INTERNATIONAL INTERNSHIP IN DEVELOPMENT

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Major Essay

Exploring the relationship between theory and practice of endangered plants conservation: case study of the role of botanical gardens and their challenges and limitations

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Introduction

Botanical gardens originated in the sixteen century in Europe about the same time universities started teaching the properties of medicinal plants (Tomasi 2005). At this stage, botanical gardens were places with a particular designed landscape for congregation and relaxation but also a place were scientist especially naturalist could study plants and their healing properties as well as botanist who analysed the structure of plants for identification purposes and started the process of differentiation between species what is known now as Taxonomy (Tomasi 2005). In the present, their role has evolved to a more specific agenda; botanical gardens are now concentrating their efforts in the conservation of plant biodiversity on earth (BGCI 2015a).

Plant biodiversity around the world is decreasing due to various factors, for example: land clearance, competition with invasive species, the domestication of plants, lost of habitat, etc. It is well known that other of species on earth depend on plants for their survival not only as a main source of food, but because plants for their functionality indirectly produce resources that are essential to life on planet earth (Polis & Strong 1996). Furthermore, it has been estimated that by the end of the 20th century as much as 15 % of the worlds plant species will be at risk of extinction (Bily 2015). Due to climate change some species of plants go through a process of adaption, some will shift ranges to more suitable ecosystems and others will face extinction (Edwards 2015). Among other variations related to changes in distribution, phenology and abundance (Gallagher et al. 2015). Nevertheless, some species and systems have the ability to cope with change, this
is known as adaptive capacity, though in an ecological context this attribute depend this changes have to occurred slowly in order for the species to adapt and evolve (Armitage 2005). Accordingly, rare species of plants are more susceptible to those changes because they have limited ability to adapt to climate-induced selection or may adapt very slowly (Edwards 2015). Being the most vulnerable species those that cannot adapt in their site of origin and are in need to be relocated for conservation purposes (Gallagher et al. 2015).

In light of the above, this paper questions the ability of botanical gardens to accomplish their goals regarding the conservation of plant diversity. It analyses ecological, social, administrative and political factors limiting botanical garden’s actions to achieve those goals. In the analyses it includes the ability of botanical gardens to put into execute and practise their agenda accordingly to local and international agreements, protocols and specific framework.

**Current thinking and strategies**

According to the IUCN red list (Internationals Union for Conservation of Nature) the number of threatened plant species (including critically endangered, endangered and vulnerable) in 2015 reached 10,896 (IUCNredlist.org, 2015). To addressed this, the IUCN works with botanical gardens in conservation programs around the world (Iucn.org, 2015). As it was mentioned before, botanical gardens (BG) have evolved, redirecting their work to meet conservation goals (BGCI 2015a). In the international
scientific atmosphere, the concern about future effects of biodiversity loss has increased due to changing climate (D'Angelo 2009). Due to threats causing changing in the ecosystems of many species, adaptive management is a commonly used technique to manage natural resources. Adaptive management can be considered as the work being done under the pressure and uncertainty of future events and their effects over plant species around the world (Armitage 2005; Folke et al. 2002; Holling 1978).

Preparing for the future by doing something in the present is the current trend in managing the environment and setting environmental policies. Collaborative work has been effective in conservation of natural resources by sharing a mission and responsibilities and also to influence governments to act towards meeting goals (Brown, Deletic & Wong 2015; Olsson, Folke & Berkes 2004). However, political or diplomatic pressure has been in some cases an effective driver of change (Lu, Stegman & Cai 2013). It is interesting to read about the concepts that are being applied to protect plant biodiversity and that botanical gardens play regarding this matter. First, for a species to be considered as threatened, an assessment of its status in the wild have to be performed, IUCN implemented Red list about 50 years ago and governments and other institutions have been collaborating the protection of those species. However, the numbers of threatened species on the Red list has only gone up since 1996 (IUCNredlist.org, 2015). It is clear that the ecosystem of threatened species is changing and those that are most vulnerable might face extinction if nothing is done to save the species. Botanical gardens have taken the responsibility to reduce the number of threatened species (BGCI 2012a), which is an important role in the conservation of thousand of plants around the world.
Due to the critical role that botanical gardens play, it is also important to analyse the impact of their work and their ability to perform their role in the present.

**Collaborative work and networking (in science, co-management, participation)**

Being loss of plant biodiversity a worldwide issue, collaboration and networking between nations is critical for biodiversity conservation. For this reason, Botanic Gardens Conservation International (BGCI) was created in 1987, as a network that supports BG (botanical gardens) around the world to achieve their conservation goals and regulates the procedures of ex-situ collections and seed banks, it also works in terms of the Global Strategy for Plant Conservation (GSPC) (BGCI 2015b). GSPC is part of a global strategy for conservation of species and it was created by the Convention on Biological Diversity (CBD). CBD has a broader function; in 2002 this institution established a set of goals to reduce biodiversity loss at a global, regional and national level by the year 2010 (Campbell, Hagerman & Gray 2014). In 2004 according to BGCI this goal was updated and in 2010 those goals were reported as failed. When reviewing some of the reason why those goals were not achieved, inter-institutional collaboration and setting realistic goals were two of the issues (Campbell, Hagerman & Gray 2014). This demonstrates that conservation work can not only be written on paper but in practice it is the conjunction of connected actions that make possible positive outcomes and that unrealistic goals cannot be met in practice.
Due to the results obtained in 2010, new sets of SMART (specific, measurable, achievable, realistic and time-related) targets have been set by the CBD for 2020. This new approach includes the application of political and scientific actions in collaboration with NGOs, governments and accordingly to international frameworks (Campbell, Hagerman & Gray 2014). This global initiative is a great example of collaboration and government getting involved to protect endangered plant species. The GSPC sets goals by country but a list of threatened species is reported as global, therefore collaborative work is necessary. In the present BGCI challenge associated botanical gardens to work accordingly to the 16 targets agreed for 2020. More than 500 botanical gardens are members of CBD and their collections contain no less than the third of the world’s plant species (BGCI 2015a).

Having a regulating institution is a good way of clarifying roles, setting limits and rules, and to standardized processes. Although, some of the activities performed by botanical gardens are costly, for example expedition expenses and the maintenance of ex-situ (Griffith, P & Husby 2010). Consequently, these targets might be unreachable for small botanical gardens in countries with little or non-funding and might also weaken their ability to work in these terms, mainly in comparison to other gardens in developed countries where government and public funding is available (Mwebaze & Bennett 2012).

To have GSPC targets for botanical gardens clear, they have been summarised in table 1. Target 7 and 8 are directly related to in-situ and ex-situ collections in botanical gardens, seed banks and tissue culture facilities, and the necessity to manage both in an
in an integrated way at a national level. Target 8 explicitly demands ex-situ collections to be accessible and duplicated and preferably located in the country of origin (BGCI 2012).

In theory the most recommended practice by BGs should be in-situ or place of origin conservation and efforts should be made towards achieving this (BGCI 2012). In practice this is not always possible especially for countries where economical factors are responsible for the failure of in-situ conservation work. For example the conservation of medicinal plants in countries like Africa and India, are affected by “poverty, market failures, corruption and global economic order (Hamilton 2004, p. 1492). Being these barriers to implement conservation programs, or even assigning governmental funding to those programs when other issues are more important to address. But this cannot be criticised of BGs in developing countries since solving this problem is not their role and their effort can only go as far as their power allows them. On the other hand if fund are assigned to protect or conserve threatened species this effort might not be sustainable since the same factors that originated the problem are not addressed. Setting worldwide goals to improve the way we manage natural resources is a practice that has been performed for various years to share and distribute the responsibility of every party involved. Though, achievement has not always characterized the result because individual governance and interest are involved in retarding the practical part that is needed to transform agreements into actions.
<table>
<thead>
<tr>
<th>GSPC</th>
<th>Global Strategy for Plant Conservation</th>
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<tr>
<td><strong>Objective I:</strong></td>
<td>Plant diversity is well understood, documented and recognized</td>
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<td><strong>Target 2</strong></td>
<td>An assessment of the conservation status of all known plant species, as far as possible, to guide conservation action</td>
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<td><strong>Objective II:</strong></td>
<td>Plant diversity is urgently and effectively conserved</td>
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<tr>
<td><strong>Target 4</strong></td>
<td>At least 15 per cent of each ecological region or vegetation type secured through effective management and/or restoration</td>
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<td><strong>Target 7</strong></td>
<td>At least 75 per cent of known threatened plant species conserved in-situ.</td>
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<td><strong>Target 8</strong></td>
<td>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</td>
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<td><strong>Target 9</strong></td>
<td>70 per cent of the genetic diversity of crops including their wild relatives and other socio-economically valuable plant species conserved, while respecting, preserving and maintaining associated indigenous and local knowledge</td>
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<td><strong>Target 10</strong></td>
<td>Effective management plans in place to prevent new biological invasions and to manage important areas for plant diversity that are invaded</td>
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<td><strong>Objective III:</strong></td>
<td>Plant diversity is used in a sustainable and equitable manner</td>
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<td><strong>Target 12</strong></td>
<td>All wild harvested plant-based products sourced sustainably</td>
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<td><strong>Target 13</strong></td>
<td>Indigenous and local knowledge innovations and practices associated with plant resources, maintained or increased, as appropriate, to support customary use, sustainable livelihoods, local food security and health care</td>
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<td><strong>Objective IV:</strong></td>
<td>Education and awareness about plant diversity, its role in sustainable livelihoods and importance to all life on earth is promoted</td>
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<td><strong>Target 14</strong></td>
<td>The importance of plant diversity and the need for its conservation incorporated into communication, education and public awareness programmes</td>
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<td><strong>Objective V:</strong></td>
<td>The capacities and public engagement necessary to implement the Strategy have been developed</td>
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<td><strong>Target 16</strong></td>
<td>Institutions, networks and partnerships for plant conservation established or strengthened at national, regional and international levels to achieve the targets of this Strategy</td>
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Based on the information provided by BGCI 2012
The role of botanical gardens towards plant conservation in a changing climate

As it was mentioned earlier, due to climate change, adaptive management is the most common theory being applied by institutions working with natural resources. Quantifying the work of botanical gardens in global conservation is difficult to evaluate (Havens et al. 2006). The impact of the work done by botanic gardens is being measured by the reduction in the number of threaten or endangered species or improvement in their status (CBD 2010). Nevertheless, changes associated with climate change are still uncertain (Regan et al. 2012) and these uncertainties arise questions like: would this changes affect the collections at botanical gardens (in-situ) and would those plants be able to survive for the purposes they were being protected and for how long would this be?.

Cibrian-Jaramillo et al. (2013) suggested that for a better use of living collection in botanical gardens these should be aligned to threatened species conservation goals. According tho this, ex-situ collections should be only in botanical gardens until they are not longer threatened. Being not longer necessary to have an ex-situ collection of every plant as the way to rescue the species. In this context, botanical gardens should indeed practice different ways to protect the species of plants in the place of origin as it is theoretically recommended by the BGCI.

In practice, some of the assumptions for conservation purposes would not work as planned. In some locations, climate change will make impossible the relocation of to their original ecosystem and will have to be reintroduce to a ‘climate-ready’ location.
(Gallagher et al. 2015, p. 13) using techniques like assisted colonization which is explain in detail below. Nonetheless, it is important to consider that if climate also changes in this places where botanical gardens are located, the risk of loosing their collection is also something of concerned.

The application of science in the conservation of endangered plant species

Not all botanical gardens are responsible for conservation work and some have not included in their mission the commitment to fight extinction or the loss of biological diversity (Powledge 2011). Some gardens are use only for educational and recreational purposes this because in the past, the most representative work of botanical gardens in conservation were living plant collections to meet those purposes. Botanical gardens roles depend mostly on their budget, scope, funding, governance and size (Rae 2011). Although botanical gardens have a diverse number of plant collection on ground or in seed banks, these specimens are not always genetically diverse to be use in restoration programs in their country of origin. Knowing how diverse a living collection is, sets the start point for conservation work in botanical gardens (Knapp et al. 2014).

Science plays an important role in restoration project and in-situ collection establishment and the application of this knowledge have generated new approaches to plant conservation, being assisted colonization one of these techniques. Assisted colonization is a well-known term in conservation work that involves relocating or translocating plants at risk of extinction to a more suitable habitat and conditions
(Gallagher et al. 2015), these locations are known as novel ecosystems (Chapin & Starfield 1997).

As a technique of adaptive management, assisted colonization might be an option to uncertain variation in climate. However, there are few critics related to problems with introducing new species of plants to a different ecosystem, where they can become weeds that compete with other plants or host of diseases that may affect other species (Klenk & Larson 2013; Loss, Terwilliger & Peterson 2011). However, if done with all the correct measures, assisted colonization in conjunction with risk assessment, and other restoration techniques can facilitate the survival of plant species (Hewitt et al. 2011; Loss, Terwilliger & Peterson 2011).

Assisted colonization can be implemented in Botanical gardens in the sense of establishing ex-situ collections in location with suitable climate and with less risk of extinction (Gallagher et al. 2015). However assisted colonization is still debatable among scientist and untrusted and not well documented. Nevertheless, restoration programs are being practice in-situ around the world, as examples are collaborative projects, in which botanical gardens in developing countries work together with botanical gardens around the world to support restoration of habitat for threatened species. Two of the case supported by BGs and IUCN are the restoration projects executed by the Montgomery Botanical Center (MBC) from USA in Belize for the conservation of a threatened species of cycad (IUCN.org 2015a). The other is the collaboration of Royal Botanical Garden in Jordan to conserve sites of significant biodiversity and habitat to threatened species (IUCN.org 2015b). Nonetheless, the success of restoration programs is not solely
responsibility of BGs but of all the stakeholders (local government, community, scientist, etc.) involved in the survival of the in-situ plants (Hamilton 2004).

Meeting standards for conservation collection.

The other option and the one that botanical gardens have been performing since they first originated is maintaining collection of plants. Botanical gardens face various challenges when in the reproduction of rare plants. For example, *Zamiaseudoparasitica* has to be hand pollinated at the right time of the year to ensure viable pollen and over artificial pollination could cause the plant to die (Gorelick & Olson 2011).

Collection size

The conservation of plants in theory has been performed for many years by botanical gardens, although shifting roles and functions could make years of work insignificant in the present due to climatic or genetic factors. Collections have to ensure genetic diversity and to guarantee appropriate breeding systems with neutral and adaptive genetic diversity (Gallagher et al. 2015). The collection should be from wild collected specimens, that have genetic diversity representative of the wild population (Rae 2011). For example, specimen collected in the wild has to come from different in-situ plants, and this is crucial because genetic diversity in a population make species of plant less susceptible to new diseases (Peakall et al. 2003) and more resistant or resilient to climatic changes (Pillar et al. 2013). Species of plants with low genetic diversity have a
higher risk of becoming extinct (Burdon 2001). Looking forward to the use of this collection to help restore wild-populations (Rae 2011). This can be achieved by cultivating several individuals from multiple populations (Cibrian-Jaramillo et al. 2013). In practice this is not always achievable since some threatened species population are limited in numbers (Griffith, MP et al. 2015).

Larger collections conserve greater genetic diversity (Cibrian-Jaramillo et al. 2013). Botanical gardens have to be capable of managing the ex-situ collection to maintain genetic variation with in the collection. Methods of genetic variability have been developed to compare ex-situ collections with plants from their natural populations. This method compares allelic richness and heterozygosis, which are both indicators of a population’s baseline genetic variation (Nei & Roychoudhury 1974).

In light of the above, Jackson cited in Powledge (2011) suggested that ex-situ conservation could result into something similar to plant domestication due to the limited number of specimens in cultivation which do not allow plants to develop and evolve as the do in their natural habitat an ecosystem. Therefore, replication is important and not only one or few gardens can have in their collection the threatened species, due to this being a risk to the conservation of those species (Powledge 2011).
Exploring the challenges of this institutions

Other than the challenges associated directly with climate change, restoration programs, maintaining genetic diversity in ex-situ and in-situ collections and socioeconomically problems there are those associated with the administration of the garden. On this challenges is maintaining record of the origin of the wild collected specimen, this task gets easier with technology but in the past it was rarely performed or incomplete. Failure to do this may result in the individual plant not being used in future research or conservation work (Rae 2011). In theory, documented new specimens should be store in a herbarium with assigned accession numbers. In practice not all BGs have the infrastructure to keep those specimens in good conditions free of pests and dry. Protocols for specimen collection and documentation are follow by BG and many paper talk about way to improve the genetic diversity in plant collections and are regulated by BGCI (BGCI 2015b).

Policies and Regulations

Botanical gardens have the challenge of maintaining an ex-situ collection that conserves the greatest diversity in an efficient way in terms of cost. For this reason it is important to maintain a balance between the number of plants in the collection and the funds allocated for it maintenance without decreasing genetic capture (Cibrian-Jaramillo et al. 2013). The number of plants in a single plant collection is sometimes limited by the cost to grow those plants. In practice this can not always be done with plants in high risk of extinction. In this case, when plants are estimated to be extinct in the wild it is important to conserve
every specimen growing ex-situ since redundancy is important in a collection; eventually some thinning of genetic duplicates can be done only if necessary to reduce cost (Griffith, P & Husby 2010).

**Technology applied to conservation**

Factors related to the maintenance of the living collection in BGs are solved by the use of technology. Technology can be applied to seeds, young plants and mature plants. Below are some of the most common techniques used by most BGs.

- Germination limitations exist when the numbers of male and females is not equal: For some species of plants, especially those with male or female individuals this is the case of dioecious species which are those in which male and female reproductive structures are borne on separate plants (Elzinga 2001).

- Greenhouses and nurseries in botanical gardens are created for the germination of seeds that are wild collected and to provide adequate conditions for the plant to grow until it is ready to be planted on the ground. The use of technology in this case is important to provide the necessary conditions and facilitate the development of healthy plants (Brockway 1979).

- The use of media for seed and plants varies between species. Research has been conducted to choose the most effective media mix for specific plants (Murphy et al. 2013).
• Species Distribution Models (SDMs): modelling predicts the suitable habitats for species under current scenarios and future changes in climate (Gallagher et al. 2015).

• A platform called BGCI plant search database allows gardens to connect to other conservation communities and to build data about their collections that can be use for botanical research (Cibrian-Jaramillo et al. 2013).

Ideally, every BG should have access to basic technology to ensure the required conditions for the collection to conserve the characteristics needed to be use in restoration programs or as specimens that are genetically diverse. However not every BG has access to funds to invest in everything (Abramovitz 1991).

Public support

In the definition for botanical garden by the BGCI, it is established that this institution should be open to the public. This is an issue for gardens that are not well known or which work is not attractive to the public. As it was mention earlier the main objective of botanical gardens is the conservation of plant species specifically those that are threatened. Although this in practice, it seems that educating the public is overtaking the time and effort from botanical gardens (Maxted, Ford-Lloyd & Hawkes 1997). Maintaining the grounds (gardens) and presentable landscape and inviting for the visitor
is another of their functions. However the cost of maintenance and staff salaries, the coordination events that might demand time; are activities and expenses that for some gardens represent income but for others might not. The recognition of the work that gardens do is not only celebrated by the scientific network but should also be shared with their visitors (Maxted, Ford-Lloyd & Hawkes 1997). Public support is usually associated to governmental support and funding, this is why educational programs are ways of interacting with the general and sharing the importance of their work with visitors of the garden (Miller et al. 2004; Ward, Parker & Shackleton 2010). BGs involvement with the community is the pathway to get the support they need to do their job.

**Conclusion**

In the past, the theory of plant species conservation did not clarify the role of botanical gardens in a practical system; in the present there is a framework that every institution under this name has to accomplish to be recognized as a BG. Furthermore, BG have played a role that not others institutions have performed in the conservation of plant species. Their mission and goals are getting more specific due to changes in climate and other threats to plant biodiversity. A network of scientist that work in BG around the world has been created to share experiences, implement new ideas, do research, to establish responsibilities and create protocols.

Due to uncertainty in climate change, techniques from adaptive management are use to safeguard plant biodiversity, although further studies are necessary to evaluate their effectiveness. Botanical gardens network, BGCI plays an important role as a regulator
and coordinator of the activities and processes performed by BGs around the globe. BGs work is mainly oriented to plant conservation and works towards achieving the targets from Global Strategy for Plant Conservation GSPC based on the listed threatened species from the Internationals Union for Conservation of Nature (IUCN). Challenges are being faced because of the social, economical, administrative and political factors, being those barriers to achieving conservation. However, it is still questionable if the role of BG is a priority in plant conservation due to future uncertainties and gaps in the science being applied. However, they have been the institutions that have done this job for hundreds of years and their role has evolved and adapted to the necessities of environment.
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