within collections.

Implementation of the National Seed Strategy will scale up seed collection, seed production and ecological restoration through a coordinated approach. The first major step is a comprehensive needs and capacity assessment followed by increased research and management tools to enhance production. Communication is considered one of the four inter-linked goals with the aim of ensuring active participation of a diverse set of public and private partners.

## The role of botanic gardens

Botanic gardens were actively involved in the development of the National Seed Strategy and are now participating in its delivery. The Chicago Botanic Garden (CBG), for example, manages coordination of the SOS programme and runs a highly successful internship programme training young botanists in seed collection. CBG also conducts research to support native plant materials development and restoration. This work involves monitoring long-term study plots in Utah and Colorado to identify and help develop appropriate native plant material for restoration and to quantify how species and seed-source selection impacts ecosystem function in restored habitats (see page 16 for more information about the restoration work of CBG).

Other leading botanic gardens are involved as key partners in collecting seed for restoration. Both the North Carolina Botanic Garden and New England Wildflower Society are for example, currently engaged in the SOS East project which is responding to the impact of Hurricane Sandy. In October 2012, Hurricane Sandy had devastating impacts along the East Coast of the US, resulting in more than 120 deaths and major disaster declarations for 12 states and the District of Columbia. As part of the recovery effort, $360 million is being used to restore national parks and national wildlife refuges along the coast. The Fish & Wildlife Service (FWS) is working with partners on 31 projects designed to increase resilience by restoring coastal marshes, beaches and dunes, improve connectivity in streams and rivers and fostering collaborative science. It has been estimated that 1 million dune stabilizing native plants are needed for coastal ecosystem recovery but initially no local plants were available. Seed is now being collected to grow appropriate plants with the New England Wildflower Society responsible for collecting in Maine, New Hampshire, Massachusetts, Rhode Island, and Connecticut. In 2015, 254 collections were made in these States representing 91 species. North Carolina Botanic Garden is responsible for seed collecting in Maryland, and Virginia and made 234 collections in 2015 representing 91 species. The botanic gardens are also running training programmes to demonstrate techniques and explain the need for collecting genetically diverse seed.

*Arrowleaf balsamroot* - Balsamorhiza sagittata *in Wyoming (BLM WY, Seeds of Success)*

***Across the US, botanic gardens can engage with the National Seed Strategy working with the Plant Conservation Alliance and by engaging directly with federal agencies.***

Promoting the importance of native plants and developing propagation protocols are two very important activities linked to the Strategy, reflecting key roles already undertaken by botanic gardens. The Strategy links effectively with the newly published North American Botanic Garden Strategy for Plant Conservation which calls for *botanic gardens to increase the availability of propagated and appropriately provenanced plants and propagules to recover or restore natural ecosystems in North America*. It is increasingly important for the botanic garden community to continue conserving rare and threatened plants and at the same time help to ensure native plant diversity as a whole is conserved with materials available for restoration. With the unfolding impact of climate change, we cannot afford to ignore the more common elements of plant diversity that underpin ecological stability and enable the scarcer plants to flourish.

*For a copy of the Seed Strategy go to: www.blm.gov/seedstrategy*

*If you want to help implement the National Seed Strategy, email: SeedStrategy@blm.gov*

*For information on the National Native Seed Conference 2017 go to: http://nativeseed.info/*

# RESOURCES

## Pilbara Seed Atlas and Field Guide: Plant Restoration in Australia's Arid Northwest

Erickson, T., Barrett, R., Merritt, D. and Dixon, K. 2016.
ISBN: 9781486305520

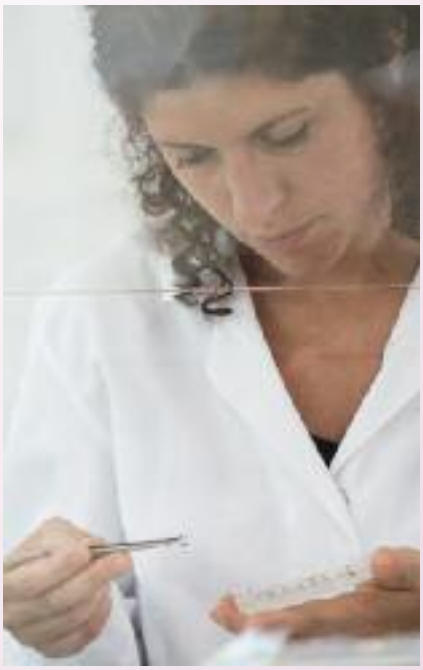
This book provides photos and information to support identification and guidelines for seed collection, cleaning, storage and germination of 103 plant taxa from the Pilbara region in Australia's arid northwest, an area rich in flora. The authors, from Kings Park and Botanic Garden and the University of Western Australia, are involved in large scale ecological restoration in the area, following mining activities (find out more about this work on page 20). This book is a useful resource for practitioners working in the region, and provides a good model of a resource that could be replicated to support ecological restoration in other areas. The book is available as a paperback and e-book: http://www.publish.csiro.au/pid/7527.htm



*Participants at the ERA second public symposium (Hideyuki Narita)*

## Restoring degraded ecosystems: Regional and international perspectives: Presentations from the public symposium of the Ecological Restoration Alliance of Botanic Gardens, Amman, Jordan, 30th March 2015

The ERA held its second public symposium in Amman, Jordan in Spring of 2015, in collaboration with the Royal Botanic Gardens Jordan. All presentations from this symposium were recorded and can be viewed online here: http://royalbotanicgarden.org/http://royalbotanicgarden.org/



## UK Germination Toolbox

This online database developed by the Royal Botanic Gardens, Kew provides seed germination conditions for UK native species. It is intended to support practitioners propagating UK native species from seed and is also a useful resource for researchers seeking seed trait data. The toolkit can be accessed online: http://www.kew.org/science-conservation/research-data/resources/uk-germination-toolbox

## Restoring Tropical Forests: A practical guide

Elliot, S., Blakesley, D. and Hardwick, K. 2013.
ISBN 9781842464427

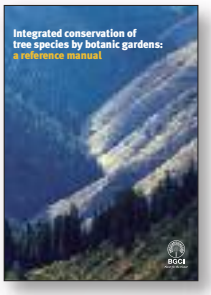
This user-friendly and globally relevant practical guide to restoring forests throughout the tropics draws information from research undertaken at Chiang Mai University's Forest Restoration Research Unit (FORRU). The book covers the general concepts of tropical forest dynamics and regeneration that are relevant to the practice of tropical forest restoration, proven restoration techniques and case studies of their successful application, and research methods to adapt these techniques to local ecological and socio-economic situations. Available to purchase in English, French and Spanish as paperback from Kew Books: http://shop.kew.org/restoring-tropical-forests-a-practical-guide Or full pdf available to download here: https://www.dropbox.com/sh/21pm92tr3ctyh80/e8T7_TNTcN

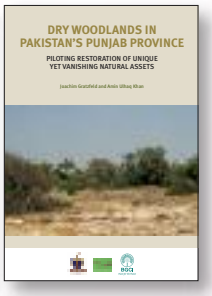
## Genetic considerations in ecosystem restoration using native tree species. State of the World's Forest Genetic Resources - Thematic study

Bozzano, M., Jalonen, R., Thomas, E., Boshier, D., Gallo, L., Cavers, S., Bordács, S., Smith, P. & Loo, J., eds. 2014. FAO and Bioversity International, Rome. 2014
ISBN 978-92-5-108469-4 (print) E-ISBN 978-92-5-108470-0 (PDF)

There is renewed interest in the use of native tree species in ecosystem restoration for their biodiversity benefits. Consideration of genetic aspects is often neglected, such as suitability of germplasm to the site, quality and quantity of the genetic pool used and regeneration potential. This study provides fundamental information for the achievement of knowledge-based ecosystem restoration using native tree species. The study includes a review and synthesis of experience and results; an analysis of successes and failures in various systems; and definitions of best practice, including genetic aspects. A copy of the report can be downloaded at: http://www.fao.org/3/a-i3938e.pd

## BGCI resources to support restoration:




- **Integrated conservation of tree species by botanic gardens: A reference manual**
  Available in English and Spanish (www.bgci.org/resources/2069/)

- **Dry Woodlands in Pakistan's Punjab Province Piloting Restoration of Unique Yet Vanishing Natural Assets** (www.bgci.org/where-we-work/pakistan/)

- Look out for our Species Recovery Handbook! To be published by BGCI in early 2017.

## Ecological Restoration photo library

Conservation photographer, Barney Wilczak, has been documenting the work of the Ecological Restoration Alliance of Botanic Gardens (ERA). He has developed a portfolio of photographs which can be made available to BGCI members on request for use in fundraising and promotion of ecological restoration. See a selection of Barney's ERA photos on pages 12-13 and more of Barney's photos can be viewed on his website: http://wilczakphotography.photoshelter.com/


## Journal articles from the Ecological Restoration Alliance of Botanic Gardens

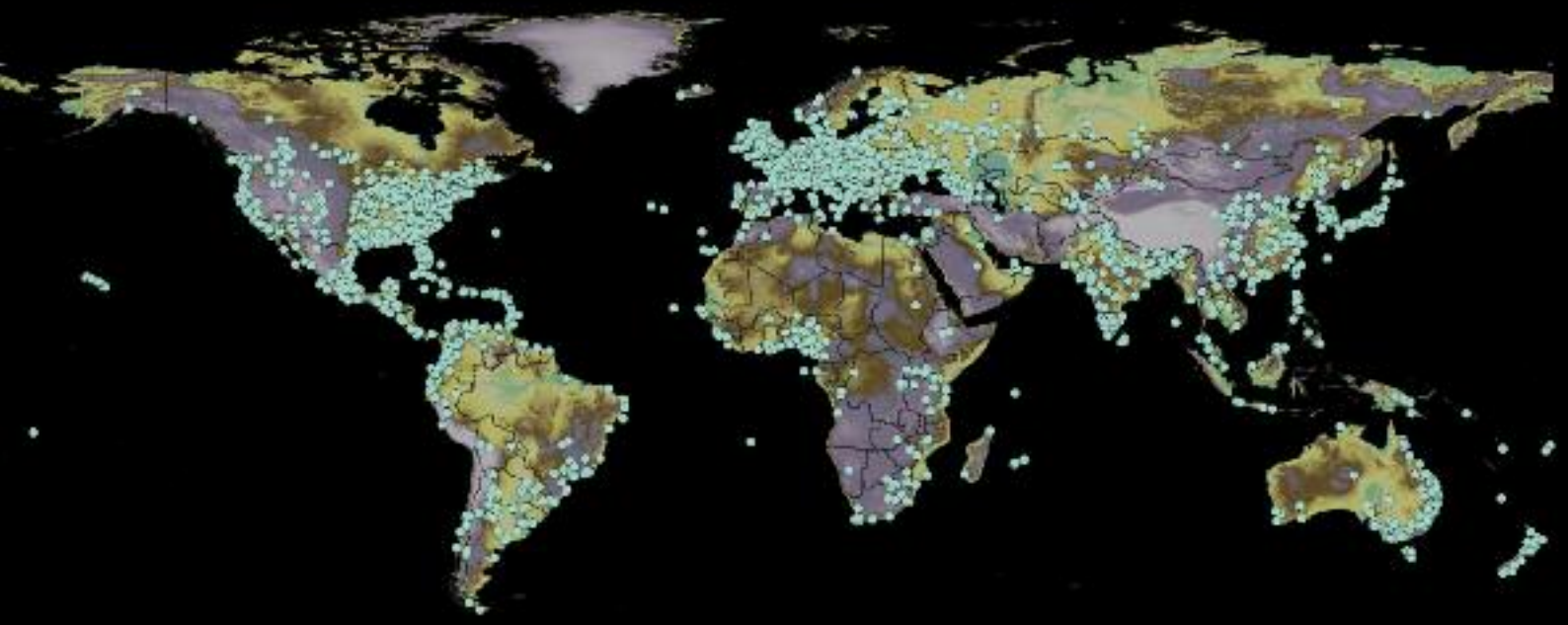
Hardwick, K., *et al*. 2011. The Role of Botanic Gardens in the Science and Practice of Ecological Restoration. *Conservation Biology* **25**(2): 265 - 275

Aronson, J. and on Behalf of the Ecological Restoration Alliance of Botanic Gardens. 2014. The Ecological Restoration Alliance of Botanic Gardens: A New Initiative Takes Root. *Restoration Ecology.* **22**(6): 713 - 715

Shaw, K., *et al*. 2015. Encouraging and Enabling a Science-Based Approach to Ecological Restoration: an Introduction to the Work of the Ecological Restoration Alliance of Botanic Gardens (ERA). *Sibbaldia*. **13**: 145 - 152

Abu Taleb, T., Aronson, J., Shaw, K. and on Behalf of the Ecological Restoration Alliance of Botanic Gardens. (2016). Rays of Hope from the Ecological Restoration Alliance of Botanic Gardens, following its recent meeting in Amman, Jordan. *Restoration Ecology*. Preview available online: http://onlinelibrary.wiley.com/doi/10.1111/rec.12380/abstract

# JOIN THE WORLD'S LARGEST PLANT CONSERVATION NETWORK



For 30 years Botanic Gardens Conservation International has represented the botanic garden and arboretum community.

**BGCI's directory of botanic gardens, GardenSearch, lists 2,500 botanic gardens that conserve a third of known plant diversity and attract 500 million visitors a year.**

**BGCI is a leadership and catalyst organisation that works to promote botanic gardens as a professional community, share knowledge and skills and mobilise funding for plant conservation.**

## Membership benefits include

- BGCI's publications, including our journals, BGjournal and Roots
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- Major discounts on registration fees for BGCI Congresses
- Access to advanced collections data analysis services
- Eligibility for BGCI project funding
- Eligibility for subsidized BGCI training courses
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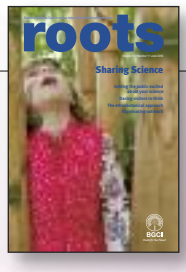


- Eligibility for BGCI twinning/ mentoring scheme
- Eligibility for BGCI prizes and awards
- Use of the BGCI website to promote your events and news
- Use of BGCI's logo and name
- A membership pack, including a Certificate of membership

# MARSH AWARDS FOR INTERNATIONAL PLANT CONSERVATION AND EDUCATION IN BOTANIC GARDENS

BGCI is pleased to announce a call for nominations for the Marsh Awards for International Plant Conservation and Botanic Garden Education sponsored by the Marsh Christian Trust.

*Nursery with seedlings for reforestation of the Atlantic Forest, in Rosario do Limeira, Brazil (Alf Ribeiro / Shutterstock.com).*

The Marsh Christian Trust was established in 1981 and runs a portfolio of awards which recognise the contribution of dedicated individuals working in different sectors – to improve the world we live in.

### Marsh Award for International Plant Conservation

We aim to give the Marsh Award for International Plant Conservation to an early/mid- career individual who has made an outstanding contribution to the implementation of the Global Strategy for Plant Conservation (GSPC) of the Convention on Biological Diversity (CBD). The prize for this Award in 2016 is £1,000.

### Marsh Award for Education in Botanic Gardens

We aim to give the Marsh Award for Education in Botanic Gardens to an early/mid-career individual who has made an outstanding contribution to promoting public awareness of the importance of plants and/or undertaking impactful education activities within a botanic garden. The prize for this Award in 2016 is £1,000.

### How to make a nomination

If you know of somebody who you think merits one of the awards above, please nominate that person using the forms available on the BGCI website:
**www.bgci.org/news-and-events/news/1346/**

The deadline for nominations is 2nd September, 2016. Nominations should be sent to **liz.smith@bgci.org**

*Note that self-nominations are not eligible.*

### How will the award be judged?

Nominations will be judged by a panel comprising two BGCI Board members; and one representative from each of five external organisations, including the Marsh Christian Trust. A shortlist of three will be sent to Brian Marsh and the Trust for the final selection.

Bian Tan

Bian Tan

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26th - 30th June 2017

# 6th Global Botanic Gardens Congress

*Les Jardins botaniques dans la société : Visions pour l'avenir*

*Botanic Gardens in Society : Visions for the Future*

**Hosted by the Conservatory and Botanical Garden of the City of Geneva, Switzerland, at the International Conference Centre of Geneva (CICG).**

The scientific programme will explore the role and relevance of botanic gardens in today's society. The congress, a forum for the exchange of ideas on future opportunities as well as potential challenges faced by botanic gardens, aims to explore creative and innovative ways to engage botanic gardens and their expertise with and for society. The main themes of Science and society, Plant conservation, Education and outreach, Capacity building and Management challenges for botanic gardens in the future, will be complemented by workshops or discussion sessions on specific topics.

**Information on the congress programme and registration: www.6gbgc.org**

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