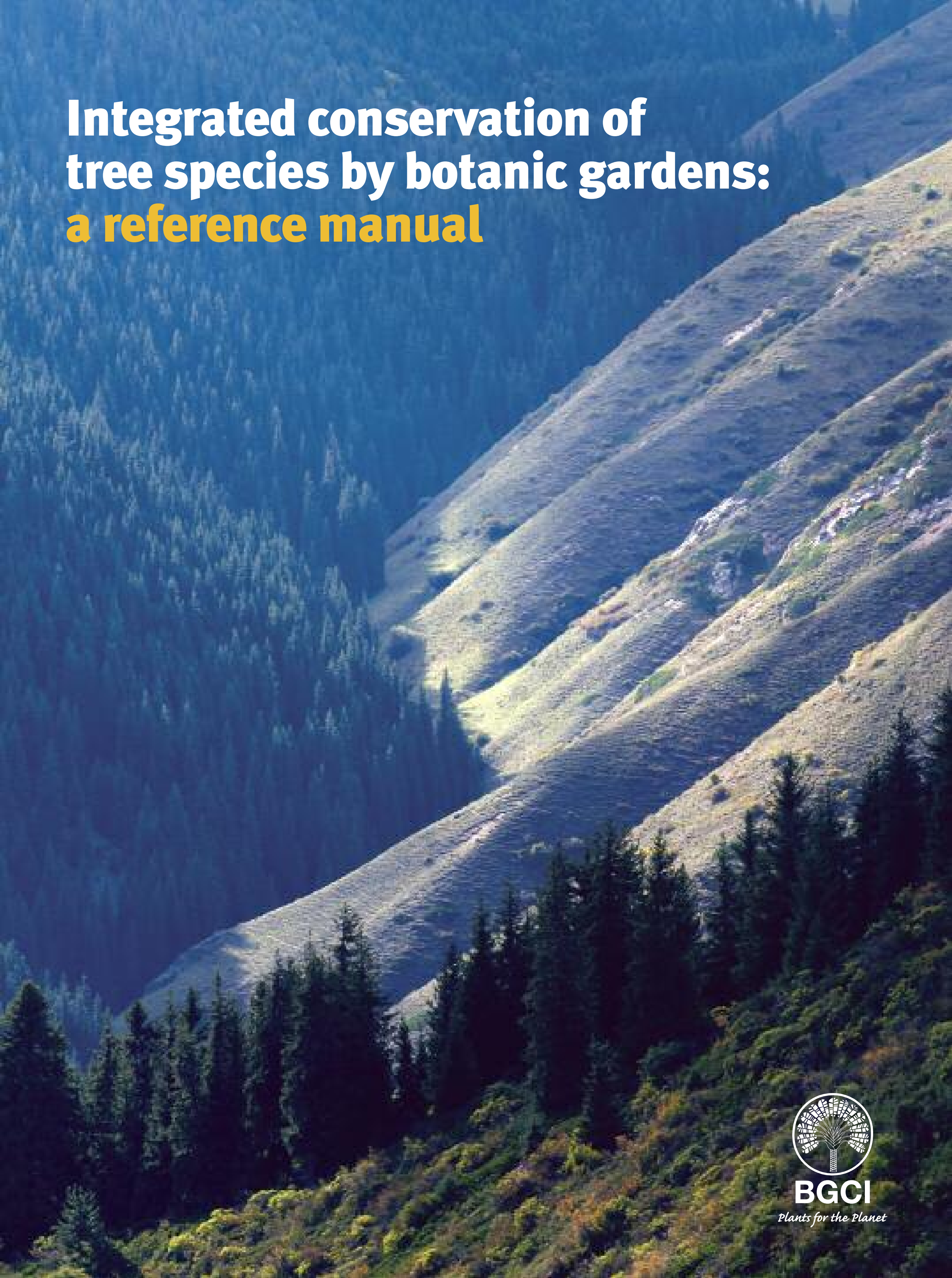
Integrated conservation of tree species by botanic gardens: a reference manual



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Integrated conservation of tree species by botanic gardens: a reference manual

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Foreword

This manual focuses our attention on tree conservation, and is designed to guide and stimulate action to save threatened trees from extinction. Trees do not often receive special focus for conservation, yet they are enormously important and under threat worldwide. As many as one in ten tree species is endangered, threatened, or vulnerable.

Trees provide the structure for natural ecosystems where they grow and habitat for myriad other living things. They influence growing conditions, biogeochemical cycles, and light and water regimes, and sequester carbon that is of principal influence in planetary climate trends.

Trees are also valuable for human use: timber, fiber, food, fuel, and medicine. Because of this, they tend to be harvested and often over utilized – threatening the very source of these values. Forest clearing for agriculture and development also threatens tree and forest biodiversity. And because of their long lifespans, and often-constrained reproductive and dispersal capabilities, trees are more susceptible to the effects of rapid climate change.

For those of us associated with arboreta and botanical gardens, we are in a position to address the challenge of saving the world's threatened tree species. We need to do more than just include them in the plant collections of our gardens. Effective tree conservation may require a finessed combination of different kinds of *ex situ* and *in situ* actions, ecological restoration and plant reintroduction, and socio-economic and regulatory considerations to truly secure them from threat.

With this book, Sara Oldfield and Adrian Newton bring together pertinent thinking about plant conservation and apply it to the special considerations associated with tree conservation. They present step-by-step guidelines that can be used in launching conservation work with trees.

The series of case studies the authors present provide a range of perspectives on tree conservation, including population diversity assessments, propagation techniques, *ex situ* and *in situ* approaches, and integration with planning, policy, monitoring, education, and sustainable use. As inspiring as they are, the case studies also paint a picture of how much more there is to do.

This book provides a valuable framework for integrated approaches to tree conservation. The need is great, and the opportunities to make meaningful contributions to both conservation and our collective knowledge are many. The authors and I hope this manual will spark your attention and stimulate you to act to save the world's trees.

Gerard T. Donnelly, Ph.D.
President and CEO
The Morton Arboretum

(Kemal Jufri)

1. Introduction

This reference manual has been developed to support the integrated conservation of threatened tree species by botanic gardens and arboreta (referred to collectively as botanic gardens within the manual). It is aimed at the staff and associates of the world's botanic gardens, and is designed to help the development, planning and implementation of conservation activities focusing on tree species. Botanic gardens are exceptionally well placed to make an important contribution in this area, as they have access to the skills and techniques to identify, cultivate and propagate a wide range of trees. In addition, they hold important collections of living trees, seeds and other germplasm that can be of value in supporting both *in situ* and *ex situ* conservation efforts.

Many botanic gardens are increasingly becoming involved in conservation activities that integrate *in situ* and *ex situ* approaches to tree conservation, which are typically undertaken in partnership with other organisations, such as national park agencies, forest services, non-government organisations (NGOs) and local communities. Case studies of such initiatives are highlighted in this manual, to demonstrate how botanic gardens can provide leadership in this area, leading to highly successful outcomes for both plants and people. Tree conservation is not without its challenges, however, and therefore a further objective of this manual is to help identify potential problems and pitfalls, and how these may be overcome in practice.

There is an urgent need to conserve tree species. Around 7,800 tree species are currently recorded as threatened with extinction at the global scale (Oldfield *et al*., 1998; Newton and Oldfield, 2008). However, information is lacking on the status and distribution of many suspected rare species of trees, and the true figure is likely to be much higher. Trees are of exceptional ecological importance, providing habitat for a wide range of other organisms. Many of these trees also benefit people, and are associated with social, economic or cultural values. Consequently, their continued decline or loss can have a major impact on human wellbeing.

This manual builds on *A handbook for botanic gardens on the reintroduction of plants to the wild* published by BGCI in 1995 (Akeroyd and Wyse Jackson, 1995) and reflects the increasing imperative to restore and conserve damaged ecosystems. It draws on both the scientific literature and on practical experiences gained in tree conservation projects from around the world. We are grateful to a wide range of experts who contributed their knowledge and experiences, as acknowledged on p 01. The following sections first briefly consider why tree species should be conserved and restored, and how integrated approaches to conservation can be developed. A step-by-step guide is then provided to support the design and practical implementation of integrated conservation approaches. While this manual can only serve as a brief introduction to what is a large and complex subject, it is hoped that it will both facilitate and encourage botanic gardens and land management agencies to develop integrated conservation activities focusing on tree species.

Sophora toromiro. *(Magnus Lidén)*

2. Why conserve and restore tree species?

2.1 Importance of tree species

Trees are of exceptionally high ecological, socio-economic and cultural importance. As the principal biomass component of forest ecosystems, they provide habitat for at least half of Earth's terrestrial biodiversity (Millennium Ecosystem Assessment, 2005), supporting 80% of amphibian, 75% of bird and 68% of mammal species (Vié *et al*., 2009). Forest ecosystems play a major role in the Earth's biogeochemical processes, and contain about 50% of the world's terrestrial carbon stocks (FAO, 2010; Millennium Ecosystem Assessment, 2005), highlighting their importance for moderating human induced climate change. Trees and forest ecosystems provide a wide range of benefits to people including production of timber, fuelwood and fibre, and ecosystem services such as clean water, flood protection and prevention of soil erosion from watersheds, as well as being of high cultural and spiritual value (Millennium Ecosystem Assessment, 2005; UNEP, 2009). The total value of such services has been estimated at US$4.7 trillion per year (Costanza *et al*., 1997). Some 1.6 billion people depend directly on trees for their livelihoods (World Bank, 2004), and forest industries contribute around $468 billion annually to the global economy (FAO, 2011). Recent research has confirmed that high plant diversity is needed to maintain provision of many ecosystem services (Isbell *et al*., 2011).

2.2 The need for action

The widespread loss and degradation of native forests is now recognised as a global environmental crisis. From 2000-2005, global forest area declined by around 20 million ha/yr (Hansen *et al*., 2010), with undisturbed primary forest declining by an estimated 4.2 million hectares (or 0.4%) annually (FAO, 2010).
The loss and degradation of forest ecosystems resulting from human activity are major causes of global biodiversity loss (UNEP, 2009; Vié *et al*., 2009). Clearance of forest for agriculture, mining, urban and industrial development all contribute to the loss of forests and tree species in the wild. Management activities within forests, including burning, logging and overgrazing also impact on forest structure, functions and processes and can additionally contribute to the loss of tree species. Climate change is an additional over-arching threat, which may particularly affect species with limited distributions and those with poor regeneration and dispersal mechanisms. Climate change could also potentially interact with other threats, increasing the risk of drought and fire, as suggested for example in the Amazon (Nepstad *et al*., 2008).

Araucaria *in Conquillo National park, Chile (P. Hollingsworth, RBG Edinburgh)*

The conservation status of the world's tree species is poorly understood. It is striking that many countries do not yet possess a complete list of tree species occurring within their borders, let alone assessments of their extinction risk. There are as many as 400,000 plant species worldwide (Govaerts, 2001), and trees make up approximately 25% of this total, although the total number of tree species that exists is not known with any precision (Oldfield *et al*., 1998). An initial assessment of tree species involving around 300 experts was conducted in 1998, which evaluated 14,000 taxa of which 7,886 were found to be globally threatened with extinction (Oldfield *et al*., 1998). While subsequent assessments have continued to increase this total, many species have not yet been assessed (Newton and Oldfield, 2008). In addition, many species that are not currently threatened have experienced major declines in abundance, including many that have been exploited for timber and other forest products. This highlights the widespread need for conservation action focusing on tree species.

Case study 1: *Prunus africana (African cherry)*

Prunus africana is native to high-altitude, montane habitats of tropical Africa. Commonly known as African cherry, Red stinkwood or by its former scientific name *Pygeum africanum*, this multiple-use, evergreen hardwood tree has significant economic and medicinal value both for local communities and internationally. A combination of complex and inter-related economic, social and ecological factors contributed to the mounting pressure on African cherry populations in the last decades of the 20th century. As a result, the species was listed in Appendix II of CITES in 1995, regulating the trade of *P. africana* products, and has been included in the IUCN Red List of Threatened Species as "Vulnerable" since 1998. Subsequently, a shift has been observed from an exclusively wild harvest of the species towards increasing cultivation and domestication, complemented by integrated conservation and development projects.

African cherry has been highly valued for many generations across Africa for its durable and strong timber, the medicinal properties of its bark and leaves, and as fuel-wood. The traditional beliefs and associated taboos of local people, for example in Cameroon, protected and controlled the use of these trees in sacred forests. Sustainable harvesting techniques limited the extent of bark removal and preserved the vascular cambium, so that the tree could regenerate its bark.

Large-scale commercial exploitation of *P. africana* began with the patenting of the bark extract in 1972 as a treatment for benign prostatic hyperplasia. The tree became an important source of income for highland forest communities, especially in the main exporting countries of Cameroon, Madagascar, Kenya, and Equatorial Guinea, with an estimated output of 3,500 tonnes per annum. However, growing international demand (mainly from Europe and the USA) for the raw material and the economic hardship of many local communities led to overharvesting.

Although guidelines, regulations and management plans for sustainable harvest exist to varying degrees in exporting countries, the scattered distribution of African cherry and lack of resources in the range countries make monitoring and community control difficult. The low prices paid to harvesters encourage unrestrained and destructive collection in return for short-term financial gain and stifle the development of more expensive alternatives. Inappropriate or illegal practices - such as excessive or complete girdling, felling, or harvesting immature trees - by unskilled or careless workers causes the destruction of trees and a serious decline in wild populations of *P. africana*. The removal of mature trees also causes reduced seed production and poor recruitment, resulting in a lack of saplings and young trees. The habitat of the African cherry has also been affected by deforestation and the establishment of exotic tree plantations, which resulted in fragmented and genetically isolated populations and competition from invasive alien species, respectively.

In the face of such complex threats to wild populations of *P. africana*, the conservation strategies are similarly wide-ranging, with a focus on both ecological and economic factors. Sustainable wild harvest seems feasible only within a robust and enforceable regulatory framework, underpinned by deterrent sanctions and strong community support. Wild harvest can be seen as an interim phase until a complete transition into agroforestry or plantation production, which could reduce the pressure on natural resources.

Recent projects concentrate on the domestication and small-scale cultivation of *P. africana* (e.g. in Buea, Cameroon and in Tanzanian homegardens), as well as larger scale planting programmes (e.g. the reforestation in Lebialem Highlands, Cameroon). These schemes utilise the fast growth rate of the plant and its suitability for steep sites and take into account the considerable genetic diversity amongst and within plant populations. One of the advantages of cultivation is that the genotype of plants grown for pharmaceutical production can be controlled according to demand. For example, a reforestation and trade programme in Uganda utilised the discovery that trees in the local national parks have the highest concentration of the active pharmaceutical ingredient in the country, and a nursery of superior genotypes was established to supply the farmers with the required planting stock. The Nile Basin Reforestation Project in Uganda - involving other African trees along with *P. africana* and launched in 2009 in association with local community organisations - aims to generate 700 local jobs and will count towards emission reductions under the Kyoto Protocol.

The most significant constraints on conservation, cultivation and reforestation of *P. africana* are limited seed availability owing to the late maturity of the plants (approximately 15 years), fluctuating yields and the intermediate/recalcitrant nature of the seeds. Tissue culture techniques offer a viable solution for rapid multiplication of selected African cherry germplasm for cultivation purposes, helping to preserve valuable genetic resources, prevent the destructive sampling of wild populations and assist in and *ex situ* conservation.

Source: Prepared by Ildiko Whitton with reference to Cunningham (2005) and UNFCCC (2009)

Prunus africana *growing in Tooro Botanical Garden. (BGCI)*

Above: Flower of Dipterocarpus sarawakensis, *a species that is Critically Endangered in Peninsular Malaysia. (Wong, W.S.Y.)*

Left: Fruit of Dipterocarpus sarawakensis. *(Wong, W.S.Y.)*

Case study 2:

Restoring dipterocarp forests – constraints in the utilisation of endangered species

Trees of the Dipterocarpaceae family dominate large areas of forest in Southeast Asia and account for 80 percent of timber exports from the region. Many dipterocarp species are threatened with extinction as a result of general deforestation and logging pressures. In general the species have a low density of reproductive adults, depend on insects for pollination, have poor seed dispersal and recalcitrant seeds. It has been suggested that restoration of dipterocarp forest is likely to be via two pathways: enrichment planting, planting seedlings of selected species in degraded forest or complete forest restoration by establishing a nurse canopy of fast-growing light-demanding species followed by under-planting with dipterocarps. Enrichment planting is likely to be the most cost-effective but less beneficial in terms of ecological functioning and local livelihoods. Incorporation of endangered species of dipterocarps should be considered in any restoration efforts. Technical knowledge to propagate dipterocarps on a relatively large scale exists but dipterocarp reproductive ecology presents challenges. Seed production is unpredictable with mast-fruiting. The sheer size of the trees can make seed collecting difficult. Seeds need to be collected as quickly as possible, protected from fungal infection, overheating, physiological breakdown and then germinated as soon as possible. An alternative approach is to collect wildlings (wild seedlings) from the forest floor. Care should be taken not to over-collect wildlings as this will impair natural regeration. Enrichment planting in Indonesia typically uses plants propagated from stem cuttings from wildlings. Ideally seed should be used in propagation of dipterocarps for forest restoration but in logged forest the seed production can be very low. Identification of species is a key problem. Incorporation of endangered species is likely to be dependent on both the taxonomic expertise and supply of seeds or cuttings from botanic gardens and arboreta. Currently 264 species out of a total of around 500 dipterocarp species are recorded in botanic garden collections based on the BGCI PlantSearch Database. Of these species in cultivation, 175 are recorded as globally threatened with extinction according to the IUCN Red List.

Source: Kettle, 2010

Dipterocarpus sarawakensis. *(Wong, W.S.Y.)*

2.3 Policy context

The need for action to reduce the rate of biodiversity loss, the degradation of ecosystems and their associated goods and ecosystem services, has been recognized by a number of policy initiatives. At the global scale, the most important of these is the Convention on Biological Diversity (CBD), which provides a broad framework for the conservation of all components of biodiversity. The CBD delivers its objectives through Programmes of Work. The conservation of tree species is integral to various Programmes including the Forestry Programme, Protected Area Programme and Sustainable Use Programme. It is particularly relevant to the cross-cutting Global Strategy for Plant Conservation (GSPC). The CBD's Strategic Plan for Biodiversity agreed at the Tenth Meeting of the Conference of the Parties (COP10) in Nagoya, Japan in 2010 provides a new global framework on action for biodiversity, not only for the biodiversity-related conventions, but for the entire United Nations system. The Strategic Plan includes a range of targets for the period 2011 - 2020. These include:

- **Target 15:** By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15% of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification.

The GSPC, first adopted in 2002, was revised in 2010 with plant conservation targets in line with the Strategic Plan for Biodiversity. All targets of the GSPC are relevant to the conservation of tree species. Targets specifically relating to *ex situ* conservation, *in situ* conservation and restoration of tree species are:

- **Target 4:** At least 15 per cent of each ecological region or vegetation type secured through effective management and/or restoration.

- **Target 7:** At least 75 per cent of known threatened plant species conserved *in situ*.

- **Target 8:** At least 75 per cent of threatened plant species in *ex situ* collections, preferably in the country of origin, and at least 20 per cent available for recovery and restoration programmes.

This provides a clear policy context for linking the recovery and restoration of natural populations of plant species with *ex situ* collections, which is the focus of this manual.

Other global policy initiatives relevant to forests and tree species include:

- **The United Nations Framework Convention on Climate Change (UNFCCC)**. This is an international treaty adopted by 193 Parties in 1992 in an attempt to reduce global climate change. Forest restoration, reforestation and afforestation are recognised as valuable approaches for climate change mitigation, through the capture and storage of carbon by trees. Such approaches could potentially be supported by the developing market for carbon. Regulated or compliance carbon markets, governed by rules in the Kyoto Protocol of the UNFCCC, include Clean Development Mechanism (CDM) projects of which a number are forestry related. In addition there are voluntary carbon markets that are unregulated, but which have voluntary project standards, such as the Climate, Community and Biodiversity Project Design Standard (CCB) and Voluntary Carbon Standard (VCS). These have been applied to a wide range of conservation and forestry schemes, many of which are operated by NGOs.

- **The United Nations Convention to Combat Desertification (UNCCD)**. Combating desertification (i.e. the degradation of land in arid, semi-arid and dry sub-humid areas) is essential to ensure long term productivity of drylands and the biodiversity that they support. The UNCCD was adopted in 1994 and aims to promote effective action through innovative local programmes and supportive international partnerships.

- **The Convention on International Trade in Endangered Species of Wild Fauna & Flora (CITES)**. This Convention provides an international legal framework for the regulation of trade in those plant and animal species that are exploited commercially for international trade. The treaty operates through the issue and control of export and import permits for species, and their products, listed in three Appendices. CITES certifies sustainable trade in species, listed in Appendix II, that can withstand current rates of exploitation, but prevents trade in those, listed in Appendix I, that face extinction. At present over 20 tree species are listed on the Appendices of CITES, including species for which case studies are included in this manual, such as *Fitzroya cupressoides* and *Prunus africana*. For Appendix II species, monitoring of the levels of export is required so that the species is maintained throughout its range at a level consistent with its role in the ecosystems in which it occurs. Synergies between CITES and CBD are promoted in various ways at national and international scales, including directly through targets of the GSPC.

In the context of mitigation of climate change, a promising mechanism for funding forest restoration is "REDD" (Reducing Emissions from Deforestation and forest Degradation), which aims to offer incentives for developing countries to invest in low-carbon approaches to sustainable development (Bullock *et al*., 2011). Developed within the UNFCCC, and led by the Coalition for Rainforest Nations (http://www.rainforest coalition.org/), the original focus of REDD was to reduce emissions from deforestation and forest degradation. However, its focus has been expanded (as REDD+) recently to include 'enhancement of forest carbon stocks', which provides opportunities for supporting forest restoration efforts. REDD+ activities are being supported by national and local governments, NGOs and the private sector, with support from a number of development agencies and research institutes. International initiatives in support of REDD and REDD+ include the World Bank's Forest Carbon Partnership Facility (http://www.forestcarbonpartnership.org/fcp/) and the UN-REDD Programme (http://www.un-redd.org/). Revenues may be generated from the global market in carbon, which had reached US$125 billion by 2008; funding for REDD itself has already exceeded $6 billion (Stickler *et al*., 2009). The mechanism has been criticized, however, for its focus on the single ecosystem service of carbon; there is a possibility that other services and social issues could be adversely affected (Bullock *et al*., 2011; Stickler *et al*., 2009). Potential negative social impacts include loss of livelihoods or access to lands undergoing reforestation, a risk that is particularly high in areas where land tenure is insecure. This highlights the need for an appropriate institutional and regulatory environment to support restoration activities, and to ensure equitable delivery of benefits at the local scale (Bullock *et al*., 2011). Current and potential roles of botanic gardens in relation to the REDD+ process are set out in Probert *et al*. (2011).

In addition to such international policy initiatives, the CBD also requires individual countries to develop National Biodiversity Strategies and Action Plans (NBSAP). By October 2010, 171 of the 193 Parties to the CBD had developed NBSAPs. These are being re-aligned with the GSPC Targets and the overall 2020 biodiversity targets. Requirements for species conservation are included in the National Plans that provide a strong policy basis for tree restoration. Many additional countries have also developed additional policies or legislation promoting species protection and recovery, which may also relate to tree species.

Magnolia silvioi *seedling in the wild. (A. Cogollo)*

3. Conservation approaches

3.1 *In situ* conservation

It is generally recognized that the most effective way to ensure the long-term survival and evolution of tree species, and the ecological communities of which they are a part, is to maintain viable populations in their native environment (Kramer *et al*., 2011). This is referred to as *in situ* conservation. Typically this is achieved through the designation and management of some form of protected area, such as national parks, wilderness areas and nature reserves (Newton, 2007). The extent of the global network of protected areas continues to increase, with nearly 133,000 areas now designated, representing 12% of the Earth's terrestrial surface (Butchart *et al*., 2010). Parties to the CBD recently committed themselves to raise this figure to 17% by 2020. Despite the substantial efforts being made to support the development and management of protected areas, many are currently under threat from human activities such as urban encroachment, infrastructural development, habitat conversion, illegal harvesting and fire (Chape *et al*., 2005). Additional problems include policy-related issues such as weak government institutions, conflicting policies and resource tenure (Brandon *et al*., 1998). Because of such problems, and the fact the coverage of protected area networks is not complete, additional conservation approaches are also required.

3.2 Ecological restoration and reintroduction

The widespread environmental degradation that has occurred as a result of human activities has led to a growing interest in ecological restoration. This may be defined as the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed (Bullock *et al*., 2011). Ecological restoration has grown rapidly over the past few decades, both in terms of a scientific discipline and in terms of environmental management practice (Nellemann and Corcoran, 2010). Billions of dollars are now being invested in restoration actions throughout the world (Goldstein *et al*., 2008), supported by international policy commitments such as the CBD. Many environmental organisations and community groups are actively engaged in ecological restoration projects, but increasingly restoration actions are also being undertaken by other organisations, including governments and large companies.

A number of related terms are widely used. *Rehabilitation* emphasizes ecosystem recovery, without including the re-establishment of some pre-existing state as a management goal. *Reclamation* generally refers to the environmental improvement of mined lands, and may incorporate soil stabilization and aesthetic improvement (Newton, 2007). In this case there may be less emphasis on restoring the original biodiversity present at a degraded site, and greater emphasis on restoring productivity. *Afforestation* and *reforestation* refer to the establishment of trees on a site, in the former case where no trees existed before, and in the latter case following deforestation (Mansourian, 2005).

It is also helpful to differentiate approaches involving the restoration of entire ecosystems or ecological communities, from those that focus on individual species. For example, conservation actions might focus on restoring populations of an individual tree species that had been depleted by timber harvesting. This could be achieved by artificial establishment of individuals of the tree species concerned, for example by *enrichment planting*, using planting stock derived from an *ex situ* population. If a species has been extirpated from its original habitat, it may be a candidate for *reintroduction*, which aims to re-establish new, self-sustaining populations of a species in the locations where it occurred previously. In recent years, reintroduction has increasingly been used as a plant conservation tool (Falk *et al*., 1996). For example, one-fourth of the plant species listed by the U.S. Endangered Species Act include reintroduction as a component of their recovery plan (Kramer *et al*., 2011). To be successful, reintroductions are dependent on the availability of appropriate material either from other nearby adapted populations or from suitable *ex situ* populations. Integrated conservation approaches will therefore generally involve an element of reintroduction of an individual species, as described in this manual. However, such reintroduction might form part of a broader effort to restore an entire ecosystem, as also explored further below.

Case study 3:
Restoring native trees in the Kenyan Highlands

Brackenhurst Botanic Garden is situated 25 km north of Nairobi. There is a conference facility at the site that hosts corporate, secular, scientific and religious meetings from across Africa. The land includes one side of a valley stretching from a dam and thence downstream for 1.5 km. The other side is Government land. Both sides of the valley were covered with exotic plantations of eucalyptus, cypress and Australian black wattle (*Acacia mearnsii*) typical of the district that has lost over 99% of its native forest to coffee, tea and exotic tree plantations, smallholder agriculture, horticulture and urban expansion. In 2000/2001 efforts began to convert half of Brackenhurst's land (40 ha) from exotic tree plantations to indigenous forest. The vision was to create a forest comprising only indigenous trees, shrubs and lianas from the East African uplands.

Tree planting began in 2001 after clearing five acres of eucalyptus, wattle and cypress. Although the project began as an arboretum, it has developed into a 'natural' forest. This is important as the biodiversity is much higher than in a mown arboretum and has allowed a large variety of understorey and non-climax species to thrive, such as shrubs, lianas, understorey Rubiaceae and Euphorbiaceae, orchids, ferns, and herbaceous species. Concomitant with this has been an increase in avian, small mammal and insect life.

Ten years later there is 20 ha of land under a growing forest of between one and eleven years old, comprising about 300 species of trees, shrubs and lianas. The Garden and Indigenous Forest is a now centre for East African upland plant biodiversity. With over 50 acres, over 80,000 plants propagated from over 1,400 species, the botanic garden is a source of seed and plant material, and a model for indigenous reforestation projects in East Africa. Ecological restoration has resulted in improvements in the avian and insect fauna, in soil fertility, watershed protection and perennial stream flow.

Brackenhurst is of major importance as a model in Kenya where 100,000 ha of the Mau forest (Kenya's major "water tower") has been destroyed over the last 20 years. Efforts are being made to reforest on a large scale but the challenges are similar to those faced by the Brackenhurst reforestation project. In addition, negotiations are underway with tea growers to help replant steep valleys with indigenous forest to prevent heavy siltation of rivers and reservoirs. At present, periodic removal of eucalyptus (four acres of tea requires one acre of gum forest for drying the tea) means that soil erosion is serious because undergrowth below gum trees is minimal owing to the toxic qualities of eucalyptus oils in dead leaves. Replanting native forest near streams will help watershed protection and ensure year-round stream flow.

Brackenhurst garden and indigenous forest now has the largest cultivated *in situ* and *ex situ* plant biodiversity in East Africa. Many species on the IUCN Red List are cultivated and many more species that should be listed. There are over 40 young specimens of the endemic climber *Embelia keniensis* of which only five adult specimens are known to exist in the wild (and not yet on the IUCN Red List).

Source: Mark Nicholson

Tree nursery at Brackenhurst Botanic Garden, Kenya. (BGCI)

3.3 *Ex situ* conservation

Ex situ conservation can be defined as the conservation and maintenance of samples of living organisms outside their natural habitat, in the form of whole plants, seed, pollen, vegetative propagules, tissue or cell cultures. As many plant species are declining in abundance as a result of human activities, and increasing numbers are becoming threatened with extinction, there is an increasing need for *ex situ* conservation approaches. Botanic gardens play a major role in the *ex situ* conservation of plants, but a number of other organisations also maintain *ex situ* plant collections including academic institutions, non-profit organizations, forest services and other government agencies. Such collections can have value for research, horticulture and education, but here the focus is on their potential value for conservation.

The value of *ex situ* collections for conservation depends on three main factors (from Kramer *et al*., 2011):

1) **The type of plant material collected** (including seeds, explants, and living plants), which varies according to each species' reproductive biology, seed characteristics, and/or adaptability to *ex situ* conditions. For species with orthodox seeds (i.e. able to be dried and stored at low temperatures for many years and still remain viable), *ex situ* collections maintained as seed banks provide the greatest direct conservation value at the lowest cost. For species with recalcitrant seeds (i.e. not able to be dried and stored), tissue culture or cryopreservation collections can also provide high direct conservation value but at a higher cost. Living plant collections can also be of conservation value, depending on how they are collected and maintained.

2) **The protocols used for collecting;** in general, well-documented, wild-collected *ex situ* collections that capture as much genetic variation of the species as possible will have the greatest conservation value. Botanic gardens often maintain collections of living plants represented by one or more specimens per species, and from sources that are of wild or non-wild (cultivated or unknown) origin. As only genetically diverse and representative collections are appropriate to directly support *in situ* conservation (e.g. through reintroduction), living collections represented by only a few individuals will often be of limited value. However they can nevertheless be of indirect conservation value, for example through research, horticulture and education. It is also important to note that *ex situ* collection efforts must be conducted carefully to ensure wild populations are not placed at additional risk.

Case study 4:
The dawn redwood – conservation or museum collections?

The Critically Endangered tree species that is most widely represented in living collections is the dawn redwood, *Metasequoia glypterostroboides*, which is recorded in 187 botanic gardens and arboreta according to BGCI's PlantSearch database. The species has been widely propagated and is cultivated in over 60 countries. This attractive tree, the only species in its genus, was first described in 1941 from Hunan Province in China. A few years later the largest population was logged for timber. Seeds were initially sent to the Arnold Arboretum in Boston, USA. The original seed introductions were derived from just three trees, and the genetic base of the species in cultivation in botanic garden collections remains narrow today. In China, wild trees of *Metasequoia glypterostroboides* are scattered in farmed hilly areas with paddy fields and villages, and are also present in at least one Forest Park, where the trees may have been planted before the scientific discovery of the species. A Conservation Committee was formed for the species shortly after its discovery and it has been legally protected in China since 1983. There has been no conservation recovery plan for the species but it has been widely planted within China and is now a common landscape tree.

A study of the genetic composition of wild and artificial populations of *M. glypterostroboides* was carried out by Li *et al*. (2005) in order to guide species recovery. This study showed that the wild populations of this charismatic conifer had a wide range of genetic variation, whereas genetic variation in cultivated populations is restricted. This is thought to be due to seed collection from a few productive and easily accessible maternal trees, reliance on one population for propagules, and the wide extent of vegetative propagation. Li *et al.* (2005) recommend that for *M. glypterostoboides*, special stations should be established to manage wild populations from which to collect propagules for planting at specially designed sites within the natural range. Each wild population should have several *ex situ* genetic reserves and there should not be mixing of propagules from other wild populations. The magnificent dawn redwood trees in botanic gardens around the world are potent symbols for species conservation and are of greater importance for historical and landscape value rather than for species recovery programmes.

Source: Li et al. (2005)

3) **The subsequent maintenance of viable germplasm**, which plays a critical role in determining the ultimate conservation value of an *ex situ* collection. Without proper curatorial management, the conservation value of a collection, or the collection itself, can be entirely lost. Collections with the most direct conservation application are genetically diverse and representative of the species, and must be managed to ensure the material is genetically sound and available for conservation activities over the long-term. Many living collections today do not meet these standards owing primarily to genetic issues such as having too little genetic diversity, being of unknown provenance, or losing genetic diversity via drift or adaptation to cultivation and hybridization. Management of *ex situ* collections should also minimize the risk of loss due to random events or natural disasters (such as staff changeover, theft, fire, disease, or other catastrophic loss) by ensuring that collections are maintained at more than one site. Additionally, curatorial oversight of living collections through time is crucial to maintaining associations between collection data (e.g. provenance) and specimens.

3.4 Integrated conservation approaches

In recent years, increasing emphasis has been placed on integrated conservation approaches, in which *in-* and *ex situ* approaches are combined, often together with reintroduction and ecological restoration. The traditional idea that the role of botanic gardens was to hold cultivated stocks of threatened species during a period of habitat degradation, in what has been described as the "ark paradigm," is no longer believed to be sufficient (Havens *et al*., 2006). Rather, for botanic gardens to be

Case study 5:
Repatriation of Rhododendrons

The Royal Botanic Gardens, Edinburgh has extensive experience in the taxonomy, propagation and cultivation of Rhododendrons. Knowledge sharing and exchange of material has contributed to the development of this specialist expertise. In recent years the Garden has been involved in the repatriation of Rhododendrons returning plant material to the country of origin for re-establishment in botanic gardens and/or in the wild.
In 1994 a project to repatriate *Rhododendron* spp. to Sichuan, China was initiated. Plants were raised vegetatively, mostly by semi-ripe wood cuttings grown in an open medium to accommodate washing for phytosanitary reasons. In preparation for transit to China, the roots were placed in a water-soaked inert media of vermiculite; plants were sealed individually in polythene bags, packed in cardboard boxes with polystyrene to insulate against temperature fluctuations. Repatriation to Hua Xi Sub Alpine Botanic Garden was carried out in the autumn to avoid stressing plants during the high early summer temperatures sometimes experienced in the region. On arrival the plants were immersed in water for several hours. They were planted in raised nursery beds in soil with similar properties to the media in which they had been grown in Edinburgh. Of the 230 plants, representing almost 100 species, more than 80 percent established successfully. The main causes of death were physiological disorders arising from transplant stress, drying out, pathogen attack and theft. Concurrent with the repatriation programme and aided by training from Royal Botanic Garden, Edinburgh, species stabilisation work for *Rhododendron davidii* and *R.calophytum* endemics of Long Xi Reserve were undertaken by Hua Xi staff. A second repatriation exercise took place in 2005 in association with BGCI. Fourteen *Rhododendron* spp. originally collected from Indonesia were repatriated to the Cibodas Botanic Gardens from Royal Botanic Gardens, Edinburgh. Training was provided by experts from Edinburgh covering topics such as identification and taxonomy; field collection techniques, propagation and collection data management.

Demonstrating Rhododendron propagation at Cibodas Botanic Garden. (BGCI)

Source: Paterson (2003) and BGCI project report

Rhododendron forest in Guizhou, China. (Zhang Lehua)

effective with respect to conservation, the species banking approach must be integrated with other conservation approaches focusing on habitats and ecosystems (Havens *et al*., 2006).

The concept of integrated conservation of plant species is described by Falk (1987), who notes the need for multiple conservation approaches to be employed. Given the variety and complexity of threats to biodiversity, a single approach, such as legal protection for a species or the acquisition of land, is unlikely to be successful. According to Falk (1987), integrated conservation is based on the assessment and synthesis of three sets of information:

(i) determination of the biological entity of concern, including definition of the target level of biological organization (such as species, sub-species, variety or race);

(ii) identification of the threats to this entity; and

(iii) consideration of the full range of conservation resources that may be brought to bear on the problem.

Integrated conservation approaches deliberately seek a broad base of information about a conservation problem and employ a wide range of complementary tools to accomplish a given objective (Falk, 1987). Such approaches are typically highly site-specific and based strongly on local context, in contrast to traditional approaches that are more general in scope. Individual approaches can be of value at different scales; for example, seed banks are well suited to conserve genetic diversity within a population, but are incapable of conserving communities or ecosystems. However, they may play a role as part of an overall integrated strategy to address diversity at multiple levels of organization. Rather than being viewed as separate and distinct, *in* and *ex situ* conservation approaches can therefore be viewed as part of a spectrum of compatible, mutually reinforcing methods (Falk, 1987). For example, Falk (1987) provides the example of the successional management of a fire-adapted ecosystem, such as a prairie or savanna, which may involve fencing, site preparation, controlled burns, and reseeding with native species. Such a management regime may differ from a reintroduction program only in terms of the number of years during which a particular species is absent from the site, or from ecological restoration only in terms of the number of species that are the focus of conservation efforts.

Integrated conservation of tree species therefore includes both *in situ* and *ex situ* action, linked by restoration, reintroduction and collection, to support species survival. This process can be supported by research, horticulture and education that can ultimately increase the success of conservation efforts (Figure 1). Botanic gardens and related organizations can play a major role in integrated plant conservation throughout the world, and are uniquely positioned to be able to support such efforts (Havens *et al*., 2006).

Warburgia – *a medicinal tree valued in Africa. (BGCI)*

Fuelwood collection in the walnut forests of Kyrgyzstan. (J. Gratzfeld)

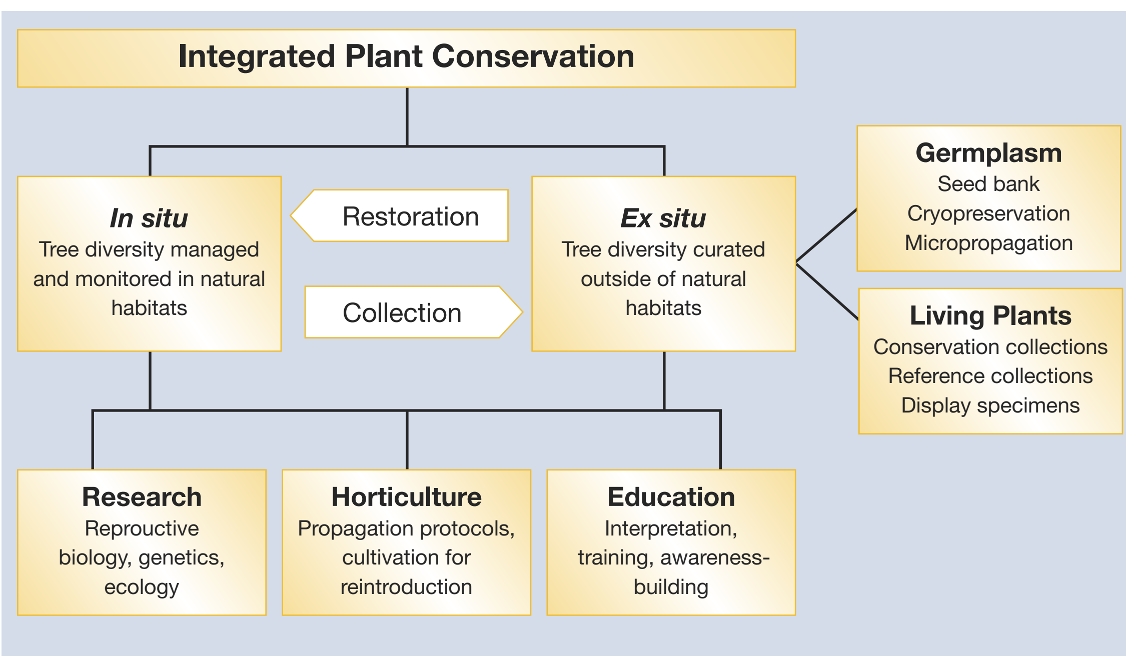


Figure 1. Integrated plant conservation combines in situ *(on-site) and* ex situ *(off-site) conservation approaches to support species survival.* In situ *conservation protects species in their native habitat, while* ex situ *conservation ensures plant material is available for research, horticulture, and education activities that ultimately support reintroduction efforts, to prevent species from going extinct. (Adapted from Kramer* et al.*, 2011)*

Case study 6:

Increasing the chance of survival for an imperiled Eucalyptus

Eucalyptus imlayensis, commonly known as Mount Imlay mallee, is a rare Australian tree species at high risk of extinction in its native New South Wales. The species is listed as endangered under Australia's Environment Protection and Biodiversity Conservation Act 1999. It is not currently included in the IUCN Red List but as the species is only known from a single population of about 80 mature trees, it qualifies as Critically Endangered.

First described in 1980, *Eucalyptus imlayensis* is endemic to the Mount Imlay National Park near the south-eastern coastal town of Eden in New South Wales, where it occupies less than 4 m^2 of the steep, rocky eastern slope of the mountain summit at an altitude of about 860 m. Its habitat is described as grassy sclerophyll woodland on skeletal soil, where mosses dominate the ground layer and a 3 m-high, closed shrubland (primarily made up of *Leptospermum scoparium*) surrounds the *Eucalyptus* population.

Studies carried out by E.A. James and K.L. McDougall since 1998 showed a decline in the population of *Eucalyptus imlayensis*, affecting both the health and the number of individuals. Of the total stems in the population, a tenth fully lost their foliage and a third showed more than 50% crown death by early 2001. In addition, no fruit production was recorded between 2004 and 2007, and no evidence of seedlings or juvenile plants was found in the population since 1998. Significant clonal reproduction from large lignotubers is however known to occur.

There are a number of identified and potential threats to *Eucalyptus imlayensis*, including genetic and ecological factors, pests and diseases. Above all, the extremely restricted geographic distribution, the very low number of mature individuals from a small, narrowing gene pool and unreliable sexual reproduction expose *Eucalyptus imlayensis* to the effects of catastrophic events, as well as minor ecological disturbances or modifications to its habitat. In addition, insect damage by unknown, gall-forming psillids and a probable susceptibility to *Phytophthora cinnamomi* - a soil-borne pathogen causing dieback – have also affected *Eucalyptus imlayensis*. The increased frequency and severity of dry periods, which may be related to climate change, could also be a possible threat to this species.

In order to recover *Eucalyptus imlayensis*, research priorities include investigations into the causes of plant deaths and the factors affecting sexual reproduction both *in* and *ex situ*, investigation of various propagation methods and the use of phosphate inoculation as a treatment of dieback. Recovery and threat abatement actions need to concentrate on monitoring the existing plant population (health, recovery progress, effect of habitat maintenance activities) and implementing management protocols, developing seed collection programmes and establishing live *ex situ* collections in partnership with botanic gardens, and raising public awareness.

In 2007, concerns over the population decline of this rare species prompted a collaboration between the Office of Environment and Heritage (New South Wales Government), the Australian National Botanic Gardens with funding from the National Parks and Wildlife Service and help from volunteers. A trial recovery programme to increase and strengthen the *Eucalyptus imlayensis* population has been established. The project had to overcome the logistical difficulties of seed collection and planting of the seedlings, as well as the challenges of propagation and after-care.

The remote location and the steep, rugged terrain of Mount Imlay made access to the trees difficult. Specialised extendable seed collecting equipment was used to reach the seeds from trees precariously positioned on the edge of the mountain top. The seeds were collected with help from the Australian National Botanic Gardens and propagated in their nurseries in Canberra. By September 2011, 23 seedlings were successfully propagated and ready to be planted in their native habitat. The grant funded the transportation of supplies by helicopter to the mountain top and the building of remote boot-cleaning hygiene stations to prevent the spread of pathogens. In order to establish the most favourable conditions for the plants, the seedlings have been planted in different terrains. Their development will be monitored and cared for with the help of volunteers. In addition, more seeds were collected in September 2011 for a possible supplementary planting in 2012.

Source: Prepared by Ildiko Whitton with information from DSEWPC (2008) and NSW OEH (2011)

Case study 7:

Towards integrated conservation of fruit and nut trees in Kyrgyzstan

As a region hailed for its botanical diversity in landraces, local ecotypes and crop wild relatives, the Central Asian Kyrgyz Republic has been a focus country for a multitude of related research and conservation efforts, especially over the last thirty years. Home to some 4,100 vascular plant species, this floral wealth includes over 130 species of wild relatives of economically important crops found in Kyrgyzstan's Tien Shan region, notably various fruit and nut bearing trees. Exploitation of timber and fuelwood, grazing and fire, have been highlighted as major causes threatening the survival of many of these species and their populations.

As part of a highly interdisciplinary project funded by the UK Darwin Initiative between 2009 and 2012, BGCI has been working with Gareev Botanical Garden of the National Academy of Sciences of the Kyrgyz Republic to develop public outreach activities. These focus on the importance to safeguard Kyrgyzstan's fruit and nut bearing tree species and the ecosystems they are part of. Through the activities of Fauna & Flora International and a range of Kyrgyz partners, efforts have also begun to strengthen the *ex situ* conservation of fruit and nut tree species, and their potential reintroduction in the wild.

Lack of facilities, resources and management capacity have hampered Kyrgyzstan's botanic garden development and environmental outreach capacity in recent years. This represents a challenge for the region as whole. Enormous scope therefore exists to enhance institutional and administrative competencies in Central Asia to raise environmental awareness and strengthen public outreach, as well as strengthen interest and participation in conservation action.

As elsewhere in the world, Kyrgyzstan is pursuing various research and *ex situ* conservation initiatives through living collections and germplasm banks, especially for economically important plant species and their wild relatives. Living *ex situ* conservation collections are especially maintained by Gareev Botanical Garden of the National Academy of Sciences of the Kyrgyz Republic (NASKR), which hosts a large collection of fruit tree cultivars, in particular apples, pears and plums. There are also a number of crop wild relatives including *Malus niedzwetzkyana*, *M. sieversii*, *Armenica vulgaris* and *Prunus sogdiana*. In collaboration with BGCI, outreach activities and capacity of staff at Gareev Botanical Garden have been developed. Promotional materials as well as an interpretational display exhibit about Kyrgyzstan's fruit and nut forests have been established. Eight species-specific panels and one display described the conservation goals of this initiative. The exhibit provides information on the species' use, distribution and conservation status, in three languages. This project also provided training and capacity building to a range of Kyrgyz institutions to support both the *in* and *ex situ* conservation of fruit and nut tree species, including national surveys of wild populations, support for the participatory management of native forests, and the collection and cultivation of plant material.

Source: Joachim Gratzfeld, BGCI

Walnut forest in Kyrgyzstan. (J. Gratzfeld)

4. A step-by-step guide to integrated conservation of tree species

As indicated above, integrated plant conservation can be considered as an iterative process, involving both *in situ* and *ex situ* approaches. The selection of which conservation actions are appropriate in a particular case will vary between species, locations, their native ecosystem and the resources available. To be effective, integrated conservation approaches need to be designed carefully, to address the individual needs of each specific situation. This manual cannot hope to provide a detailed prescription for any specific conservation problem. Rather, the intention here is to provide some general guidance in the form of a flexible strategic framework, which can potentially be adapted to any given situation. A variety of case studies are provided to illustrate how such a strategic framework can be implemented in practice. However, it should be emphasized that the information presented here should be viewed as a starting point, rather than as a strict protocol. Conservation is more of an art than a science (Newton, 2007), and there is enormous scope for innovation and creativity in identifying cost-effective, workable solutions to conservation problems.

The overall process of conserving a threatened species can be divided into three stages (Wilcove, 2010):

(i) identifying which species are threatened,
(ii) determining and implementing short term measures to halt species decline and recovery, and then
(iii) determining and implementing longer term measures to rebuild viable populations.

The entire conservation process is dependent on successfully diagnosing why a particular species is declining or under threat; conservation action will likely be unsuccessful unless an accurate diagnosis is made. Unfortunately, such diagnosis is often difficult, and many interacting factors may be responsible (Sutherland, 2000). Some suggested methods of identifying threats to species are presented below.

The following guide is designed to support a botanic garden that wishes to engage in integrated conservation activities, focusing on one or more tree species. The perspective of a botanic garden will likely differ from that of a conservation NGO, government agency or a local community, whose priorities and way of working may be very different. Ultimately, conservation actions are only likely to be successful if undertaken as a partnership, so one of the first steps should be to develop good working relationships with other organisations and stakeholders who share a common interest. Botanic gardens can play a leading role in developing such partnerships, gaining public understanding and support and in identifying priority actions.

The guidance presented below is organised as a series of discrete steps, but in reality the process may be highly iterative, in response to the information that emerges during the process. The process is considered here as four steps:

1. Step 1: Identify priorities for action
2. Step 2: Plan and implement *ex situ* conservation approach
3. Step 3: Plan and implement reintroduction programme
4. Step 4: Develop and implement longer term conservation strategy

4.1 Step 1: Identify priorities for action

One of the fundamental principles of conservation planning is that resources are always limited. As a result, decisions have to be made regarding which taxa should be the focus of conservation efforts. Any action must be carefully planned and prioritized according to defined needs and goals. Such decisions are not simple, and will reflect the particular interests of those involved, and the different values of a particular taxon held by different groups of people. Some species, for example, might be accorded high priority because of their exceptional cultural or economic significance, whereas others might be targeted because of their ecological roles. Maunder *et al*. (2004a) suggest that selection of threatened species for *ex situ* management can be guided by a range of factors including threat level, legislative and institutional responsibilities, likelihood of successful reintroduction, cost-effectiveness, relevant social and economic issues, and curatorial preferences. These authors also suggest the five "E" criteria, which provide a simple heuristic to help identify species priorities (Maunder *et al*., 2004a):

- **endangerment** (selecting the most threatened taxa needing *ex situ* support),

- **endemism** (selecting threatened taxa that represent a unique local or regional responsibility),
- **economic** (selecting taxa that provide local or regional economic or social resources, such as medicinal plants),
- **ecological** (selecting taxa that have a role in maintaining ecological processes or supporting habitat restoration), and
- **emblematic** (selecting threatened taxa that can be used as flagships for promoting landscape- and habitat-level conservation).

As noted by Maunder *et al*. (2004a), a further relevant criterion for selecting taxa is *phylogenetic position*. In other words, is the taxon the sole remaining representative of an ancient evolutionary lineage, or a sub-species that is the result of recent diversification of a highly speciose group? In terms of their contribution to genetic diversity, losing 10 species from a group of closely related species is very different from losing 10 monotypic genera or families (Maunder *et al*., 2004a).

Generally, decisions about which species should receive priority for conservation action are made at the national scale, a principle reinforced by the CBD. However, international collaboration in saving the world's threatened trees is increasingly important, and there are a number of examples of skill sharing and material exchange included in this manual. When considering the possibility of helping to restore a threatened tree species in a country other than your own, it is important to consider principles of Access and Benefit Sharing (ABS) as outlined in Annex 2.

In order to prioritize conservation and restoration action, a number of tools are available to identify which species are under threat and to understand the circumstances that have led to this threatened status. This information is a necessary first step in determining not only which species are most in-need of action, but also those that will benefit most from different types of conservation intervention. The following resources are available to help identify threatened species in your region:

- **The IUCN Red List** (www.iucnredlist.org) provides the most reliable and robust source of information available on the global conservation status of species. Approximately 6,200 tree species are currently included in the IUCN Red List. The IUCN/SSC Global Tree Specialist Group is working on additional assessments and aims to map and assess the conservation status of all tree species by 2020. Information on the conservation status of selected groups not yet incorporated into the IUCN Red List can be found at: www.globaltrees.org.

- In some cases, prioritization based on threatened status may rely on national assessments rather than global threat status; information on national lists of threatened species can be found at www.nationalredlist.org. Other information on the conservation status of plants is often available from a number of different sources maintained by government agencies and NGO organizations, which are specific to each individual country. Sources that might be consulted include national Red Data Books or other lists of threatened plant species.

- Local importance of a species may provide a strong motivation for conservation, particularly where a species is valued for its uses or cultural importance. Information on local or traditional values may be anecdotal in many parts of the world, but it is important not to discount such information as a basis for considering conservation action, particularly as it relates to local preferences and livelihoods. Perceived rarity because of declining availability of resource is likely to be of more direct concern to local people than a formal conservation assessment.

- For institutions that cultivate plant collections (living plants, seed banks, or other types of germplasm), BGCI provides the PlantSearch database as a way to quickly and easily determine the conservation status of plants in individual collections, including IUCN status, crop wild relative status, other regional threat statuses, and the number of other gardens that report maintaining the species in their collections. This free service is available online at http://www.bgci.org

Practising Rhododendron propagation at Cibodas Botanic Garden. (BGCI)

Case study 8:
Returning Sophora toromiro *to the wild*

Sophora toromiro, or toromiro, is a leguminous tree endemic to the remote Easter Island (Rapa Nui), a small volcanic outcrop in the Pacific Ocean 3,700 km west of Chile. The tree has great cultural, historical and biological significance to the Polynesian islanders who highly value its wood (for example, for carving religious statuettes) and see its reintroduction as recovering part of their heritage. The species is included in the IUCN Red List of Threatened Species as “Extinct in the Wild”, surviving only in cultivation primarily in the care of Chilean, European and Australian botanic gardens. Despite several failed attempts in recent decades to reintroduce toromiro to its native habitat, renewed efforts have recently been made.

Within a century of the first description of toromiro in 1774, a dramatic population decline occurred following the human settlement of the island and the introduction of livestock. Natural groves were decimated by settlers cutting down the valuable, multi-purpose timber and livestock grazing on the bark. By 1917 only one remaining specimen was found growing in the Rano Kau crater, which survived until 1962 when it was cut down for firewood. Forest clearance and agricultural activities completely transformed the island’s ecology – the toromiro and its natural habitat were destroyed.

Seeds collected by expeditions to the island provided the material for the first recorded cultivated plants in the early 20th century. Specimens of known origin that currently exist are descended from seeds collected by Thor Heyerdahl in 1958 and found predominantly in botanic gardens. There are also several toromiro plants of unconfirmed origin, mainly in private collections. Therefore, the surviving stock covers a very narrow range of genetic diversity, and may include incorrectly identified congenerics and specimens that hybridised through open pollination.

The obscured genetic status and corresponding conservation value of toromiro stocks was one of the main constraints faced by botanic gardens involved in the previous conservation efforts during the 1980’s and 1990’s. A global directory of cultivated toromiro trees with associated data from genetic fingerprinting has been established in response. The identification of genuine *Sophora toromiro* specimens remains central to the conservation work of this species. Chilean scientists from the Universidad Católica de Chile and Forestal Mininco, a forestry development and conservation company, reported at the VI Plant Biology Meeting in Chile (2011) on recent molecular validation of over 20 specimens against a control sample from the *Sophora toromiro* tree in the Museum of Natural History of Santiago.

Propagation methods used for the toromiro tree include seed germination, vegetative propagation from cuttings and micropropagation. As toromiro seeds are recalcitrant and the plants are very slow-growing, developing successful micropropagation techniques for this species is an increasingly important task. The results of the latest *in vitro* propagation experiments appear to be very promising. However, the very limited availability of plant material is a significant constraint on experiments and future reintroduction projects. Not only are there fewer than 10 recognised *Sophora toromiro* trees believed to exist in the world, but some may be reaching the end of their productive life.

The low survival rate of plants from previous reintroductions (e.g. a population of 150 plants in 1995) was assigned to the failure of root nodulation in plantlets owing to a lack of nitrogen-fixing bacteria. Toromiro trees have a symbiotic relationship with these organisms in order to survive and their absence leads to nutrient deficiencies and exposure to attack from root nematodes. This biological requirement makes both propagating and re-establishing these plants in a significantly altered environment very challenging.

Degraded soil conditions on Easter Island remain one of the major problems faced by the current reintroduction project. However, concerns of previous international undertakings about the views and opinions of the islanders and the insufficient infrastructure for conservation projects seem to have been addressed. The current project is led by a Chilean team of scientists, with the engagement of the islanders overseen by the Cultural Director of Easter Island. The project is based on the idea of “one Rapa Nui, one Toromiro”, with the aim of planting around 5,000 trees to equal the number of islanders, starting with 3,000 trees by the end of 2011. Young students are educated about caring for the toromiro plants and involved in the planting of 1,500 specimens held in a specially established temporary nursery on the Island. The progress of reintroduced plants will be monitored with the help of volunteers and managed using a dedicated website. The interest and participation of the local population is seen as the key to the expected success of the current project.

The case of the toromiro highlights the importance of *ex situ* collections and an integrated approach in reintroduction projects, including the collaboration between relevant institutions (e.g. botanic gardens, conservation authorities, scientific bodies) and the protected areas, together with a consideration of social and economic, as well as ecological, requirements.

*Source: Prepared by Ildiko Whitton with information from Montero (2011) and from Professor Patricio Arce (*In litt.*).*

In situations where lists of threatened tree species are lacking or are inadequate, botanic gardens can play a leading role in conducting assessments of conservation status. Many members of the IUCN/SSC Global Tree Specialist Group are staff of botanic gardens, who are often well placed to conduct conservation assessments because of their field knowledge and access to collections of herbarium specimens. Distribution maps based on such data can inform the assessment of conservation status, and help to identify regional or national endemics. If you are interested in conducting conservation assessments of tree species, please contact the IUCN/SSC Global Tree Specialist Group for information and support.

When considering how to prioritize activities, it is also useful to consider the role that individual tree species play within their natural ecosystems. *Keystone species* are ecologically pivotal species whose impact on a community or ecosystem is disproportionately large in relation to their abundance (Newton, 2007). Examples include canopy dominant tree species, or species that are an important food resource for animal species, such as many tropical palms. A tree species might be a candidate for *ex situ* conservation if it provides a food resource or habitat for another species of conservation concern, such as a bird or mammal species. For example, the Afromontane species *Prunus africana* (see Case Study 1) is an important food resource for endemic birds such as Bannerman's Turaco and Cameroon Mountain Greenbul, and endemic primates such as Preuss's Guenon (Cunningham and Mbenkum, 2003).

4.2 Step 2: Plan and implement *ex situ* conservation approach

4.2.1 Identifying partners

Once a decision has been reached on which tree species to conserve, it is important to identify appropriate partners with whom to work. The case studies throughout this manual highlight the crucial need to form partnerships with the right skill sets and institutional affiliations to enhance the likelihood of success. There is significant scope for increased collaborative interaction between different sectors involved in the conservation of trees, including for example the forestry sector, academia, botanic gardens and local communities. Identification of other partners will largely need to be done on a species-by-species basis, considering not only other botanic garden partners, but also other public and private landholders where the species occurs, academic institutions that can answer or help address research questions, and other government agencies or NGO organizations that can contribute experience and expertise. When planning an international project, finding a partner institution in the overseas country that can collaborate and benefit from the work is an essential first step.

To identify other potential partners within the botanic garden community, BGCI's GardenSearch database can help connect institutions looking for an array of facilities as well as expertise in research, conservation, and education. For example, there are currently 228 institutions worldwide listed in GardenSearch as maintaining a seed bank, while 288 and 124 institutions indicate they maintain plant conservation programs and restoration ecology research programs, respectively. When it comes to locating horticultural expertise on a species and potential *ex situ* plant material, BGCI's PlantSearch database provides a useful starting point. This online database allows users to identify the threat status of a tree species together with information on whether the species is recorded in botanic garden collections. PlantSearch also allows users to send a blind request to all gardens that indicate curating specific species, which can help identify possible collaborators, important species information, as well as possible plant material. In addition, for selected genera of woody plants, more detailed analyses have been undertaken to identify *ex situ* collections. The results for *Acer, Magnolia* and *Quercus* can be found at: www.bgci.org/ourwork/globaltrees

4.2.2 Selecting ex situ *techniques.*

Ex situ approaches include field gene banks and *in vitro* banks, conservation stands or orchards, living collections in botanic gardens, and seed banks (conventional and cryogenic) (De-Zhu and Pritchard, 2009). To implement these approaches successfully, a variety of different techniques may be employed. The precise choice of technique will depend on the resources and capacity available, the characteristics of the species concerned and the particular conservation problem involved, and the cost-effectiveness of the techniques concerned (Table 1). The strengths and weaknesses of selected techniques are summarized below, adapted from Maunder *et al*. (2004a):

Cryopreservation: Seeds, pollen, or tissue is stored frozen in liquid nitrogen. This technique is used for long-term storage of plant material, but it requires substantial capital investment and access to trained technicians and supplies of liquid nitrogen.

Case study 9:

Assessment of propagation of nine threatened southern conifer tree species at the Royal Tasmanian Botanical Gardens

The Royal Tasmanian Botanical Gardens (RTBG) covers approximately 14.5 hectares and has a cool temperate climate. Its collection focus includes Tasmania's flora and associated flora from the southern hemisphere. The RTBG was therefore pleased to accept several large donations of Southern Hemisphere plant species between 1998 and 2003. The majority were wild collected and provenanced. Nine were globally threatened conifers:

- *Acmopyle sahniana* (Critically Endangered)
- *Afrocarpus usambarensis* (Vulnerable)
- *Fitzroya cupressoides* (Endangered)
- *Libocedrus chevalieri* (Critically Endangered)
- *Libocedrus yateensis* (Endangered)
- *Neocallitropsis pancheri* (Endangered)
- *Pilgerodendron uviferum* (Vulnerable)
- *Podocarpus salignus* (Vulnerable)
- *Widdringtonia schwarzii* (Vulnerable)

The conifers primarily comprise a potted collection. In order to maintain the collection within the available size and space, propagation programs were carried out in 2004/05; and also in 2008 and 2011. The nine species listed were not all necessarily propagated each time. In some cases between 2004 and 2012 the health and vigour of the original plant declined as it remained in the largest pot size available. In the majority of cases only small numbers of cuttings could be taken as most of the potted parent material is less than 3 metres in height and therefore does not carry significant cutting material.

Various types of cuttings were taken using either Clonex Purple Gel by Growth Technology, active constituent Indole Butyric Acid 3g/l or Clonex Red Gel, active constituent Indole Butyric Acid 8g/l. The cutting types were:

1. Semi hard wood with a hardwood knob; terminal or ascendant growth with a small piece of hardwood at the basal end.
2. Semi hard wood – half hardened current year's growth.
3. Semi hard lateral; side shoots (not favoured as cutting material as the consequent plant grows in a sidewards direction).
4. Laterals with heel; usually taken from terminal or ascendant growth to maximise the number of cuttings.
5. Wounded cuttings; removal of up to 5mm of bark at basal end.

Cuttings which had the cambium tissue exposed (wounded and heel) were the most successful. Of the eight wounded cuttings seven had strike rates of 57% success and above with two having 100% strike rate. Average strike rate was 73% with wounded hardwood being the least successful and wounded semi hard with knob marginally more successful than semi hard. Only one group of heel cuttings was taken; these had an average strike rate of 75% but due to the small sample size, conclusions should not be drawn. Of the semi hard only one group of cuttings were taken that were not wounded – these had an average strike rate of 66.6% but again, due to the small sample size, conclusions should not be drawn. Lateral cuttings had an average of 62% success. However this is an academic exercise as cuttings taken from laterals grow lateral trees. Lateral cuttings are only taken in cases of extreme need! Hardwood cuttings did least well with an average of 41.5%.

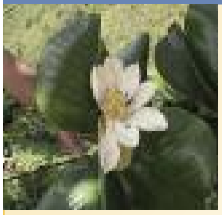
In conclusion, observations on the propagation of these species have revealed that more work is required to ensure maximum success! For example additional work needs to be done on the closed cases (upturned plastic tubs which enclosed the cutting punnets), from observations the health of the cuttings seems to benefit from the higher humidity than those outside of the case in the open, misted environment. However, this small case study showed that with conventional propagation techniques reasonable success can be achieved.

Source: Compiled by Megan Marrison in collaboration with Lorraine Perrins, Curator, Conservation Collections and Subantarctic Flora and Simon Marshall, RTBG Horticultural Trainee.

Above: Conifer cuttings in a closed case at the Royal Tasmanian Botanical Gardens (RTBG)
Right: Flower of Magnolia yarumalensis. *(A. Cogollo)*

A remnant tree of Magnolia yarumalensis. *(W. Buitrago)*

Case study 10:
Involvement of local people in tree restoration in Colombia



BGCI has been supporting the restoration of endangered *Magnolia* spp. in Colombia working with local botanic gardens. Workshops have been held to promote input from local communities.

The identification of key individuals in the local community has proved one of the most useful outcomes of these workshops. Not only can local knowledge greatly benefit our understanding of the distribution and ecology of threatened species, it can also further our research into the restoration and rehabilitation of wild populations.

In one such community workshop a participant was a farmer who also sold a range of timber species, including the Endangered *Magnolia yarumalensis*. Over the past ten years he had also been identifying and collecting seedlings of this threatened *Magnolia* in the forest, bringing them back to his nursery and growing them on. The 2008 *ex situ* survey carried out by BGCI identified only a single botanic garden to be cultivating this particular *Magnolia*.

When the seedlings reached about 30 cm, the farmer planted them back in the forest, in a range of locations where he could monitor and help them establish themselves over the subsequent years. The success of this individual effort, carried out entirely on his own initiative and with minimal resources, clearly demonstrates that a wider restoration of wild populations of *M. yarumalensis* is technically possible. However, local community awareness-raising work carried out so far by the garden only partially addresses the broader drivers of habitat loss, which will need to be tackled to ensure the long-term survival of the remaining wild populations and the reintroduced trees.

Source: Gibbs, 2010

Seed banking: Seeds are stored in conditions of low moisture and temperature. This technique is routinely used for orthodox seeds of wild species, for which it is an effective storage technique. Facilities can vary from small-scale (storage in airtight conditions over silica gel) to freezers and large-scale gene banks with walk-in seed vaults.

Tissue culture storage: Somatic tissue is stored *in vitro* under temperature-and light-controlled conditions of slow growth. This technique is effective for the conservation of material over short time periods, but it requires significant initial capital investment and access to trained technicians and laboratory supplies. It should be used as a propagation rather than storage technique, with cryopreservation replacing tissue culture storage for long-term storage.

Tissue culture propagation: Somatic tissue and seed are propagated *in vitro*; this technique is used for the proliferation of clonal plants and controlled seedling production. It is effective for the propagation of difficult material (e.g. small amounts of vegetative tissue, immature seeds), but it requires a significant initial capital investment and access to trained technicians and laboratory supplies.

Cultivation in a dedicated conservation facility: Plants are cultivated under a specific horticultural regime with the aim of cultivating and propagating threatened species. Conditions are managed to minimize artificial selection, hybridization, and disease transmission. This is usually a short-term activity to produce material for recovery activities or to bulk up material for long-term seed storage.

Specialist cultivation in a controlled environment: Plants are cultivated in an artificial environment (e.g. heated glasshouses). A very high horticultural investment is needed, and space limitations often preclude adequate genetic representation.

Cultivation in mixed display or reference collections: Plants are cultivated as part of reference collections under ambient environmental conditions. The majority of holdings in botanic gardens are held in such collections, where the focus is on taxonomic representation or horticultural display. However, this method carries a high risk of artificial selection, hybridization, genetic drift and disease transmission.

Field gene bank: An open-air extensive planting used to maintain genetic diversity, an approach that is often used for woody species, particularly those of high economic value. Field space allocation allows extensive genetic representation but represents a very long-term horticultural investment with high recurrent maintenance costs. There is a risk of hybridization between accessions and taxa.

Commercial cultivation: Plants are cultivated as a profit-generating horticultural or forestry crop, where management is dictated by commercial pressures. There are few opportunities for genetic management or control of provenances. However, this method can generate large numbers of individuals of threatened taxa that can be used for restoration or reforestation approaches, thereby encouraging the planting of native taxa and possibly reducing pressure on wild populations.

Community garden: Plants are cultivated in village- or community maintained plots. Management is dictated by local community needs and available resources, with few opportunities for genetic management and control of provenances. Community gardens are effective in maintaining valued plant resources, but carry a high risk of artificial selection.

***Inter* (or *cerca*) *situ*:** Plants are cultivated in horticulturally maintained near natural conditions, such as a managed population within restored semi-natural vegetation. This technique is effective in maintaining populations of threatened plants when natural habitats are extensively degraded. This technique allows horticultural or forest management (e.g. weeding) in semi-natural conditions, such as fenced exclosures.

***In situ* horticulturally managed populations:** Wild plants undergo some degree of species-specific horticultural management, such as controlled hand pollination. This method allows the horticultural, genetic, and demographic management of threatened taxa without the inherent risks of moving plants or propagules to *ex situ* facilities.

Case study 11:

Developing new techniques to conserve critically endangered oaks in ex situ *collections*

Seed banking is not an *ex situ* conservation option for oak species, as acorns are recalcitrant. Micropropagation and cryopreservation techniques are currently not viable options for *ex situ* collection development either, as oaks are challenging to propagate from anything other than seeds owing to their high tannin content. This means most if not all current *ex situ* collections of oaks are found only in living collections, with unclear conservation value.

To address this, BGCI US has undertaken a project with the US Forest Service, Cincinnati Zoo and Botanical Garden's Center for Research of Endangered Wildlife, and Longwood Graduate Program to understand the conservation value of current living collections of four threatened oak species. The project is also undertaking research that will improve options for *ex situ* conservation of these study species and other globally threatened oaks. The species include: *Q. acerifolia* (Endangered), *Q. arkansana* (Vulnerable), *Q. boyntonii* (Critically Endangered), and *Q. georgiana* (Endangered). Among other threats, the continued survival of these species is increasingly threatened by a combination of stresses relating to climate change and the advance of Sudden Oak Death (*Phytophtora ramorum*), making *ex situ* conservation an important conservation priority.

Collecting field data on Quercus georgiana*. (A. Kramer)*

Quercus georgiana. *(A. Kramer)*

Project partners are working with the botanic gardens and arboreta curating living collections of these species in the United States to carry out genetic studies and micropropagation trials. BGCI's PlantSearch database was used to locate the species in *ex situ* collections. The aims of the project are to:

- Determine genetic diversity of wild populations and living collections in order to make recommendations for collection development that will increase the conservation value of *ex situ* living collections for these species, through the use of more collaborative collection planning for conservation.

- Determine micropropagation protocols for these taxa, using material provided by botanic gardens and arboreta that curate collections of these study species. If micropropagation protocols are successful, cryopreservation of plant material will be considered as an additional long-term conservation option.

- Planning interpretation that can be used as a part of collection displays to help illustrate the important role botanic garden collections play in supporting research and conservation of threatened oak species.

Source: Kramer and Pence (2012).

Type of *ex situ* collection	Genetic diversity	Longevity	Relative costs per individual	Relative conservation value	Notes
Seed bank	High (if proper protocols followed)	High (with proper storage)	Low (if facilities exist)	Reintroduction – high Research – high Education – low	Seed storage is not possible for many tree species particularly those of the humid tropics
Cryopreservation	High (if proper protocols followed)	High (with proper storage)	Intermediate (if facilities exist)	Reintroduction – high Research – high Education – low	Techniques for most tree species not yet available
Tissue culture	High (if proper protocols followed)	Intermediate (with proper storage)	Intermediate (if facilities exist)	Reintroduction – high Research – high Education – low	Techniques for many tree species not yet available
Conservation collection/field gene bank	Intermediate	Short (species' generation length)	High	Reintroduction – intermediate Research – high Education – high	Cultivation is the only option for many tree species; adaptation to cultivation and hybridisation may be a concern
Reference living collection	Low*	Short (species' generation length)	High	Reintroduction – low* Research – Intermediate* Education – high	Source may be unknown, often one or few individuals, likely adaptation to cultivation
Display living collection	Low*	Short (species' generation length)	High	Reintroduction – low* Research – Low* Education – high	Source often unknown, often one or few individuals, likely adaptation to cultivation

Table 1. The relative conservation value of ex situ *approaches. (* May have higher genetic diversity or conservation and research value if material is wild-collected and maintained as multiple genetically diverse accessions, although adaptation to cultivation and hybridisation is a concern.) Source: Adapted from Guerrant* et al. *(2004b) and Kramer* et al. *(2011).*

4.2.3 Developing an ex situ *conservation resource*

Once an appropriate *ex situ* conservation technique or combination of techniques has been selected, they will need to be applied to develop a resource of germplasm or plant material, which could potentially be used to support subsequent reintroduction efforts. The starting point would logically appear be to capitalise on the existing *ex situ* resources that are available to a botanic garden, most notably the living collections. However, the *ex situ* plant populations associated with botanic gardens often have the following characteristics (after Maunder *et al*., 2004b):

- Populations are small and are often derived from a small number of closely related founder individuals. The latter problem may not be evident, particularly if records of plant accessions have been lost, as can often be the case.

- The cultivated stocks are subject to fluctuating population size as a result of changing horticultural fashions and episodic mortality events. This can affect the genetic structure of the population.

- Often little or no associated ecological or biological information is available to guide *ex situ* managers in cultivating and managing the stocks. Many species may be difficult to propagate.

- There is little information on the history of the taxa in cultivation and often no satisfactory horticultural protocols. Information on the geographic origins of the accessions may be lacking or imprecise.

- Individual plants are scattered through a number of collections with varying horticultural and curatorial capacity and hence differing patterns of regeneration and mortality.

- Individuals are susceptible to artificial selection, genetic drift, inbreeding, and hybridization with congenerics, limiting their conservation value.

- Persistence in collections is highest for horticulturally amenable taxa and particularly for taxa with ornamental display or commercial value. Many threatened species are not well represented in botanic garden collections.

These problems are illustrated by the case of alerce (*Fitzroya cupressoides*), a threatened conifer native to southern South America. In the UK, the species has been cultivated in a number of gardens and arboreta since its introduction in 1849. In an attempt to evaluate the importance of this resource for *ex situ* conservation, patterns of genetic variation were examined in 48 trees from throughout the British Isles using molecular markers (Allnutt *et al*., 1998). All samples from the cultivated trees of unknown origin, with one exception, were found to be genetically identical. This suggests that virtually all of the *F. cupressoides* trees currently cultivated in the British Isles have been derived from a single individual by vegetative propagation. Their value for *ex situ* conservation is therefore likely to be extremely limited. In contrast, when the threatened Chilean vine *Berberidopsis corallina* was examined in a similar way, the genetic variation within plants cultivated within Britain was found to be comparable to that recorded in small natural populations (Ehtisham-Ul-Haq *et al*., 2001). However, analyses suggested that only populations from the northern part of the natural range of the species are represented in cultivation. In a further example, patterns of genetic variation were also examined in British *ex situ* populations of the threatened Chilean conifer *Podocarpus salignus*. Results provided evidence of novel hybridization with other species (*P. hallii* and *P. totara*) that are endemic to New Zealand, but which are also present in the same arboreta (Allnut *et al*., 2001).

These examples highlight the value of analyzing patterns of molecular marker variation in order to evaluate the potential value of *ex situ* populations for conservation. They also highlight the need for caution when developing an *ex situ* conservation resource, particularly when genetic information is lacking. Given such problems and limitations, often there will be a need to both evaluate and further develop any *ex situ* resource, prior to any reintroduction activities.

Guidance on collecting material for *ex situ* conservation of plant species is provided by Guerrant *et al*. (2004a). Key questions include:

- How many populations should be sampled per species?
- How many individuals should be sampled per population?
- How many propagules should be collected from each individual?

Guidance on developing an *ex situ* conservation resource is provided by the Center for Plant Conservation (CPC), who developed genetic sampling guidelines for conservation collections of endangered plants (CPC,1991). These were further developed by Guerrant *et al*. (2004a). The revised guidelines are organized around the following list of contextual questions, which are intended to assist practitioners in the process of balancing the many factors that must be taken into account in collecting material of threatened plant taxa (Guerrant *et al*., 2004a):

What purpose is the material intended to serve?

- For example, many fewer propagules are needed to develop germination and cultivation protocols, and the genetic considerations are very different from those for acquiring a genetically representative sample for long-term storage or reintroduction.

What material is available?

- What is the nature of the sampling universe (or the total number of plants that could potentially be sampled)? Sample sizes appropriate for a species limited to one or a few small populations are very different from those for a species known from 50 locations, each with a large population.
- Is seed storage an option, or must samples be maintained as growing plants? It is generally much easier and more economical to store large numbers of seeds in a seed bank than it is to maintain fewer actively growing plants in a botanic garden or other non-native setting. However, depending on available resources, seed storage may not necessarily be a realistic option, even for taxa with orthodox seeds.

What will it take to have enough material for use when needed, and is the benefit worth the cost?

- What sources and magnitude of attrition in a collection might be expected during storage and later use to restore diversity to the wild? Not all propagules collected will survive *ex situ* storage; indeed, some may be used to monitor their condition during storage, and of those that survive, not all propagules planted out will successfully reproduce.
- When is the short-term danger posed by collection high enough to indicate that collection should be spread over two or more years? In order for collection to be justified, the expected potential value of the sample must outweigh the short-term impact of collection. Under what circumstances might such restrictions not apply and emergency salvage collection be justified?

Based on an evaluation and revision of the CPC guidelines, Guerrant *et al*. (2004a) make the following recommendations:

- For species with 50 or fewer populations, collect from as many populations as resources allow, up to all 50. For species with more than 50 populations, collect from as many populations as is practical, up to 50. For populations with 50 or fewer individuals, collect from all known individuals; for populations with more than 50 individuals, collect from 50. This represents the ideal sample meant to serve the broad range of expected purposes, but it is recognised that in practice, and especially for very threatened species, sample sizes will often be much smaller than these benchmark guidelines.

- For developing germination and propagation protocols, or to determine seed storage behaviour, use existing *ex situ* material if available. For extremely rare taxa, it may be advisable to begin with pilot studies using closely related but more common congeners. If wild populations must be sampled, begin with small collections from the largest and most secure. Actual sample sizes should be determined in consultation with those who will be working with or who are familiar with the material in question.

- Maintain *ex situ* collections as dormant seed, if possible. For seed storage, sample size is limited mostly by available resources, such as the size of the sampling universe, the impact of collection on wild populations, and the technical capability to store seeds for a long period of time. The limit for the number of growing plants is set more by the practical constraints in handling a species than by other factors, so the total number generally is lower for growing plants than for seed storage.

- To develop reintroduction protocols, begin with the smallest collections necessary to address the management questions being posed in the experimental reintroductions.

- To increase the probability of successfully reintroducing self-sustaining populations of threatened plant species, collect from as large and diverse an array of suitable founders as is prudent, given the sampling universe. Collect and maintain separately seeds from each maternal line. Only in this way can representation of the different founders be known and controlled intentionally.

- Collection for other purposes should be evaluated in light of their intrinsic estimated conservation value and in light of the cumulative impact of all collection activities anticipated for those species and populations.

- If a species of conservation concern exists in *ex situ* collections, the survivorship, health, and genetic status of the off-site collections should be monitored. To minimize genetic changes in *ex situ* conditions, emphasis should be placed on improving storage or cultural conditions rather than or at least before additional wild collection.

Cibodas Botanic Garden and surrounding vegetation (Kemal Jufri)

- To compensate for propagule mortality during reintroduction, start with an estimate of desired numbers of individuals surviving to reproduction in a new founding population. Then, account for expected losses during establishment. Some of these calculated losses can be mitigated by maintaining backup clonal material.

- Less intense, frequent harvests of propagules are expected to have lower impact on sampled populations than more intense, infrequent harvests. To the degree possible, spread collection over two or more years, especially for small populations.

- For populations of species with extremely low overall numbers, particularly those that have 10 or fewer reproductive individuals and a poor history of recruitment or those that are known to be in precipitous decline, collect up to 100 percent of seed at the discretion of the permitted collector. Such collection levels assume that adequate facilities, procedures, and resources are available to care for the material and that such collections are part of a more inclusive strategy that is endorsed by the appropriate regulatory authorities.

When collecting plant material for *ex situ* conservation, it is also important to consider legal issues. Many countries have legislation governing the collection of wild plant material particularly for species that are threatened with extinction. It is necessary to check such legislation in the planning of any tree conservation project that involves taking material into an *ex situ* collection. Always check with competent national authorities. In addition permission will be required from land owners or land managers both for access to the land and removal of material from it. When planning to work in an overseas country is important to be aware that there may be different access rules to plant material for country nationals and foreigners, particularly if plant material may be exported. Some indigenous groups have developed codes of practice for workers who wish to work on their lands.

The transfer of plant material between countries is governed by various international Conventions. Certain tree species are covered by the provisions of CITES (see Section 2.3, www.cites.org). Permits are required for international “trade” in listed species. More broadly the CBD has requirements for international transfer of biodiversity under Access and Benefit Sharing (ABS) provisions. The principles of ABS are outlined in Annex 2. It is advisable to check the CBD website (www.cbd.int) for information on national ABS laws.

Case study 12:
Propagation of Prumnopitys *andina* – *a south American conifer*

Prumnopitys andina is an evergreen species of the Podocarpaceae that is native to Chile and Argentina. It is considered Vulnerable in the wild. In general the germination of podocarps is slow and unreliable. A joint study between the UK Forestry Commission, Royal Botanic Garden, Edinburgh and Universidad Austral de Chile, Valdivia aimed to obtain as many seedlings as possible from 1,270 fruits (female cones). The fruits were from 12 different seed accessions collected at 12 different locations in Chile. A secondary aim of the study was to increase germination rate, which was previously recorded to take up to four years.

A sequence was developed to raise seedlings within one year. The steps involved were to completely remove the fleshy sarcotesta; thoroughly wash the seed-coat; ‘pretreat’ the imbibed seeds by incubating them in moist peat and sand at daily alternating temperatures of 10/15˚C for several months; carefully cracking the seed coat in a vice and extracting the embryo; culturing viable embryos on moist filter paper at daily alternating temperatures of 20/30˚C (with lights during the 30˚C phase); where necessary freeing the cotyledons of all seedlings that became trapped in the female gametophyte; transplanting seedlings to conventional nursery conditions. The procedures were very effective but the seed cracking and embryo extraction proved to be extremely time consuming and labour intensive. Extending the pretreatment period was considered to be a likely alternative to the seed cracking.

This study formed part of an integrated conservation programme for threatened endemic forest species in Chile which included research on the distribution, conservation status, cultivation and genetic variation of threatened trees, the development of habitat management plans for private land containing threatened plants, developing the arboretum at Universidad Austral de Chile, Valdivia as an *ex situ* conservation centre and the provision of training in *ex situ* and *in situ* conservation methodologies.

Source: Gosling et al. *(2005).*

Case Study 13: *Propagation of* Xanthocyparis vietnamensis

Xanthocyparis vietnamensis is a conifer that was discovered in 1999 in the Bat Dai Son mountains of Ha Giang Province in northern Vietnam, and is listed as Endangered by the IUCN Red List. Conservation action for the species has been undertaken collaboratively by the Centre for Plant Conservation, Hanoi, Vietnam; Fauna & Flora International; International Conifer Conservation Programme, Royal Botanic Gardens, Edinburgh; Bedgebury National Pinetum, UK; and Forest Research Station, Alice Holt Lodge.

The species was introduced into cultivation by the Royal Botanic Gardens Edinburgh on the 17th November 2002 in the form of cutting material. Plants were subsequently distributed to a few selected sites as part of the International Conifer Conservation Programme (Gardner, 2003) with Bedgebury National Pinetum being one of them. Until recently propagation from seed had not been attempted.

The most successful way to propagate *Xanthocyparis vietnamensis* has been from semi-ripe heel cuttings taken around November in the UK. The cuttings have a much higher success rate if they are taken from younger plants with lots of healthy foliage. The cuttings should be about 10-15cm long and dipped in a semi-ripe rooting hormone powder containing IBA. The cuttings are placed in a tray making sure that the cuttings are close enough together without touching one another, and placed on a heated bench either under polythene or in a box and misted. The cuttings should be kept from drying out by misting. After about four months the cuttings should have started to root, when they can then be potted on.

Seed was brought over from Vietnam in 2010 and taken to the Forest Research Station at Alice Holt where they were x-rayed. This enabled selection of only the seeds that appeared to be filled and healthy. The viable seed was stored in a domestic fridge at 4°C. After five weeks of cold stratification the seeds were sown on April 4th 2011 into a fine peat and bark mix (4:1 ratio) which was moistened before sowing. Seeds were gently pushed into the compost and then covered with a thin layer of coarse grit. The seed trays were kept in a cool greenhouse and watered as required. First germination occurred after 28 weeks on October 19th 2011.

Source: Dan Luscombe and Matt Parratt, Bedgebury Arboretum

Xanthocyparis vietnamensis *seedlings. (P. Drury)*

4.3 Step 3: Plan and implement reintroduction programme

Reintroduction refers to the placing of material of an endangered species within its historic geographic range, in appropriate habitat. It can therefore be considered as a form of ecological restoration, which focuses on rescuing or recovering endangered species (Armstrong and Seddon, 2008; Falk *et al*., 1996; Maunder, 1992). Reintroduction of threatened plant species can be very challenging, and has been the subject of a high rate of failure, which has led some authors to question the overall value of the approach (Fahselt, 2007). On the other hand, as some of the case studies presented in this manual illustrate, reintroduction can make a highly valuable contribution to the conservation of threatened species, when it is successful. A key issue, therefore, is to identify the lessons that can be learnt from both successes and failures. Falk *et al*. (1996) provide a comprehensive overview of plant reintroduction, including both theoretical and practical aspects, and a number of informative case studies. The reader is referred to this authoritative source for further detail. Maschinski *et al*. (2012) present the CPC *Best Reintroduction Practice Guidelines*, which provide additional detailed guidance. Further information is available from the IUCN, who have also developed guidelines for plant reintroduction: http://www.kew.org/conservation/RSGguidelines.html

4.3.1 Reintroduction strategy

Kaye (2008) presents a concise step-by-step strategy for guiding plant reintroductions, which emphasizes the development and testing of hypotheses about factors that may affect success, allows for feedback through adaptive management, and considers how success can be monitored and measured. This strategy is summarized below (adapted from Kaye, 2008):

(i) Plan and set clear objectives
Identify a clear statement of objectives, for both state and process, and for the short and long term. Many conservation projects suffer from poorly defined objectives, and as a result, practical interventions can be poorly focused or ineffective. The identification of clear objectives also helps monitor progress. Also it is important to obtain necessary permits.

(ii) Obtain source material for reintroduction
Collect seeds, cuttings, etc. from *ex situ* collections, such as seedbanks. Ensure that genetic diversity is maximised when deploying material, paying particular attention to species that have a “small neighbourhood” or experience outbreeding depression. Also consider the adaptive potential of the material to be planted. Genetic material that has been obtained from plants growing in environmentally similar sites to the reintroduction site, in terms of soil, climate, altitude and latitude, is more likely to be adapted to local conditions. Poorly adapted planting material is a major cause of failure of reintroductions.

Forest restoration at Brackenhurst Botanic Garden, Kenya. (BGCI)

(iii) Propagate plant materials
Identify or develop cultivation protocols. Generally, standard horticultural techniques will be appropriate for propagating tree species; see the additional information presented below. Approaches used in forestry can also be very useful to successful propagation of tree species in conservation projects.

(iv) Select appropriate site(s) for reintroduction
Logistical criteria include site ownership, access and management. Biological criteria include the need to choose sites within historic geographic distribution, with appropriate environmental conditions (soil, climate, altitude, aspect etc.), and where threats such as invasive species can be successfully managed. Small-scale, pilot trials can be useful to help identify which sites are most suitable.

(v) Prepare the site for plant establishment
There will typically be a need for some form of site preparation, such as clearing of competing vegetation. Such vegetation may need to be cleared regularly, following outplanting, to avoid mortality of the young tree. If present, the existing forest canopy may need to be manipulated (for example by thinning) to ensure that the light environment is appropriate for the species concerned. Nurse plants may also help establishment of some species, particularly on highly degraded or dry sites. Protection from herbivory may be another key element of site preparation, for example through the use of fencing or guards.

(vi) Conduct outplanting
Use a variety of outplanting and establishment methods, and monitor their relative success, to help inform future outplanting efforts. Consider implementing outplanting as a designed experiment, to test hypotheses about the factors influencing tree establishment. This could involve manipulation of factors such as existing vegetation cover, shade, nutrient availability and herbivory. Monitor the outplanting regularly, to replace plants that have died.

(viii) Employ adaptive management approaches
Adaptive management involves monitoring the results of management interventions, and then using the results of monitoring to guide future management activities. This requires an effective monitoring programme to be implemented. The cost of future monitoring needs to be considered as part of the initial project planning. The use of “citizen scientists” may be appropriate in some cases. Further information on adaptive management is presented below.

Prunus sogdiana*. (BGCI)*

(ix) Communicate results to others
It is important to communicate the results – both successes and failures – to help guide reintroduction efforts elsewhere. Consider ways to distribute findings as soon as possible through networks and grey literature as well as publishing in refereed journals. Increasingly, resources are being developed to foster communication among practitioners, such as http://www.conservationevidence.com/

Godefroid *et al*. (2011) provide a very useful recent review of plant reintroductions, from which some additional lessons can be learned. Results indicated that survival, flowering and fruiting rates of reintroduced plants were generally rather low (on average 52%, 19% and 16%, respectively). A number of factors were identified that positively influence plant reintroduction outcomes:

- working in protected sites,
- using seedlings,
- increasing the number of reintroduced individuals,
- mixing material from diverse populations,
- using transplants from stable source populations,
- site preparation or management effort, and
- knowledge of the genetic variation of the target species.

This study also revealed shortcomings of reintroduction attempts:

- insufficient monitoring following reintroduction (usually ceasing after four years);
- inadequate documentation, particularly for reintroductions that are regarded as failures;
- lack of understanding of the underlying reasons for decline in existing plant populations;
- overly optimistic evaluation of success based on short-term results; and
- poorly defined success criteria for reintroduction projects.

These authors therefore conclude that the value of plant reintroductions as a conservation tool could be improved by: (1) an increased focus on species biology; (2) using a higher number of transplants (preferring seedlings rather than seeds); and (3) taking better account of seed production and recruitment.

4.3.2 Propagation techniques

Problems in natural regeneration of rare and threatened tree species may be one of the key factors in their decline. Changes in population size and structure, for example as a result of increasing isolation of individuals, may lead to decline in pollination and seed production. Loss of pollinators can also be a critical issue. Frequently the reasons for the lack of natural regeneration of tree species are poorly understood. Propagation may therefore be equally difficult. The horticultural skills and propagation research of botanic gardens are of great importance in both maintaining living collections and contributing to the propagation of plant material for restoration in the wild. Despite the difficulties in propagation, there is usually a method that will succeed, and all attempts are worth recording for species of conservation significance. There is a wide range of general publications on propagation techniques (see, for example MacDonald (2000) and Dirr and Heuser (2006) for temperate trees and Longman (2002-2003) for tropical species). In addition the International Plant Propagators Society is a rich source of information. As noted by Blythe (2007) available information should always be viewed as a starting point, rather than a strict protocol, as propagation requirements of a species can vary from place to place.
Experimentation is therefore a key activity in propagation. Information on propagation of a particular species from other botanic gardens is also worth considering. BGCI's PlantSearch database allows you to contact all gardens holding records of a species in cultivation. An expanded bibliography of references on the propagation of tree species can be found at http://www.bgci.org.

The method of propagation, whether in a botanic garden or local field nursery, will depend on the nature and amount of tree material available and the availability of equipment and technical resources. The preferred option for propagation of rare and threatened trees is from seed, helping to ensure that sufficient genetic variation is present in the established population. Other options include vegetative propagation, propagation from cuttings, micropropagation and grafting. Describing the protocols involved with these different types of propagation for different species is beyond the scope of this document, but summary information is presented in Table 2. Before work begins on any new species, it is important to consult with potential partners and available resources (e.g., online search engines for published and unpublished literature, etc.) to determine if information is available on specific species of interest (or related genera) that may inform decisions about propagation. For the many unique plant species that botanic gardens curate, the expertise and facilities they maintain are invaluable when developing protocols for new and understudied species. Indeed, they may hold the only propagation knowledge for a number of threatened tree species, and there is a need to capture and make this information more widely accessible so that it can be used to support conservation and restoration work.

Table 2. Overview of some propagation techniques used with tree species

Seed propagation: Seed germination requirements vary wildly depending on the species and the seed conditions. Some seeds that appear ripe suffer from immature embryos (e.g. *Ilex, Magnolia* spp.) and require a considerable after-ripening period (usually in warm temperatures) before the seed will germinate (Dirr & Heuser, 2006). Germination rates are affected by factors such as the time of collection, cleaning procedures, storage, moisture content of the seed and various treatments given to induce germination. If enough seed is available it is helpful to try various treatments including combinations of warm and cold stratification. At the Morris Arboretum, all seeds that need stratification are placed in plastic bags in moist perlite. This allows the seed to uptake water but prevents rotting (Dillard, 2005).

Vegetative propagation: Woody plants can be propagated from *leaf cuttings* (including a leaf blade, petiole and short piece of stem with the axillary bud). More typically *stem cuttings* are used, categorised as softwood (emerging shoots), semi-hardwood (reasonably firm summer growth) and hardwood (last season's growth). Cuttings taken from the current season's growth are typically 10-15 cm long with three or four leaves retained and trimmed to reduce surface area. Basal wounding prior to hormone application can be undertaken to improve rooting. After hormone application, cuttings are usually inserted into a flat or propagator filled with a porous medium, and maintained at high humidity (Tubesing, 1998). Cuttings derived from "juvenile" material (e.g. vegetative resprouts from cut stems) may display higher rooting potential than those derived from the shoots of mature trees.

Grafting, joining two plants or parts of plants together to enhance growth, is used to propagate plants that are difficult to reproduce by other means. A graft consists of the scion and understock. The scion is a short stem piece with two or more buds that will develop into the upper shoot of the plant. If the scion is reduced to a single bud attached to a thin wood slice the technique is known as *bud grafting* or *budding*. The understock also known as the rootstock or stock is the lower part that becomes the root system. Generally the chances of success in grafting improve if the two plants are closely related taxonomically. Where two plants cannot be grafted they are said to be incompatible.

Micropropagation involves growing plants from seed or small pieces of tissue under sterile conditions on specially selected growth media. This has been immensely useful in plant conservation for the past thirty years or so. Challenges include obtaining appropriate material for propagation, for example that derived from outdoor plants may be difficult to disinfect, prior to placing them in sterile culture. Once established in culture, some species produce phenolic compounds as a wound response and these inhibit growth. To overcome this problem the tissue needs to be transferred to fresh medium every four weeks. Induction of roots can be challenging but can be enhanced by the appropriate application of auxins (Tubesing, 1998).

Case study 14:
Propagation of endangered Sorbus *spp. in Scotland*

There are currently 19 endemic species of *Sorbus* (whitebeam) considered to be at risk of extinction in the UK (with 11 included in the IUCN Red List). The Isle of Arran off the south-west coast of Scotland has three endemic species: *Sorbus arranensis*; *S. pseudofennica* and *S. pseudomeinichii*. The latter has only been recently discovered and is known only from one individual in the wild. This single tree has now been fenced to prevent further grazing damage and offer the potential for seed germination. *Ex situ* collections for the three Critically Endangered species have been established at the Royal Botanic Garden, Edinburgh. Seed propagation and vegetative propagation by chip budding have been successfully carried out. Initially seeds were collected to establish the *ex situ* collections. Permission was obtained from Scottish Natural Heritage to collect fruit of all species. Unfortunately although *S. pseudomeinichii* seemed to be fruiting well, most of the seed were found to be damaged by insects or pathogen infection.

Following collection, seed of *S. pseudomeinichii* were extracted from the fruit and rinsed under tap water. Ten seeds were sown in individual Rootrainers™ with one seed per cell. Seeds were not pre-treated. They were sown in propriety seed compost and top-dressed with flint grit. Of the ten seeds, one germinated in June 2007 producing a vigorous sapling of 50 cm by August 2011.

The limited seed production in the wild is further constrained by insect predation and climatic factors. Chip budding was trialled as an alternative as it requires the collection of only a small amount of vegetative material. Again with appropriate permission, a twig with several buds was removed from the wild tree of *S. pseudomeinichii* in August 2007. The following day buds were grafted onto *Sorbus aucuparia* rootstocks. To do this, a chip of bark was removed from the rootstock and replaced by a chip from the bud-stick that contained a bud. Both chips were cut to expose the cambium layer. Grafting tape was used to seal the cut edges and hold the chip bud in place. The buds united after one month and after growth was well established the top of the rootstock was cut off above the scion growth. The final step in chip budding was to separate the growing scion from the mother plant.

The *ex situ* collections of the three endemic whitebeams of Arran maintained at Royal Botanic Garden, Edinburgh are providing an insurance policy against loss of plants in the wild and duplicates will be distributed to other gardens. They will also be used to understand the requirements for cultivation and propagation of these extremely rare species and for training students in practical conservation techniques.

Source: McHaffie, Frachon and Robertson (2011).

4.3.3 Site selection

The choice of an appropriate site on which to establish tree species is a particularly important part of the reintroduction process. Foresters appreciate the importance of correct species-site matching when establishing plantation forests, and the same principles are relevant in a conservation context. If a species is not established on an ecologically appropriate site, then the risks of failure will be high.

Maschinski *et al*. (2012) provide the following guidance in this context:

- A number of factors influence a species' ability to colonize a new site, including appropriate soil and climatic conditions, availability of associated species, and ongoing management to address threats. Review what is known about a proposed recipient site. Seek a recipient site that is similar, in terms of its environmental characteristics, to locations where the species is thriving.
- Try to imagine the future conditions that the reintroduced population will face. Ongoing management and threat abatement are essential for maintaining conditions conducive to maintaining viable populations.
- Consider landscape-level processes. Think about any recipient site in the context of the species' broader distribution. A reintroduced population can serve an important function of connecting existing populations by forming a stepping stone between them, or by expanding the extent of existing populations. Evaluating the landscape from the perspectives of topography, ecosystem dynamics, and patterns of possible restoration trajectories will help determine the locations with greatest likelihood of sustaining a reintroduced population.

Case study 15:
Seed propagation of threatened Magnolia spp.

Magnolias have large seeds that are relatively easy to collect and they have simple dormancy, most temperate species requiring a moist-chilling period of two to three months at approximately 5˚C to promote germination. The seeds are recalcitrant, losing viability rapidly under dry storage.

The South China Botanic Garden has a rich collection of Magnolias that includes specimens of ten Critically Endangered and thirteen Endangered Chinese species. Botanists from the Garden are studying the ecology and conservation status of a range of *Magnolia* species in the wild, as a basis for conservation and reintroduction. One species being conserved is the recently discovered *Magnolia longipedunculata*, first described in 2004. Growing in evergreen forests in Guangdong, recent field surveys in three counties of the Province have identified only a single population of 11 mature *M. longipedunculata* specimens and the species is considered to be Critically Endangered.

In order to improve the germination rate, one of the most important issues is to collect the fruits at the appropriate time. If the seeds are collected too early, they will develop incompletely, which will lead to a greatly reduced germination rate. After collection, the aggregate fruits should be placed in a shaded and cool place for drying, to let the follicles dehisce and the seeds fall out.

To remove the sarcotesta of seeds collected for propagation, it is recommended to soak them in water for more than three days, then squeeze the seeds and rub them against a sieve. The treated clean seeds may either be sowed in a greenhouse at once or stored over the winter and sowed in the spring. In tropical and southern subtropical regions, the seeds of *M. longipedunculata* are usually sowed as soon as they are collected. In the north, the seeds are usually stored through winter and sowed in spring. Proper cold treatment and storage must be employed. The seeds should be stored in clean, moist river-sands, and kept in a cool and shaded place. The seeds should be rinsed in a fungicide or chlorine bleach solution prior to bagging to protect them against diseases. The results of germination experiments show that the best temperature for the germination of *M. longipedunculata* seeds is 20-25ºC and the germination is inhibited when the temperature is ≥ 30ºC or below 10ºC. The duration from seed sowing to its germination usually lasts 25-30 days. The process of germination lasts 12-15 days from start to completion.

Source: Zeng Quingwen

Fruit of Magnolia longipedunculata. *(Zeng Qingwen)*

- To account for uncertainty, incorporate heterogeneity into the reintroduction plan. Use multiple sites and multiple microsites to test heterogeneity of conditions needed for successful growth and survival of all life stages of a species.

- Because the fine-scale needs of tree species are often unknown, using microsites as an experimental factor is good practice. Measure abiotic conditions (e.g. soil, precipitation, temperature) and biotic conditions (e.g. presence of herbivores, mutualists, invasive species) at the reintroduction site that are associated with plant growth and reproduction. Ensure that there are adequate areas for population expansion (e.g. microsites are available within the recipient site and adjacent suitable habitat is available outside of the recipient site). If environments conducive to positive population growth are rare or nonexistent, additional management activities, beyond simply reintroducing young plants, will be necessary.

4.3.4 Adaptive management

As noted above, whichever tree conservation approach is adopted, *adaptive management* techniques should be employed. Particularly useful resources on this topic have been developed by Foundations of Success (FOS), a not-for-profit organization committed to improving the practice of conservation through the process of adaptive management. A number of information resources are accessible from their website (http://fosonline.org/); see Margoluis and Salafsky (1998) and Salfasky *et al*. (2001, 2002). This brief account is based on these sources, which should be consulted for more details (see also Newton, 2007).

Adaptive management can be defined as the integration of design, management and monitoring to systematically test assumptions in order to adapt and learn. It also offers a method by which research can be incorporated into conservation action. The approach includes the following elements:

- **Testing assumptions.** This involves systematically trying different management actions to achieve a desired outcome. This depends on first thinking about the situation at the specific project site, developing a specific set of assumptions about what is occurring and considering what actions could be taken to affect these events. These actions are then implemented and the results are monitored to assess how they compare to the ones predicted at the outset, on the basis of the assumptions.

Cercocarpus traskiae. *(A. Kramer)*

Case study 16:
Santa Catalina Island mountain-mahogany (Cercocarpus traskiae).

The Santa Catalina Island mountain-mahogany (*Cercocarpus traskiae*) is a small, broad-leaved, evergreen tree in the rose family (Rosaceae) that grows on saussurite gabbro substrate in a single canyon (Wild Boar Gully) on the west side of Santa Catalina Island, Los Angeles County, California. It is widely cited as California's rarest native tree, and most consider it to be the rarest native tree in the continental United States (Wallace *et al.*, 2007). When this species was first discovered by Blanche Trask in March of 1897, there was an estimated population of 40 to 50 individuals. Currently, in the wild on Santa Catalina Island, there are six known "pure" Santa Catalina Island mountain-mahogany plants, five plants of hybrid origin, and numerous seedlings. A suspected seventh "pure" mature individual was found in 2008 in the Wild Boar Gully watershed. There is a small population of plants from the Santa Monica Mountains (on the mainland in Los Angeles County) that need further testing to determine their relationship to *Cercocarpus traskiae*.

There is also a living cultivated specimen at the University of California's Blake Estate in Kensington, California that was reportedly collected by Willis Linn Jepson in the early 1900's, and should its identity be confirmed, it may further expand the gene pool for this rare species. Additional living specimens are known from the Rancho Santa Ana Botanic Garden (Claremont, California), the Regional Parks Botanic Garden (in Tilden Regional Park, Berkeley, California), the Santa Barbara Botanic Garden (Santa Barbara, California), the San Francisco Botanical Garden at Strybing Arboretum (San Francisco, California), and the University of California Botanical Garden at Berkeley. Plants grown from seeds from the type specimen were reported and documented as growing in Golden Gate Park in San Francisco and in Mill Valley (Marin County) in the 1930's, though it is not known if any of these specimens (or their progeny) are still alive (Everett 1957, RSABG Herbarium specimens 6211, 7480, 15457).

Cercocarpus traskiae was listed under the California Endangered Species Act as Endangered by the State of California in 1982, and was listed as Endangered on August 8, 1997 under the Federal Endangered Species Act. On Santa Catalina Island, *Cercocarpus traskiae* is threatened by hybridization with another species, *Cercocarpus betuloides* var. *blancheae* which occurs on adjacent land that is underlain by Catalina blue schist. Additional past and present threats include predation and habitat disruption from non-native mammals (goats – eliminated from the island in 2003, pigs – nearly eliminated by 2007, bison, and mule deer), fire, and non-native invasive plant species.

Currently, there is no federal or state mandated recovery plan for *Cercocarpus traskiae*. Should genetic analysis of the Santa Monica Mountains population and of the living specimens in cultivation reveal additional "pure" individuals with alleles not present in the wild population on Santa Catalina Island, vegetative propagules from these plants could be reintroduced to the island population. However, due to the geographically restricted habitat and the limited gene pool of the species, the future prospects for this species will continue to be of critical concern.

The species has been successfully propagated vegetatively. The best results from cultivated clonal plants (grown from cuttings from the wild) growing at Rancho Santa Ana Botanic Garden in Claremont California that have been recorded are: (i) 26 softwood tip cuttings were wounded and treated with 10% Dip'N Grow and were inserted in a plastic nursery flat of compacted perlite. (ii) 45 firm tip cuttings were wounded and treated with 20% Dip'N Grow and were struck in a plastic nursery flat of compacted perlite on December 18, 1997. Both of these approaches led to high success rates.

Plants have been grown from wild collected seed of *Cercocarpus traskiae* at Rancho Santa Ana Botanic Garden on very few occasions. The most successful group of seedlings of wild origin was raised in 1969 from seed collected and sown in 1968. In this case, a trace amount of seed (less than one-eighth ounce) was sown in a mixture of loam, peat moss, perlite, and sphagnum on October 9, 1968 that was then placed in a refrigerator at 38 °F until they were removed to ambient conditions on November 20, 1968. From this test, a total of 23 seedlings were potted up in 1969 into successively larger containers.

Source: Bart C. O'Brien, Rancho Santa Ana Botanic Garden, Claremont, California; see also Wallace et al. *(2007).*

- **Adaptation.** If the expected results were not obtained, then the assumptions were wrong, the actions were poorly executed, the conditions at the project site have changed or the monitoring was faulty. Adaptation involves changing assumptions and interventions in response to the information obtained as a result of monitoring. This is the defining feature of adaptive management.

- **Learning.** This refers to the process of systematically documenting the management process, and the results achieved. This helps avoid repeating the same mistakes in the future.

The adaptive management process typically involves six steps (Figure 2).

4.4. Step 4: Develop and implement longer term conservation strategy

The successful reintroduction of trees into the wild will not necessarily guarantee their long-term survival. To achieve this, development and implementation of a long-term conservation strategy is required. This will typically require long-term commitment and support from a range of partners, including the landowners or local communities on whose land the tree populations are present. Such a strategy will need to address the threatening process or factors responsible for the decline in the species of interest. Without an effective diagnosis of these threats, conservation will ultimately be unsuccessful, and therefore some suggestions are provided below for identification of threats. A further

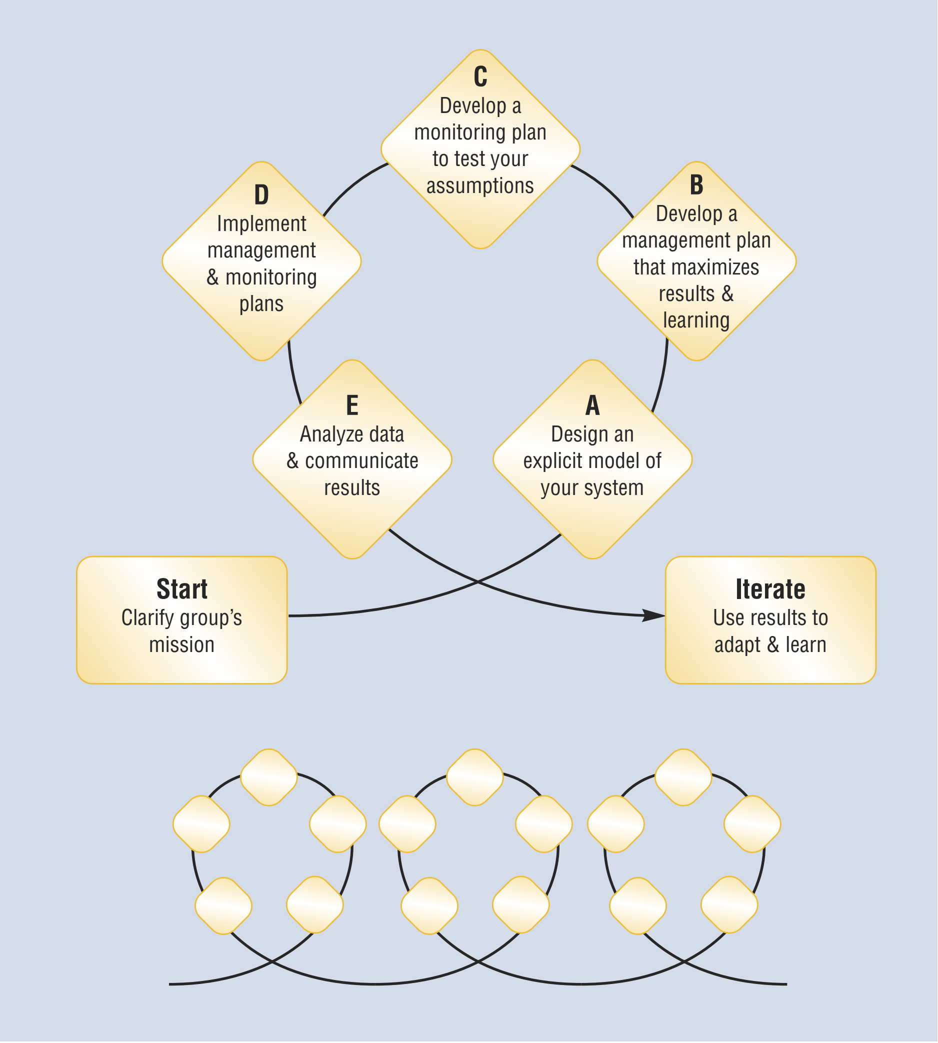


Figure 2. The adaptive management process (from Salafsky et al. *2001). The starting point of the cycle involves identifying the overall mission. Step A involves assessing the conditions and determining the major threats to biodiversity at the project site. Using a conceptual model, the project team defines relations between key threats, other factors and elements of biodiversity at the project site. Step B involves using this model to develop a project management plan that outlines the results that the project team would like to accomplish and the specific actions that will be undertaken to reach them. Step C involves developing a monitoring plan for assessing progress. Step D involves implementing the management actions and monitoring plan. Step E involves analysing the data collected during monitoring and communicating this information to the appropriate audiences. Results of this analysis are used to change the project and learn how to improve it in the future. Based on feedback information, there may be a need to modify the conceptual model, management plan, or monitoring plan.*

Community involvement in tree conservation. (BGCI)

point is that species may be dependent on a range of other species for their survival, including those involved in pollination, seed dispersal, and maintenance of a suitable growing environment. It may therefore be necessary to consider reintroductions of threatened species as just one element of an approach that aims to restore entire ecological communities or ecosystems. Some information on such approaches is also provided below.

4.4.1 Identification of threats

Effective conservation depends strongly on a full appreciation of the causes of biodiversity loss. Yet identifying such threats or 'threatening processes' often receives surprisingly little attention from either conservation managers or researchers. There is enormous scope for improving methods for assessing threats and diagnosing their impacts, and improving the quality of information available to support practical conservation management (Newton, 2007). However, identifying the precise causes of decline in the abundance of a particular species can often be surprisingly difficult.

Different types of threat may be identified. *Direct* threats are those that are directly responsible for loss or degradation of forests, or their associated biodiversity. *Indirect* threats are the underlying causes of such direct threats. For example, an underlying threat such as a government policy may be responsible for the direct threat of forest conversion to agriculture. Other terms used to describe threats include 'drivers' or 'pressures'; these terms may be preferred because they imply that effects on biodiversity can be either negative or positive, whereas the term 'threat' implies only negative impacts. However, it should be remembered that different authors interpret these terms in different ways. Salafsky *et al*. (2002) list many of the most widespread threats to biodiversity.

Robinson (2005) identifies the following main methods of assessing threats:

- **Conceptual modelling**, used to illustrate the relation between threats and their impacts, and for providing a strategic framework for identifying appropriate management interventions. Such approaches can be implemented very simply, for example by producing a diagram that illustrates the main features of an ecological system and how they are interconnected. This can then be used to explore the potential impacts of different threats on the system.

- **Threat matrices**. Matrices can vary from simple tables to complex logical frameworks linking different threats and interventions to conservation targets. Matrices are relatively simple to implement and can readily be updated, but their dependence on subjective information is a weakness. An example of a threat matrix is illustrated in Table 3.

- **Participatory threat mapping**, which can involve use of pictorial maps or diagrams to elicit information about changes in forest habitat quality or quantity, or the status of individual species, when working with community groups.

- **GIS-based mapping**, incorporating quantitative spatial data. Direct threats, such as habitat fragmentation, can be assessed and displayed by using GIS. Spatial or statistical models of land cover change can be used to explore and illustrate the potential impacts of different threats on forest extent, structure and composition.

Wilson *et al*. (2005) provide a detailed review of the concept of vulnerability in conservation planning, noting that information on threatening processes and the relative vulnerability of areas and features to these threats pervades the planning process. Pressey *et al*. (1996) defined vulnerability as 'the likelihood or imminence of biodiversity loss to current or impending threatening processes'. Wilson *et al*. (2005) extend this definition by distinguishing three dimensions of vulnerability, *exposure, intensity*, and *impact*, and provide the following information regarding their measurement:

- **Exposure** can be measured either as the probability of a threatening process affecting an area over a specified time, or the expected time until an area is affected. Exposure is commonly measured categorically, for example as 'high', 'medium', or 'low' suitability for agriculture, but has also been measured on continuous scales by some authors. Maps can be produced illustrating the relative exposure of different areas to a particular threat.

- **Intensity** measures might include magnitude, frequency, and duration of the threat. Examples include livestock density, volume of timber extracted per hectare of a forest type, or the density of an invasive plant species. Intensity can also be estimated categorically, and can be mapped across whole planning areas.

- **Impact** refers to the effects of a threatening process on particular features such as the distribution, abundance, or likelihood of persistence of a species of interest. For example, logging is likely to have a much greater impact on those species of high timber value than on other species that are not directly targeted during harvesting. Impact might also depend on the spatial pattern of the threatening process, for example on the degree of connectivity between forest patches retained after logging operations.

As conservation planning is generally spatial, a key issue is whether vulnerability can be mapped, and therefore integrated with other spatial information such as forest cover, boundaries of management units etc. According to Wilson *et al*. (2005), this requires mapping of spatial predictions of the future distribution of threatening processes. Maps of exposure can be based on the current distributions of threats and knowledge of variables that could predispose areas or features to those threats. For example, the likelihood of forest conversion to agriculture is often related to the suitability of the soil for agricultural crops, topography, and proximity to infrastructure or population centers. Impact is the most difficult dimension of vulnerability to map, as this may require feature-specific information on the effects of different levels of intensity, spatial information on features relative to variations in intensity, and ways of integrating this information across assemblages of species, sets of vegetation types, or other groups of features (Wilson *et al*. 2005).

As noted by Wilson *et al*. (2005), a comprehensive assessment of vulnerability would consider all of the threats affecting an area and also include the dynamic responses of threats to conservation actions. Combining vulnerability scores for multiple threats can be achieved by differentially weighting threats to reflect their relative importance, ideally informed by their respective impacts. It should also be remembered that risk analysis and hazard assessment are widely practiced by foresters, and a substantial literature exists on this topic, which could potentially be of value in a conservation context (Newton, 2007). Some methods used as a basis for assessing risk are described briefly below for some of the most important types of disturbance (after Newton, 2007).

- **Fire.** Forest fire risk is generally assessed by identifying the potentially contributing variables and integrating them into a mathematical expression or index. The index is used to indicate the level of risk, and can be mapped. A wide variety of different approaches are used to produce such indices, which vary particularly in terms of the timescales involved. Estimates of the probability of fire occurrence are typically based on variables such as the amount and type of fuel available for burning, topographic variables, vegetation characteristics and meteorological variables.

- **Wind**. A number of different approaches to analysing and modelling windthrow risk have been developed. Statistical models use empirical information on damage collated over a number of years in selected areas, whereas deterministic models consider tree or stand characteristics and the windiness of a site or the critical wind speed.

- **Herbivory**. The determination of browsing damage on forest regeneration at a given time can be used to forecast impacts in the future, for example when the timber is harvested or when the function of the forest is seen to have been compromised. The effects of browsing and the resulting damage can be decades apart. In order to estimate the long-term impacts of browsing, indicators may need to be specified for young forest stands at the time when top-twig browsing is no longer possible. Ultimately the risk of damage by herbivores is a function of animal behaviour, something that is difficult to predict but is also an active area of research.

- **Deforestation**. Research has indicated that deforestation can be related to a range of factors, such as population density, population growth, agricultural expansion, income levels and amount of timber harvesting. Typically, deforestation is assessed by comparing the forest cover at different times by means of remote sensing images. The factors responsible for deforestation, such as proximity to roads or towns, can then be analysed statistically.

Wuhan Botanic Garden. (BGCI)

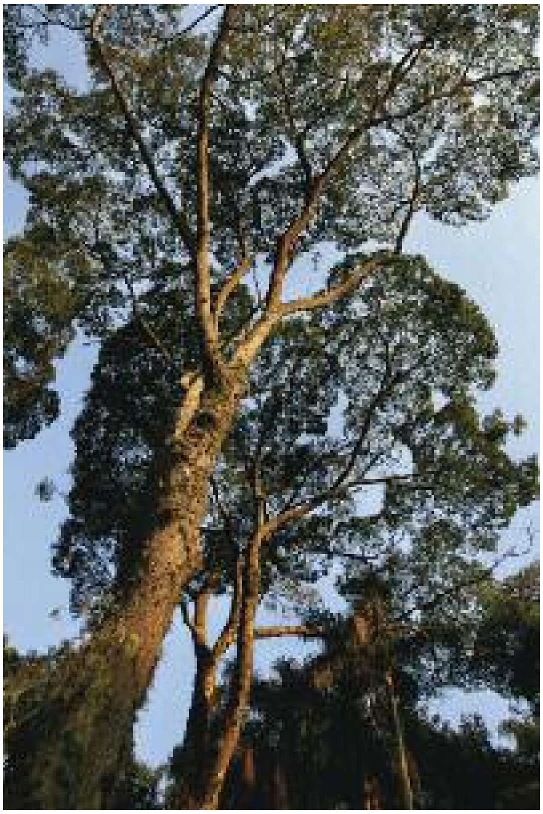
Activity	Extent	Impact	Permanence	Degree	Description and rationale
Harvesting	Localized (1)	Mild (1)	Short term (1)	1	Harvesting primarily involves collection of nuts for consumption by local residents. Harvesting occurs near an adjacent village, and harvesters generally leave large areas undisturbed.
Road	Scattered (2)	Moderate (2)	Medium term (2)	8	A road is planned through a portion of a protected area. The actual impact of construction will be minimized by using environmental best practices. It is a gravel access road, and will only be used seasonally by park staff and visitors with permits.
Tourism	Localized (3)	High (3)	Short term (1)	9	Tourists have recently begun to drive motorized, off-road vehicles through sensitive forest areas. Tourists' footwear and recreational devices can introduce invasive species including fungal diseases.
Poaching	Widespread (3)	High (3)	Medium term (2)	18	Animal species that play a crucial role in the dispersal and colonisation of tree species are being poached.
Alien species	Widespread (3)	High (3)	Long term (3)	27	Invasive alien species (such as *Hedychium*, wild ginger) are spreading through the forest, limiting seeding establishment for native trees.
Dam building	Throughout (4)	Severe (4)	Permanent (4)	64	There is a large-scale hydro-electric dam planned that would flood at least half of the protected area.

Table 3. Example of a simple method of scoring the different pressures or threats affecting a forest area (modified from Ervin, 2003). Here, different human activities have been scored on a simple scale with respect to three variables: 'extent', 'impact' and 'permanence'. Extent is the area across which the impact of the activity occurs. Impact is the degree, either directly or indirectly, to which the threat affects overall forest resources. Permanence is the length of time needed for the affected area to recover with or without human intervention. A combined score ('Degree') has been produced by multiplying the individual scores together.

4.4.2 Ecological restoration approaches

Chazdon (2008) provides a recent overview of the ecological restoration of forests, highlighting the progress being made in many countries towards reversing recent forest loss and degradation. Some initiatives have been highly successful, such as the Area de Conservación in Guanacaste in Costa Rica and the Auroville project in India, which have restored native forest over extensive areas. However, many restoration projects have faced significant challenges, such as the difficulty of addressing multiple threats and of overcoming severe ecological degradation.

One approach of particular value is *Forest Landscape Restoration* (FLR). The concept of FLR was first developed by WWF and IUCN in response to the widespread failure of more traditional approaches to forest restoration. Such traditional approaches have often been site-based, and typically focused on one or a few forest products, relied heavily on tree planting of a limited number of species, and failed to address the root causes of forest loss and degradation (Dudley *et al*., 2005). FLR represents a significant departure from such approaches (Table 4). The development and application of FLR has become a major activity of the WWF and the IUCN Forest Programmes, and is further supported by development of the Global Partnership on Forest Landscape Restoration (http://www.ideastransformlandscapes.org/), which now involves more than 25 organizations. Further details of the FLR approach are provided by Lamb and Gilmour (2003), Mansourian *et al*. (2005), Rietbergen-McCracken *et al*. (2007), Newton and Tejedor (2011) and Newton *et al*. (2012).



(Brent Stirton/Getty images/WWF UK)

Different approaches to forest restoration vary in terms of their relative cost, their benefits to biodiversity and their potential impact on provision of other ecological services, such as water regulation and nutrient cycling (Table 5). In general, the preferred method will be to allow the forest to recover naturally through a process of succession ('passive restoration'). For such successional recovery to occur, the following conditions must be met (Lamb and Gilmour, 2003):

- **The disturbing agent or agents must be removed**. If disturbances such as uncontrolled fire, timber harvesting or grazing continue, succession is interrupted and recovery is unlikely.
- **Plants and animals must remain at the site** or in the region as a source of new colonists, and must be able to move across the landscape and recolonize the degraded area. The more distant these source populations are, the slower the recolonization process. Potentially, connecting habitat fragments or 'stepping stones' can increase the rate of the recovery process. This is an argument for planning forest restoration at the landscape scale.
- **Soils at the site must remain reasonably intact.** If severe erosion has taken place or if fertility has been depleted the soils may no longer be suitable for the original species, and other species (perhaps not native to the area) may come to dominate.
- **Weed species, invasive exotic species or animal pests must be excluded or controlled** if the original community is to be re-established successfully.

In some situations the forest may be so degraded that natural recovery will be very limited. In such situations there may be a need to establish trees artificially, through methods such as direct seeding or planting of tree seedlings (Table 5). Key decisions that will need to be made include (Newton, 2007):

- **What should the spatial distribution and relative abundance of planted trees be?** Field surveys of soil characteristics and topographic variation across the site to be restored, together with autoecological information about the tree species selected, can be used to ensure that species are correctly matched to the microsites on which they are to be established. If the aim is to mimic natural forest structures, then spacing of trees should be irregular, and individuals of each species should be grouped.

- **How should planting stock be sourced?** For native forest establishment to be successful, planting material should be well adapted to the site conditions, and therefore local sources should be used.

- **How much of the area should be forested?** Open spaces within forest areas can be important as wildlife habitat, and therefore as much as 30%-40% of an area may be left unplanted initially, both to provide long-term open space and to provide areas for future tree establishment by natural regeneration or planting.

Another key issue is the need to monitor restoration progress, ideally as part of an adaptive management cycle (see Section 4.3.4). Many restoration projects neglect this important aspect. Once restoration targets or management goals have been identified, indicators will need to be developed to help track progress towards these goals. As a minimum, there will be a need to monitor the size and structure of the populations of reintroduced tree species, but the monitoring process might usefully be extended to include variables such as natural regeneration of young trees, extent of forest cover, presence of pollinators and seed dispersers, etc. Newton (2007) provides a comprehensive overview of techniques that can be used for monitoring of forest ecosystems.

Tooro Botanical Garden – involving the community. (BGCI)

Case study 17:

Native trees and shrubs for forest restoration in Madagascar

Forest restoration is underway at various scales in Madagascar to increase forest connectivity, enhance protected areas, restore mine sites and restore habitat for individual species. Production and plantation of young plants requires significant investment and would benefit from increased exchange of information between different projects to improve likelihood of success. Missouri Botanical Garden is working with a local NGO, Fikambanana Miaro ny Sohisika eto Tampoketsana (FMST), and other partners to study, conserve and expand the Ankafobe Forest, which contains much of the remaining population of the Critically Endangered tree *Schizolaena tampoketsana*.

The Ankafobe Forest area consists of fragments of humid evergreen forest surrounded by anthropogenic grassland. Fire breaks and patrols are used to promote natural regeneration of the forest and active restoration is being undertaken using young plants of native shrubs and trees. In January 2008, seedlings from 19 species were planted. The species used were those for which ripe seed samples could be collected during the previous two years. The seedlings had been raised in an outdoor nursery established by the project in the local village of Firarazana. The nursery consists of shaded propagation beds constructed of local wood with bamboo culms to provide shade. The seeds were cleaned by removing from the fruit and washing, with damaged seeds discarded. They were sown immediately in compost consisting of one third well-rotted manure, one third river sand and one third top soil from the forest. When the seedlings had at least one real leaf they were transplanted into polyethylene pots containing compost and grown in shaded nursery beds. They were gradually habituated to light and planted out when between 8-20 months old. They were planted early in the wet season on upper valley slopes of wooded grassland that was formerly forest. Each seedling was planted in a large hole where well-rotted manure had been mixed with the soil. Four to ten seedlings from each species were selected randomly for monitoring and marked with numbered stakes. The native species planted out in 2008 showed considerable variation in survival and growth rates highlighting the benefits of conducting species trials as part of forest restoration.

Source: Birkinshaw et al. *(2009)*

Table 4. Elements of Forest Landscape Restoration (FLR); from Mansourian (2005).

- Forest landscape retoration is implemented at a landscape scale rather than a single site - that is to say, planning for forest restoration is done in the context of other elements: social, economic, and biological, in the landscape. This does not necessarily imply planting trees across an entire landscape but rather strategically locating forests and woodlands in areas that are necessary to achieve an agreed set of functions (e.g. habitat for a specific species, soil stabilization, provision of building materials for local communities).

- It has both a socioeconomic and an ecological dimension. People who have a stake in the state of the landscape are more likely to engage positively in its restoration.

- It implies addressing the root causes of forest loss and degradation. Restoration can sometimes be achieved simply by removing whatever caused the loss of forest in the first place (such as perverse incentives and grazing animals). This also means that without removing the cause of forest loss and degradation, any restoration effort is likely to be in vain.

- It opts for a package of solutions. There is no single restoration technique that can be applied to all situations. In each case a number of elements need to be covered, but how to do that depends on the local conditions. The package may include practical techniques, such as agroforestry, enrichment planting, and natural regeneration at a landscape scale, but also embraces policy analysis, training and research.

- It involves a range of stakeholders in planning and decision-making to achieve a solution that is acceptable and therefore sustainable. The decision of what to aim for in the long term when restoring a landscape should ideally be made through a process that includes representatives of different interest groups in the landscape in order to reach, if not a consensus, at least a compromise that is acceptable to all.

- It involves identifying and negotiating tradeoffs. In relation to the above point, when a consensus cannot be reached, different interest groups need to negotiate and agree on what may seem like a less than optimal solution if taken from one perspective, but a solution that when taken from the whole group's perspective can be acceptable to all.

- It places the emphasis not only on forest quantity but also on forest quality. Decision-makers often think predominantly about the area of trees to be planted when considering restoration, yet often improving the quality of existing forests can yield bigger benefits for a lower cost.

- It aims to restore a range of forest goods, services, and processes, rather than forest cover *per se*. It is not just the trees themselves that are important, but often all of the accompanying elements that go with healthy forests, such as nutrient cycling, soil stabilization, medicinal and food plants, forest dwelling animal species, etc. Including the full range of potential benefits in the planning process makes the choice of restoration technique, locations, and tree species much more focused. It also allows more flexibility for discussions on tradeoffs with different stakeholders, by providing a diversity of values rather than just one or two.

- Forest landscape restoration goes beyond establishing forest cover *per se*. Its aim is to achieve a landscape containing valuable forests, for instance partly to provide timber, partly mixed with subsistence crops to raise yields and protect the soils, as well as partly improving biodiversity habitat and increasing the availability of subsistence goods.

Aloe dichotoma *(SANBI)*

Method	Relative direct cost	Relative rate of biodiversity gain	Potential ecological services benefit
(a) Prime focus of biodiversity restoration			
Passive restoration	low	slow	high
Enrichment planting	low–medium	slow–medium	high
Direct seeding	low–medium	medium	high
Scattered plantings	low	slow	medium
Close plantings of a few species	medium	medium	high
Intensive plantings after mining	high	fast	high
(b) Prime focus on productivity and biodiversity			
Managing secondary forests	low–medium	medium	high
Enrichment plantings	low–-medium	medium	medium–high
Agroforestry	medium–high	medium	medium–high
Monoculture plantations with buffers	high	slow	medium
Mosaics of monocultures	high	slow	low–medium
Mixed species plantations	high	slow	medium
Enhanced understorey development	low	slow	medium–high

Table 5. Relative costs and benefits of various methods of overcoming forest degradation (from Lamb and Gilmour, 2003)

4.4.3 Implementing a long-term integrated conservation strategy

Sutherland (2000) provides a valuable account of the elements of successful conservation strategies, which are relevant to the integrated approaches considered here. Such elements include (Sutherland, 2000):

- **Development of effective conservation plans**. Many projects are unsuccessful because of poor planning, particularly in situations where the projects are complex and involve many partners. It is important to review all available evidence and options to ensure that the appropriate approaches have been identified. The planning process involves identifying appropriate priorities, organising activities in a logical and achievable sequence, assigning responsibilities for action, involving the local public, determining budgets for the plan and its components, and identifying how to monitor and evaluate the success of the actions undertaken.

- **Organisational management**. Organisational problems are a major weakness of many conservation programmes. Leadership is an important aspect, in terms of providing direction, inspiration, confidence and enthusiasm. Managers need to create simple systems, clear measures for monitoring success of those factors that are of real importance (e.g. population size of the species of concern), clear individual or team responsibilities, and the capacity for individuals to work together on projects. Effective fund raising is likely to be an important part of organisational management, which brings its own challenges.

- **Education**. It is essential to consider the educational potential of any conservation project, because ultimately the success of the project will depend on public support, and the political and financial support that can follow on from this. Overcoming indifference to conservation problems is likely to depend on opportunities to appreciate areas and species, and education to highlight the ecological, aesthetic, cultural, spiritual, recreational and economic importance of species. Although conservation education often focuses on scientific arguments, a wider perspective is likely to generate wider support.

- **Policy changes**. The main methods of bringing about change are education, persuasion, economic incentives and changes in the law. The latter can potentially be achieved by campaigning, which is often an activity undertaken by conservation organisations. This can generate public concern and demand for change. Bringing about such change often requires tenacity and a rather visionary view of possible long-term solutions. Creation of an NGO is often a useful way of furthering a particular cause, which can unite those who share common interests.

Ceiba trichistandra *a tree of threatened tropical dry forests in Ecuador. (BGCI)*

- **Managing exploitation and sustainable use**. Overexploitation is a major threat to many species. However, many species are also of vital support to human livelihoods. Approaches are therefore required that enable species to be harvested and managed sustainably. How this can be achieved in practice for tree species is considered by Newton (2008). It is recommended that in such cases where a species is supporting human livelihoods, approaches for sustainable use are included as part of an integrated approach to conservation. In this way, the conservation action can make a positive contribution to sustainable development and poverty alleviation, which is likely to strengthen public support. Areas set aside for nature conservation through formal protection status, areas managed for commercial forestry on a sustainable basis or community run forest management all provide opportunities for *in situ* conservation of threatened trees, as does on-farm conservation.

5. Taking action

The integrated conservation and restoration of threatened tree species is urgently required and presents an exciting opportunity for botanic gardens. Such activities provide an opportunity for botanic gardens to demonstrate conservation leadership and demonstrate the valuable role they play to public and private land management agencies and to society at large, by becoming active participants in addressing the threats to tree species, the ecosystems they are part of, and the livelihoods of people that depend on them. There are many factors to consider in planning action and relatively few success stories to build on. Much of the existing literature on reintroductions relates to herbaceous plants and there is a need to address the gap for trees for which there are some different challenges. We hope this reference manual will be thought provoking and stimulate action. Access to financial resources may be challenging but the need for ecological restoration is becoming more widely recognised. Restoring tree populations and tree diversity is an essential component of this. The Global Trees Campaign a joint initiative of BGCI and Fauna & Flora International aims to conserve the world's most threatened tree species and their habitats. The recently launched Ecological Restoration Alliance of botanic gardens, coordinated by BGCI, brings together botanic gardens with a plan to restore 100 degraded and damaged ecosystems worldwide. Please join us in sharing your experiences and taking action to conserve and restore the world's imperilled trees.

Mahogany growing in its natural habitat. (Juan Pablo Moreiras / FFI)

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Annex 1: Further resources

ANPC: The Australian Network for Plant Conservation (www.anbg.gov.au/anpc/) has a number of publications on *ex situ* conservation and translocation (reintroduction) of threatened species.

ArbNet: ArbNet (www.ArbNet.org) is an online, interactive community of arboreta that supports the common purposes and interests of tree-focused public gardens. ArbNet facilitates the exchange of information and the sharing of knowledge, experience, and other resources to help arboreta achieve their goals. The ultimate goal of ArbNet and its member arboreta is to encourage the planting and conservation of trees and other plants for a greener, healthier, and more beautiful world. ArbNet is sponsored and coordinated by The Morton Arboretum, in cooperation with the American Public Gardens Association and Botanic Gardens Conservation International.

ATF: The Agroforestree Database (www.worldagroforestry.org) is a species reference and selection guide for agroforestry trees. In the context of the database, agroforestry trees are those that are deliberately grown or kept in integrated land-use systems and are often managed for more than one output. They are expected to make a significant economic or ecological impact, or both.

The main objective of the database is to provide detailed information on a number of species to field workers and researchers who are engaged in activities involving trees suitable for agroforestry systems and technologies. It is designed to help them make rational decisions regarding the choice of candidate species for defined purposes. Information for each species covers species identity, ecology and distribution, propagation and management, functional uses, pests and diseases and a bibliography. To date, more than 500 species have been included. The specific aims of the database are to:

- enable quick and efficient access to a consolidated pool of information on tree species that can assume useful production or service functions, or both;
- provide a tool that will assist with the selection of species for use in agroforestry and related research using factors that are relevant to the chosen agroforestry technologies;
- help researchers assess potential agroforestry trees for uses other than those commonly known, such as timber;
- provide indicators for the economic assessment of species through yield information on tree products.

CPC: The Center for Plant Conservation (www.centerforplantconservation.org) has produced essential resources on *ex situ* conservation and reintroduction. These include a reintroduction registry, numerous books that provide background and recommended protocols for *ex situ* and reintroduction activities.

FAO: Extensive information on forest management and forest genetic resources can be found at: www.fao.org/forestry

Floradata: www.florabank.org.au is an information system designed to help in growing Australian native plants. It collates plant species collection and propagation information on around 5,000 Australian species. A particular focus is on species used in rehabilitation.

Global Trees Campaign: The Global Trees Campaign is a joint programme of BGCI and Fauna & Flora International (FFI) that aims to conserve the world's most threatened trees and the habitats where they grow. The website www.globaltrees.org provides examples of tree conservation projects for individual tree species that are of global conservation concern.

GSPC Toolkit: The web-based GSPC Toolkit has been developed to provide assistance in the implementation of the Global Strategy for Plant Conservation of the CBD. The toolkit www.plants2020.net provides a guide to the GSPC and its 16 targets with extensive links to resources on plant conservation and restoration.

International Conifer Conservation Programme: The International Conifer Conservation Programme, established in 1991, combines taxonomic, conservation, genetic and horticultural research with international capacity building for conifer conservation. Further details at: www.rbge.org.uk/science/genetics-and-conservation/international-conifer-conservation-programme

International Plant Propagators Society: www.ipps.org is a membership organization for professionals involved in plant propagation. The website provides access to abstracts from papers presented at the conferences held annually in each of the IPPS regions around the world together with searchable indexes of papers arranged by subject, author and plant name. Access is also provided to the Plant Tissue Culture Information Exchange.

The Native Plants Website: is an online source of propagation information for species of the US. Initially designed by the USDA Forest Service, propagation protocols describe target seedling specifications and how to collect seeds or cuttings; how to grow the plant in a nursery; how to harvest the plants, seeds or cuttings; and how to outplant them. www.nativeplantnetwork.org/network/

The New Zealand Plant Conservation Network: was established in 2003 with the vision that 'no indigenous species of plant will become extinct nor be placed at risk of extinction as a result of human action or indifference, and that the rich, diverse and unique plant life of New Zealand will be recognised, cherished and restored'. www.nzpcn.org.nz/

Cercocarpus traskiae *at Rancho Santa Ana Botanic Garden (A. Kramer)*

Some internet resources on forest restoration are listed below:

UNEP World Conservation Monitoring Centre
www.unep-wcmc.org/restoration_626.html
UNEP WCMC provides a range of resources relevant to biodiversity conservation, including details of a series of case studies of forest restoration projects throughout the world.

Global Partnership on Forest Landscape Restoration
www.ideastransformlandscapes.org/
The Global Partnership is a network of governments, organizations, communities and individuals active in forest restoration at the landscape scale. The partnership is designed to support international efforts at forest restoration by fostering information exchange, and by linking policy and practice.

IUCN Forest Conservation Programme
www.iucn.org/about/work/programmes/forest/about_forest_conserv/
One of the key elements of the work of the IUCN Forest Programme focuses on Forest Landscape Restoration (FLR). This is achieved through a number of field-based projects. IUCN also provides a number of useful publications to support FLR implementation.

WWF's Forest Conservation Programme
wwf.panda.org/what_we_do/how_we_work/conservation/forests/forestlandscapes/
WWF has established a global network of over 300 forest conservation projects in nearly 90 countries, including a portfolio of forest landscape restoration programmes undertaken in collaboration with IUCN. WWF has adopted a target to restore forests in 20 landscapes of outstanding importance within priority ecoregions by 2020.

The Society for Ecological Restoration (SER) International www.ser.org/
A non-profit organization with more than 2000 members worldwide, widely recognized as a source for expertise on restoration science, practice and policy. Although it does not engage in restoration projects directly itself, the Society supports dialogue and information exchange through its website and through publication of journals such as *Restoration Ecology*. Guidelines for the management of restoration projects are provided here: http://www.ser.org/content/guidelines_ecological_restoration.asp

Annex 2: Principles of Access and Benefit Sharing

The Convention on Biological Diversity (CBD) has as one of its three objectives the equitable sharing of the benefits of biodiversity. To enable this, Article 15 of the Convention addresses the terms and conditions for access to genetic resources and benefit sharing. In CBD terminology, access and benefit sharing is generally referred to as ABS. The sovereignty of States over their natural resources is enshrined in the Convention as provided for in Article 15. This Article also provides that access to these resources shall be subject to prior informed consent and that access shall be based on mutually agreed terms in order to ensure the sharing of benefits arising from the commercial or other utilization of these genetic resources.

In 2010, the Parties to the CBD adopted the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization. By helping to ensure benefit sharing, the Nagoya Protocol creates incentives to conserve and sustainably use genetic resources. The Nagoya Protocol also covers traditional knowledge associated with genetic resources and the sharing of benefits arising from its use.

Botanic gardens hold in cultivation representatives of up to one¬third of the vascular plant species of the world, much of it obtained before the provisions of the CBD came into effect. Accordingly, botanic gardens have very special responsibilities and obligations to ensure that they follow fair and ethical policies relating to access to and use of their collections and benefit sharing that are fully in accordance with the terms of the CBD, the Nagoya Protocol and relevant national legislation. International collaboration in biodiversity conservation and ecological restoration is very well-established but is it essential to ensure that the principles of ABS are respected when plant material is exchanged between countries.

Terminology

Various terms are defined by the Nagoya Protocol as follows:

Utilization: ‘to conduct research and development on the genetic and/or biochemical composition of genetic resources, including through the application of biotechnology as defined in Article 2 of the Convention.’

Biotechnology: ‘any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use.’

Derivative: ‘a naturally occurring biochemical compound resulting from the genetic expression or metabolism of biological or genetic resources, even if it does not contain functional units of heredity.’

It will take some time to see how these terms are interpreted by governments and stakeholders, and interpretations may vary. For example, it is not yet clear how or whether straight *ex situ* plant conservation is included as ‘utilization’ if no genetic research is conducted.

Access

In the Nagoya Protocol, countries can decide whether or not to require Prior Informed Consent (PIC) for access to genetic resources and associated traditional knowledge. Those that do so must ensure that there are clear legislative, administrative or policy measures for obtaining PIC, with a permitting system in place. Countries also need to set up clear procedures for requiring and setting up Mutually Agreed Terms (MAT) in writing. As is already the case, some countries may choose to require prior informed consent in certain cases (for example in national parks) but not in others (for example on private land).

Prior Informed Consent

In practice, prior informed consent takes the form of collecting permits and material acquisition agreements, which define the uses to which plant material covered by the agreement can be put. Such agreements may also cover obligations for the exchange of information derived or resulting from research on, or from other uses of the material concerned.

Traditional Knowledge

The Protocol will require countries to work out how traditional knowledge can be accessed with the prior informed consent or involvement of indigenous and local communities. They will need to consider communities' customary laws, protocols and procedures, and work out, with these communities, how to inform potential users about their obligations. We are likely to see the development of more community protocols and model contractual clauses, and these should greatly assist botanical institutions working with traditional knowledge.

Benefit sharing

An annex of potential benefits is provided by the Nagoya Protocol. As well as the use of genetic resources, there are now several specific provisions on sharing benefits from use of traditional knowledge with the indigenous and local communities concerned.

Non-commercial research

Countries are required 'to create conditions to promote and encourage research which contributes to the conservation and sustainable use of biological diversity, particularly in developing countries, including through simplified measures on access for non-commercial research purposes, taking into account the need to address a change of intent for such research.'

This last part means that permits and agreements are likely to have clauses requiring users to ask for new PIC for commercial research, though the understanding of what is 'commercial' may vary between different mutually agreed terms.

Conservation and sustainable use

Users and providers are encouraged to direct benefits towards conservation and sustainable use. This article is useful support for the work that botanic gardens are already engaged in doing.

ABS authorities

Each country will need to set up a national focal point, to provide information on how to gain access and whom to contact, and one or more national competent authorities, responsible for granting access or issuing written evidence that access requirements have been met (if access is granted by others, such as provincial authorities or indigenous communities). The authority information will be posted on the ABS Clearing¬House.

ABS Clearing¬House

The ABS Clearing¬House will be the central information point for the protocol, where countries will share details of implementation, including what legal/administrative/policy measures are in place and ABS authority contact information, as well as information on permits issued. They may also include information on indigenous and local community authorities, model clauses for agreements, models and methods for monitoring genetic resources, and codes of conduct and best practices.

Compliance

Countries are expected to take measures to make sure that genetic resources/traditional knowledge have been accessed with prior informed consent and under mutually¬agreed terms. They also need to encourage providers and users to include dispute resolution mechanisms in their mutually agreed terms, and to set up measures for access to justice and mechanisms for recognition and enforcement of foreign judgements and awards.

Countries also must 'take measures to monitor and to enhance transparency about the utilization of genetic resources'. Measures include setting up one or more 'checkpoints' to collect or receive information on PIC, source, mutually agreed terms and/or use; users will need to provide information to them, and checkpoints will then send that information on to the relevant national authorities, the party providing PIC and the ABS clearing house. Many countries may designate patent offices and/or competent national authorities as checkpoints.

Model clauses

Countries will be encouraged to develop, update and use sectoral and cross¬sectoral model contractual clauses for mutually agreed terms, and the Protocol's governing body will periodically take stock of their use. Luckily for those gardens conducting non¬commercial research and needing some guidance, the Swiss Academy of Sciences has recently developed a model agreement with a range of options for different circumstances and concerns, based in part on analysis of many agreements already in use by a range of institutions (including some botanical gardens), and this may be a good starting point. Gardens managers would do well to familiarise themselves with this model agreement and work out how it relates to their institution's collaborations and concerns.

Codes of conduct

Countries should encourage development/update/use of voluntary codes of conduct, guidelines and best practices and/or standards on ABS, and the Protocol's governing body will periodically take stock of their use. Botanic gardens have been among the very first user communities to develop such measures in the framework of the IPEN (International Plant Exchange Network) code of conduct. This is presently being examined in line with Protocol. BGCI will endeavor to share new information on these topics via its website.

For further information on the Nagoya Protocol, please refer to the following:

An Explanatory Guide to the Nagoya Protocol on Access and Benefit-sharing, IUCN: https://cmsdata.iucn.org/downloads/an_explanatory_guide_to_the_nagoya_protocol.pdf

ABS tools elaborated by the Swiss Academy of Sciences: http://abs.scnat.ch/downloads/index.php

The CBD web pages on the Nagoya Protocol: http://www.cbd.int/abs/

Conifer propagation at the Royal Tasmanian Botanical Gardens (RTBG)

The Ecological Restoration Alliance of botanic gardens brings together the expertise, skills and plant resources of botanic gardens worldwide to restore damaged and degraded ecosystems. Launched in 2012, the Alliance aims to restore 100 sites in different ecosystems, responding to a United Nations target to restore at least 15% of the world's damaged ecosystems.

Global Trees CAMPAIGN

The Global Trees Campaign is undertaken through a partnership between **FFI** and **BGCI**, working with a wide range of other organizations around the world, to save the world's most threatened trees and the habitats in which they grow through the provision of information, delivery of conservation action and support for sustainable use.

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