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BOTANIC GARDENS FOR THE FUTURE: INTEGRATING RESEARCH, CONSERVATION, ENVIRONMENTAL EDUCATION AND PUBLIC RECREATION

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ABSTRACT: Based on centuries of historical development, botanic gardens have now developed into leading institutions in the fields of conservation, research, education and recreation on a global scale. Botanic gardens increasingly play a role in providing a scientific basis towards sustainable use and conservation of plant diversity. Due to a rising public awareness on biodiversity, they become important windows to the public. Gullele Botanic Garden is predestined to make an impact as a model institution for the Horn of Africa and beyond, building upon achievements already made through programs such as the Ethiopian Flora Project and using an excellent location in Addis Ababa as one of the major cities of the African continent. Making an impact in the area of plant biodiversity appears to be achieved best as a concerted action of administrative and scientific stakeholders. Becoming a nucleus in a future Ethiopian Botanic Gardens Network, Gullele Botanic Garden should have the potential to significantly contribute to conservation and sustainable development, as well as enriching the cultural landscape in the Ethiopian capital of Addis Ababa.

INTRODUCTION

Overview on the historical and modern role of botanic gardens

The original idea of botanic gardens as scientific plant collections dates back to the middle of the 16th century, when the first true botanic gardens were established at European universities (Hill, 1915; Hyams, 1969). These gardens in Italy (1543 Pisa, 1545 Padua, 1550 Florence), Germany (1580 Leipzig) and the Netherlands (1590 Leiden) were by that time mainly devoted to the academic study of medicinal plants (Oldfield, 2007).

During the age of European expansion and exploration of the colonies in Asia, America and Africa (17th to 19th century) botanic gardens and their associated herbaria gained an important role in the study of newly discovered exotic plants, especially those in colonial empires such as the Royal Botanic Gardens, Kew in the UK or the Hortus Botanicus Leiden in Holland (Brockway, 1979; Hyams, 1969). Furthermore, botanic gardens were active in the introduction and 'acclimatization' of new economically important plants to Central Europe. A well-known example is the

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introduction of bulbs from the Near East to the Hortus Botanicus Leiden, which where cultivated and studied there by Carolus Clusius and later gave rise to the Dutch tulip breeding industry and the "tulip mania" during 1630s (Dash, 1999).

European botanic gardens were also most influential for the cultivation, propagation and dissemination of tropical plantation crops to and between the overseas colonies, often accompanied by enormous races for commercial monopoles and seed smuggling to break these monopoles. One of the most famous examples is that of coffee: all the industrial coffee plantations in Brazil, Suriname, and French Guiana as well as in Martinique can be traced back to seeds from a single plant grown in the Botanic Garden of Amsterdam at the beginning of the 17th century (Masefield, 1967; Baker, 1978; Pendergrast, 1999). Other examples are the stories of rubber (*Hevea brasiliensis*) and cinchona (*Cinchona* spp.) which were collected illegally in South America in 19th century, smuggled to London and propagated in the Royal Botanic Gardens, Kew, and then later disseminated to and established in the British colonies in Asia (Brockway, 1979). There is also one German example of breaking plant product monopoles: in 1895 a German expedition to Central and South America brought back seeds of *Myroxylon balsamum* var. *pereirae*, the Peru balsam tree, which was used as a medicine (balsam) for burns and other wounds. Until this time, Peru balsam was produced only in Guatemala and El Salvador which exported it to the international market. However, the plants were propagated in Berlin, transferred to the newly founded botanic garden in Victoria, Cameroon, and later successfully cultivated and exploited in other German colonies in Africa (Lack and Haas, 2000). Like the Victoria Botanic Garden (today Limbe Botanic Garden), many tropical botanic gardens worldwide were founded during the colonial period as introduction and 'acclimatization' centres for tropical crops, such as in the Caribbean (e.g., St. Vincent; Howard, 1997), South America (e.g. Rio de Janeiro; Padilla, 2008), or tropical Asia (e.g., Calcutta, Bogor and Singapore; Holttum, 1970). Many of these still persist to the present day; and although the introduction of exotic plants nowadays is of much lower economic importance (except maybe for horticultural purposes), several botanic gardens still see this as part of their mission (Heywood, 2011).

Especially in botanic gardens of larger metropolitan areas, the horticultural aspects and their function for public recreation always played an important role in the institutional mission. Many civic or municipal gardens were founded during the 19th and 20th century in Europe as well as in North America and Australia (Heywood, 1987). Many of them lacked a connection

to a botanical research institution, but there are a few notable and well-known exceptions, such as the Missouri Botanical Garden in St. Louis – today one of the world's most important botanical gardens and research institutions (Heywood, 1987).

New tasks for botanic gardens arose in the second half of the 20th century, when the need for conservation and sustainable use of biodiversity was recognized globally. Many botanic gardens became active in the conservation of rare and threatened plant species, either on an individual basis (often in cooperation with local public authorities for nature conservation) or in national and international networks. A famous example is the re-discovery of an extinct tree species from the Easter Island, *Sophora toromiro*, in botanic garden collections in Bonn and Gothenburg (Lobin and Barthlott, 1988), which was propagated and later repatriated successfully in a collaborative conservation project (Maunder *et al*., 2000). Currently, botanic gardens are working on the establishment of standardized methods for the *ex situ* conservation of genetic diversity of rare and threatened plants, either in living collections (e.g., Burkart *et al*., 2005, Rucińska and Puchalski, 2010) or in seed banks (ENSCONET, 2009).

At the same time, when the conservation of biodiversity became an official objective of international policy (inauguration of the Convention on Biological Diversity, CBD, at the UN Conference on Environment and Development in Rio de Janeiro, 1992) the importance of public education and awareness raising for sustainable development was globally acknowledged (as laid down in the Agenda 21 at the same UN conference in 1992). Education for sustainable development has therefore become an important task of botanic gardens (Willison, 2006). The role of botanic gardens as windows to the public is especially important, since already half of the world's human population nowadays lives in urban areas, where people are remote from nature and agricultural practices (UN, 2010).

The modern botanic gardens are centres of plant conservation, research and education and thereby contribute substantially to sustainable development of our societies. Therefore, it seems promising that the number of known botanic gardens has increased significantly during the last decades: from 1,400 in 1987 (Heywood, 1987) to around 1,850 in 2000 (Wyse Jackson and Sutherland, 2000) and even over 2,800 in 2010 (Sharrock *et al*., 2010). This drastic increase is not only due to more comprehensive lists of existing gardens and similar institutions, but also due to actual foundations of new botanic gardens. Prominent examples of national botanic gardens still under

construction are, e.g., the Oman Botanic Garden (Patzelt *et al*., 2008; 2009) or the National Ecological Institute of Korea (Crane and Choe, 2010). Both examples will include facilities for research and conservation, as well as public education and recreation.

The impact of individual botanic gardens, in terms of conservation, research as well as education, has been significantly increased by the establishment of effective national and international networks, which nowadays exist in many countries and several regions of the world. In many cases, a major garden is the leading institution of a national network, serving for national needs (e.g., the Brazilian Botanic Gardens Network led by Rio de Janeiro Botanical Garden). Those networks allow the development of common standards and codes of conduct (e.g., on access and benefit sharing or on invasive species), the continuous exchange of knowledge and expertise (e.g., in annual meeting, working groups and workshops), as well as the exchange of seeds and other plant material. Last but not least, networks allow for effective representation of botanic gardens' interests in the political arena. The prominent projects and activities of the German Association of Botanic Gardens, for example, led to the official recognition of botanic gardens as important stakeholders in conservation and education. Botanic gardens are mentioned in the German National Strategy for Biological Diversity (Küchler-Krischun, 2007) as facilities that need to be supported in order to meet the national biodiversity conservation goals.

Furthermore, botanic garden networks have been active in promoting the conservation of diversity in so-called biodiversity hotspots in several regions of the world, e.g., the Caribbean Botanic Gardens for Conservation Network with a lot of recent new activities (Leiva Sánchez and Hernández Monterrey, 2009; 2010, Torres-Santana *et al*., 2010). This example seems to be of special relevance for the Gullele Botanic Garden, since Ethiopia is part of two of the 34 global biodiversity hotspots, the arid Horn of Africa and the Eastern Afromontane hotspots (Mittermeier *et al*., 2004).

At the global level, Botanic Gardens Conservation International (BGCI) is nowadays the most important umbrella organization for botanic gardens. The roots of this organization can be traced back to the 'Botanic Gardens Conservation Co-ordinating Body', which started its work in 1979 as a specialist group of IUCN (Oldfield, 2007). Officially founded in 1990, BGCI is since then actively networking botanic gardens worldwide, providing tools and information on conservation, education and human well-being, as well as policy frameworks such as the 'International Agenda for

Botanic Gardens in Conservation' (Wyse Jackson and Sutherland, 2000) and the 'Global Strategy for Plant Conservation' (Secretariat of the Convention on Biological Diversity, 2002; Wyse Jackson and Kennedy, 2009).

Definition and criteria of botanic gardens

A comprehensive and widely recognized definition for botanic gardens is given in the 'International Agenda for Botanic Gardens in Conservation' (Wyse Jackson and Sutherland, 2000):

"Botanic gardens are institutions holding documented collections of living plants for the purposes of scientific research, conservation, display and education".

However, the term 'botanic garden' is not protected or bound to the fulfilment of this definition. In practice, the concept of a botanic garden is often reduced to gardens where plants are labelled with scientific names. Wyse Jackson and Sutherland (2000) even note that 'some institutions have been accepted into the list even though they might only be marginally described as a botanic garden'. Thus, the current count of over 2,800 botanic gardens in BGCI's database (Sharrock *et al*., 2010) is probably an overestimation and the number of 'true' botanic gardens can be expected to be much lower.

The 'International Agenda' (Wyse Jackson and Sutherland, 2000) gives a good a guideline for botanic gardens as it lists a number of criteria that botanic gardens should strive to fulfill. Among these, we consider the following as basic principles for botanic gardens:

(1) Botanic gardens have scientific criteria for their plant collections;

(2) Botanic gardens provide adequate documentation of the plant collections;

(3) Botanic gardens are permanent institutions; and

(4) Botanic gardens are open to the public and to the scientific community.

The scientific concept underlying the living plant collections is an important characteristic that distinguishes botanic gardens from mere ornamental gardens. Of course, scientific concepts of living collections can vary widely and are often a product of the individual history of each garden. The layout of the Berlin Botanic Garden, for example, is following the theme "The World in a Garden" (Lack and Haas, 2000) and includes large areas where plants are arranged according to phytogeographical aspects as well as areas

where plants are shown in systematic order (Fig. 1). The Berlin example also shows that a scientifically designed botanic garden can be at the same time very ornamental, thereby attracting a large number of visitors (in Berlin currently over 300,000 per year).

Fig. 1. Map of the Botanic Garden and Botanical Museum Berlin-Dahlem, which covers an area of 43 hectares. The garden's design follows the central theme "The world in a garden" and thus, its outside area is subdivided into a large plant geographical section, a system of woody plants (arboretum) and a number of smaller sections (e.g., the system of herbs, the medicinal plants garden and ornamental sections such as the 'Italian Garden'). The phytogeographical theme is pursued also in the public green houses. A phytogeographical approach - "The World in a Garden".

Plants in the living collections of botanic gardens need to be documented in an adequate and sustainable way. The documentation should at least include name and provenance of each accession, but further information might be included (e.g., cultivation and propagation protocols). Only well and sustainably documented plants are adequate sources for scientific research as well as *ex situ* or *in situ* conservation measurements (Rae, 2011; Van den Wollenberg, 2011). This requires a permanent and unambiguous labelling of all accessions in the living collection. An example for the complex information that can be included in accession numbers is given in Fig. 2, but see also Fig. 3 for illustration. Furthermore, a permanent scientific curation, including verification of scientific names and taxonomy as well as the deposition of herbarium vouchers, is essential for the proper documentation of living collections. All information on the plant collections should be kept in permanent, flexible and accessible data bases (see, e.g., Berendsohn *et al*., 1999; Paton, 2009). There is also a need for especially trained gardening and technical staff, since the cultivation and maintenance of the valuable collections requires special knowledge and expertise (Leadley and Green, 1998).

All in all, the provision of well-documented, scientifically curated and professionally managed living collections is only possible in permanent institutions with a long-term commitment to plant conservation, research and education. In order to fulfil the abovementioned definition completely, these institutions need to be open to the scientific community as well as to the general public (see below). Communication and education programmes help to increase visitor numbers and to raise public awareness for the intriguing diversity of plant life and the relevance of botanic gardens. The 'Darwin Technical Manual for Botanic Gardens' (Leadley and Green, 1998) gives a good overview on the basic requirements and international standards that need to be considered when establishing and running a botanic garden.

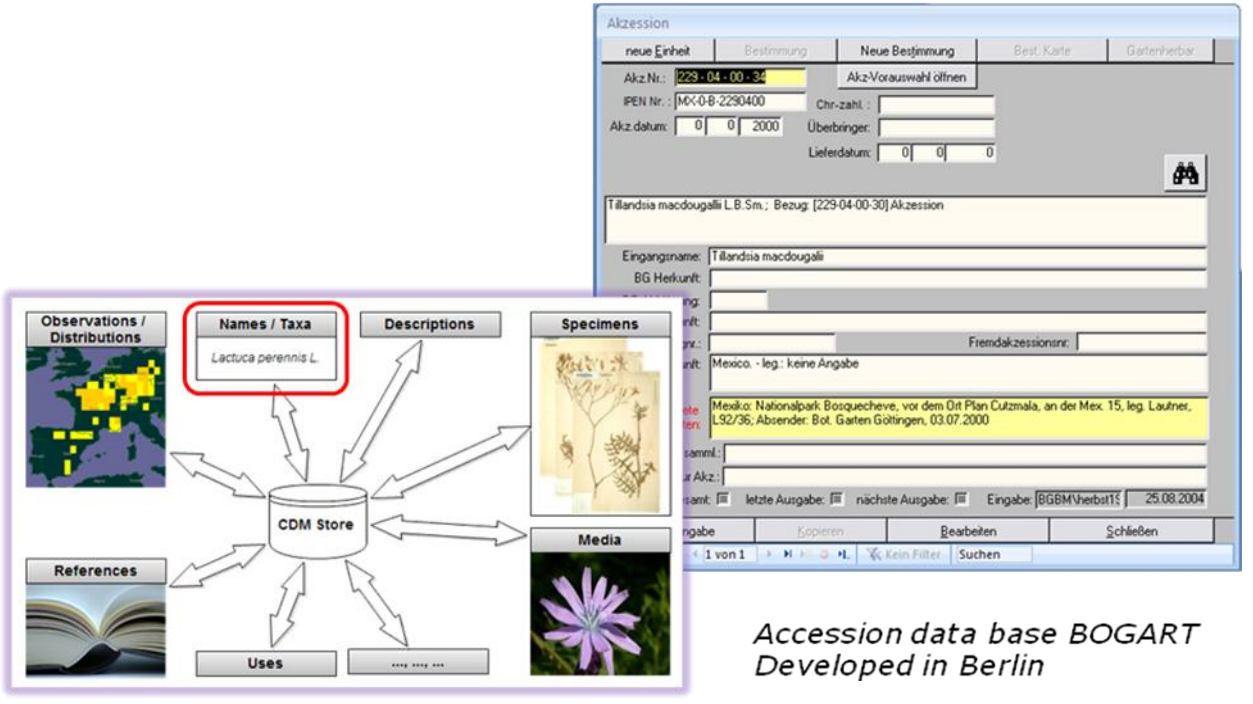
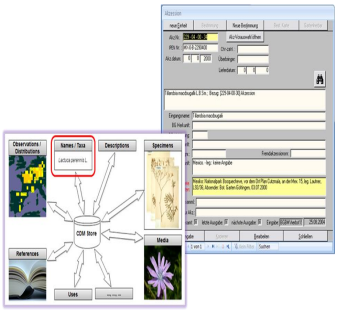


Fig. 2. The complex system of accession numbers at the Berlin Botanic Garden.

(A)

(B)

(C)



(D)

Fig. 3. Documentation of the living collection at the Botanic Garden and Botanical Museum Berlin-Dahlem: A) Typical label used in the public area of the botanic garden. This kind of labels not only show accession numbers and scientific names, but also give information on the German common names (if applicable) and the natural ranges of the respective species. B) In the nurseries, plants are labeled with at least their accession numbers. C) Vouchers of plants in the living collections are deposited in the herbarium and documented in our database. D) Screen shot of the BGBM's accession database 'BoGART', which features a complex, but flexible data structure that is compatible with online data portals such as GBIF.

Goals and tasks of botanic gardens

Given that the above mentioned basic principles are fulfilled, a botanic garden will be able to serve its purpose in scientific research, conservation, education and public recreation. We believe that well-managed botanic gardens with their valuable living collections will:

(1) Provide the basis for high quality scientific research;

(2) Be essential partners in *ex situ* as well as *in situ* conservation of plant diversity;

(3) Take action in education and public awareness raising; and

(4) Provide beautiful and fascinating places for public recreation and tourism.

Living collections of botanic gardens as well as the collections in associated herbaria are an often underestimated source for excellent research in so diverse fields such as taxonomy, phylogeny and biogeography, but also plant physiology, molecular and pharmaceutical biology as well as for conservation and restoration research and other disciplines (for overview see, e.g., Dosmann, 2006, and Crane *et al*., 2009). The Botanic Garden and Botanical Museum Berlin-Dahlem, for example, has a long tradition in taxonomic and floristic research. Major, long-term research programmes focus, for example, on the flora of the Euro-Mediterranean area (e.g., Euro+Med, 2006; Greuter and Raab-Straube, 2008) and the flora of Cuba (e.g., Greuter *et al*., 2000). Thereby, those long-term research projects are always characterized by a close collaboration with scientific partners in the respective countries, often formalized by memoranda of understandings.

However, the living collections of botanic gardens are not only relevant for taxonomic and floristic research. Until recently, disciplines like genetics, molecular biology or biochemistry traditionally used *Arabidopsis thaliana*, a tiny short-lived herb, as a model plant for nearly all experiments and analysis. Currently, there is a trend towards analysing a broader spectrum of plant diversity, which often reveals that the patterns of physiological and molecular process are much more diverse than expected. Therefore, the relevance of curated living plant collections is currently increasing considerably. A good example is the study of Van Bel and Hess (2008) who screened a variety of different plants cultivated in the botanic garden of Giessen, Germany. They found an unexpected diversity of carbohydrates functioning as transport sugars in the phloem, disproving the textbook knowledge gained from earlier studies on *Arabidopsis*. Diverse living

collections are also important for research on pharmaceutically relevant secondary compounds, e.g., own ongoing research on hypericins in the *Hypericum* family (Kusari *et al*., 2009). Because of their unique resources, such as taxonomically comprehensive living collections and controlled growing conditions, botanic gardens are perfect partners for the new field of climate change research and experiments on plant response to climate change (Primack and Miller-Rushing, 2009). Further scientific disciplines, where botanic gardens should become more active, are conservation genetics (e.g., Kramer and Havens, 2009) as well as applied research on cultivation techniques and the sustainable use of natural resources. The Berlin Botanic Garden is, e.g., involved in an ongoing project on the value and applicability of 'Terra Preta' techniques (Glaser, 2007) for horticultural purposes.

Botanic gardens should strive to work in close cooperation with their local universities in order to increase the scientific output of their collections. Furthermore, the need for basic research infrastructures will, such as laboratories for molecular and anatomical analyses (e.g., DNA sequencing and electron microscopy), libraries as well as computing facilities can more easily be met by collaboration and integration with the university. Thereby, botanic gardens can become essential stakeholders in the local universities' research agenda (e.g., Meyer *et al*., 2010) and the academic teaching programme (Scoggins, 2010).

Botanic gardens have a long tradition not only in own scientific research, but also in exchanging plant material for research and conservation purposes with other botanic gardens and research institution. In this context, Dosmann (2006) emphasizes the pivotal role of curators and collection managers that actively link the living collections of botanic gardens to the scientific community and make them accessible. In fact, the accessibility of scientific collections (living collections and herbaria) for researchers is a fundamental principle of the global scientific community. However, at least since the establishment of the Convention on Biological Diversity (CBD) in 1992, the access to collections and genetic resources is inevitably linked with the provision of fair and equitable sharing of benefits arising from the use of genetic resources. Therefore, it is essential for researchers and for managers of botanic gardens to get informed about the international regulations on access and benefit sharing (ABS) and to act adequately (Martinez and Biber-Klemm, 2010). The 'CBD Manual for Botanic Gardens' (Davis, 2008) provides some guidelines on this issue. Since the traditional system of free seed exchange between botanic gardens was

affected considerably by the new ABS provisions, the botanic garden community was among the first stakeholders who developed guidelines and standards for best practise. An important achievement is the International Plant Exchange Network (IPEN), which involves a common Code of Conduct on ABS and a system of facilitated exchange for those gardens who signed the Code (Von den Driesch *et al*., 2006). Currently, 144 botanic gardens from across Europe, but also from other countries outside Europe, are IPEN members (BGCI, 2011).

As stated earlier, the conservation of plant diversity has become another important task of modern botanic gardens. Nowadays, botanic gardens are the default partner in *ex situ* conservation, including cultivation of threatened plants in the gardens as well as long-term storage of seeds (Havens *et al*., 2006; Oldfield, 2009). *Ex situ* conservation in botanic gardens and seed banks should be seen as a complementary approach to *in situ* conservation (i.e. the conservation of plants in their natural habitats) – both, in terms of ecological and economical sustainability (Li and Pritchard, 2009; Smith *et al*., 2011). The European Seed Conservation Network (ENSCONET) has developed standards and practical protocols for the long-term storage of seeds (Eastwood and Müller, 2010; Sharrock and Jones, 2011), which provide a good guideline for botanic gardens worldwide (see also ENSCONET, 2009). Besides that, there are also several examples of botanic gardens that successfully engage in *in situ* conservation measurements (for overview see, e.g., Oldfield, 2007). Chen *et al*. (2009) see a responsibility for engagement in *in situ* conservation especially for botanic gardens in biodiversity rich countries. In any case the close cooperation with local authorities for nature conservation will be essential for the success of conservation measures. Especially when dealing with plants known as potentially invasive, botanic gardens should take as much care as possible since the risk of introducing and off-setting new invasives is not only hypothetical (Dawson *et al*., 2008; Hulme, 2011; but see also Heywood, 2011). Davis (2008) shows that botanic gardens are more and more aware of this issue and that several codes and helpful protocols have been developed. Botanic gardens should take their responsibility and communicate their knowledge on the invasiveness of certain plants to the community, to local authorities and to the public.

The example of invasive plants illustrates that botanic gardens are not only important players in conservation, but they also have a great responsibility in raising public awareness for the current threats to plant diversity and the consequences of biodiversity loss on human well-being. However, this is

not an easy task. Wandersee and Schussler (2001) show that a general lack of interest in plants (as compared to animals, for instance) is deeply rooted in human nature. The authors argue that inspiring environments in botanic gardens and personal guidance by especially trained educational staff can help to overcome this so called 'plant blindness'. Several studies show that out-of-school experiences in botanic gardens and other places can considerably increase the effectiveness of formal science education in schools (e.g., Braund and Reiss, 2006; Sanders, 2007). Besides that, botanic gardens have a huge potential for non-formal education, since they are visited by a larger number of people representing a broad spectrum of the society. It can be assumed that all botanic gardens worldwide reach a lot more than a hundred million people, given that the German botanic gardens alone have about 14 million visitors each year (Rauer *et al*., 2000).

However, the attitudes and expectations of the visitors need to be considered while planning education programmes. There are empirical studies showing that 'typical' visitors of a botanic garden are less interested in conservation issues and less motivated to learn than visitors of similar institutions, such as zoos or museums (Ballentyne *et al*., 2008). Similar observations have been made in visitor evaluations at the Berlin Botanic Garden (own unpublished data), where recreation is the most prominent motivation for visits to the botanic garden. Fortunately, there is a huge spectrum of methods and strategies to reach visitors of botanic gardens in a non-formal way. Some guidelines on this have been compiled by Botanic Gardens Conservation International (Willison, 1994; 2006). A comprehensive study on the possibilities of environmental education and education for sustainable development in German botanic gardens was recently conducted by Löhne *et al*. (2009). The results show that, although there are some inspiring examples of excellent education programmes, many botanic gardens are still far from making the most of their potentials in education and communication. In any case, the best way to reach visitors is to create fascinating places for recreation and to link the plants and plant science to people's everyday life. Good examples are ethnobotanic gardens (Innerhofer and Bernhardt, 2011), the 'Great-granny's Garden' at Oslo Botanic Garden, where people can experience familiar and forgotten plants with all senses (Borgen and Guldahl, 2011), or the Children's Garden at the Royal Botanic Gardens Melbourne, where children can practice gardening (Clancy, 2006). In view of the activities in education and awareness raising as well as the manifold positive effects of garden visits on human well-being (e.g., Rappe and Kivela, 2005; Ward *et al*., 2010), we see a great potential of botanic

gardens – especially in urban areas – to make a valuable contribution to the sustainable development of our society.

A vision for the Gullele Botanic Garden

Considering that Gullele Botanic Garden (GBG) will develop as an institution based on international standards for botanic gardens, it is evident that there are great opportunities and prospects in the future. In order to shape this future, a mission statement should be developed that explains how Gullele Botanic Garden will work in the fields of biodiversity conservation, scientific research, environmental education and rising awareness for sustainable development as well as integrating these to promote recreation and tourism.

The time appears ripe for Gullele Botanic Garden to make an impact in several ways. And of course, there are mutual benefits for the institution itself that has the opportunity to make an impact. As a consequence it should be looked at the landscape of institutions and the place GBG could have in the future. Gullele Botanic Garden certainly has the potential to become a model for the Horn of Africa as the most important internationally recognized garden. It will benefit from larger scale activities towards sustainable development and conservation of biological diversity in this region of Africa, and, in turn could fuel such activities by providing scientific expertise and helping to create public awareness. Its location in the city of Addis Ababa with its important role as the home for many African institutions such as the African Union or the United Nations Economic Commission for Africa may further facilitate Gulelle Botanic Garden to become internationally recognized. Being located close to the City of Addis Ababa, and providing a location for recreation and pleasure, there is the chance to become a window to the public for activities of both the city administration and Addis Ababa University. For example, the botanic garden can not only be an active site where the management of organic material with aims in sustainable agriculture, waste treatment and energy production is developed in model projects (see, e.g., Glaser, 2007), but also explains these issues to the broader public. As a living museum it further can show vegetation types and plants that have particular importance as crops or in natural ecosystems. This field is particularly attractive as it can be networked with other museums in Addis Ababa, such as the Ethiopian National Museum or Natural History Museum, and therefore will provide a location to display the rich cultural and natural heritage of Ethiopia. Gullele Botanic Garden could therefore play an important role in sustainable

development in Ethiopia and beyond. Within Ethiopia, Gullele Botanic Garden is predestined to become the nucleus of an Ethiopian Botanic Garden Network that actively connects to the regions and further facilitates smaller gardens to be established in connection with universities in the regions or even sites as the recently established Biosphere Reserves in Yayu and Kafa (UNESCO, 2010) that promote the conservation and sustainable use of coffee forests.

In order to successfully develop such goals, it will be important to build upon achievements. First of all, there is of course an attractive site already available that can be easily reached by many people in Addis Ababa. But at the same time it is most important to involve the many highly skilled people in various fields. There have been very successful projects such as the Ethiopian Flora Project (Sebsebe Demissew, 2010) to give a prominent example, in the course of which highly motivated people have been trained. But there are also other projects that are and have been working on various environmental topics. This adds an immense value to such projects and provides the basis for taking larger initiatives off the ground. It should be highly valued that Ethiopia now has human resources that can provide the basis for the development of Gullele Botanic Garden.

An important next step towards the establishment of Gullele Botanic Garden will be to develop an integrated strategy that allows an efficient institutional development and will also provide the basis for managing the garden on a daily base. Such an integrated strategy will essentially have to provide a roadmap for institutional development. In accordance with the roadmap, important milestones can be put forward that allow for an easy communication about which achievements should be made at what time. An integrated strategy implies to work out a science plan, a collection plan as well as an education and recreation plan. All of these areas require different expertise and will then complement into an institutional strategy in line with the overall mission statement.

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REFERENCES

Baker, H.G. (1978). **Plants and Civilization**. Wadsworth, Belmont, CA.

Ballantyne, R., Packer, J. and Hughes, K. (2008). Environmental awareness, interests and motives of botanic gardens visitors: Implications for interpretive practice. *Tourism*

Manage. **29**: 439–444.

Berendsohn, W.G., Anagnostopoulos, A., Hagedorn, G., Jakupovic, J., Nimis, P.L., Valdés, A., Güntsch, A., Pankhurst, R.J. and White, R.J. (1999). A comprehensive reference model for biological collections and surveys. *Taxon* **48**: 511–562.

BGCI (2011). Botanic Gardens Conservation International website. Information on members of the International Plant Exchange Network available at: http://www.bgci.org/resources/ipen/ [accessed at 23 March 2011].

Borgen, L. and Guldahl, A.S. (2011). Great-granny's Garden: A living archive and a sensory garden. *Biodivers. Conserv.* **20**: 441–449.

Braund, M. and Reiss, M. (2006). Towards a more authentic science curriculum: The contribution of out-of-school learning. *Int. J. Sci. Educ.* **28**: 1373–1388.

Brockway, L.H. (1979). **Science and Colonial Expansion: The Role of the British Royal Botanic Gardens**. Academic Press, New York.

Burkart, M., Von den Driesch, M., Lobin, W. and Löhne, C. (2005). *Ex situ* conservation of native species: Contribution of German botanic gardens to the GSPC Target 8. Planta Europa Newsletter 5: 7.

Chen, J., Cannon, C.H. and Hu, H. (2009). Tropical botanical gardens: At the *in situ* ecosystem management frontier. *Trends Plant Sci.* **14**: 584–589.

Clancy, S. (2006). Connecting people with plants. Proceedings of the Sixth International Congress on Education in Botanic Gardens, Oxford, 10-14 September 2006.

Crane, P.R. and Choe, J.C. (2010). Perspectives on the new National Ecological Institute in South Korea. *J. Ecol. Field Biol.* **33**(4): 271–274.

Crane, P.R., Hopper, S.D., Raven, P.H. and Stevenson, D.W. (2009). Plant science research in botanic gardens. *Trends Plant Sci.* **14**: 575–577.

Dash, M. (1999). Tulipomania: The story of the world's most coveted flower and the extraordinary passions it aroused. Gollancz, London.

Davis, K. (2008). **A CBD Manual for Botanic Gardens**. Botanic Gardens Conservation International, Richmond, UK.

Dawson, W., Mndolwa, A., Burslem, D. and Hulme, P. (2008). Assessing the risks of plant invasions arising from collections in tropical botanical gardens. *Biodivers. Conserv.* **17**: 1979–1995.

Dosmann, M.S. (2006). Research in the garden: Averting the collections crisis. *Bot. Rev.* **72**: 207–234.

Eastwood, R.J. and Müller, J.V. (2010). European native seed conservation network, working together towards GSPC Target 8. *BGJournal* **7**(2):11–13.

ENSCONET (2009). **Seed Collecting Manual for Wild Species**. European Seed Conservation Network.

Euro+Med (2006). Euro+Med Plantbase – the information resource for Euro-Mediterranean plant diversity. Published on the Internet at http://ww2.bgbm.org/EuroPlusMed/.

Glaser, B. (2007). Prehistorically modified soils of central Amazonia: A model for sustainable agriculture in the twenty-first century. *Philos. T. Roy. Soc. B* **362**: 187–196.

Greuter, W. et al. (ed.) (2000). **Flora de la República de Cuba. Serie A, Plantas Vasculares**. Koeltz Scientific Books, Königstein.

Greuter, W. and Raab-Straube, E. V. (eds.) (2008). Med-Checklist. A critical inventory of vascular plants of the circum-Mediterranean countries, 2. Dicotyledones (Compositae). Organization for the Phyto-Taxonomic Investigation of the Mediterranean Area (OPTIMA), Genève.

Havens, K., Vitt, P., Maunder, M., Guerrant Jr., E.O. and Dixon, K. (2006). *Ex situ* plant conservation and beyond. *Bioscience* **56**: 525–531.

Heywood, V.H. (1987). The changing role of the botanic gardens. In: **Botanic Gardens and the World Conservation Strategy**, pp. 3–18 (Bramwell, D., Hamann, O., Heywood, V.H. and Synge, H., eds.). Academic Press, London.

Heywood, V.H. (2011). The role of botanic gardens as resource and introduction centres in the face of global change. *Biodivers. Conserv.* **20**: 221–239.

Hill, A.W. (1915). The history and functions of botanic gardens. *Ann. Mo. Bot. Gard.* **2**: 185–240.

Holttum, R.E. (1970). The historical significance of botanic gardens in S.E. Asia. *Taxon* **19**: 707–714.

Howard, R.A. (1997). The St. Vincent Botanic Garden - The early years. *Arnoldia* **57**: 12–21.

Hulme, P.E. (2011). Addressing the threat to biodiversity from botanic gardens. *Trends Ecol. Evol.* **26**: 168–174.

Hyams, E. (1969). **Great Botanical Gardens of the World**. Nelson, London.

Innerhofer, S. and Bernhardt, K.-G. (2011). Ethnobotanic garden design in the Ecuadorian Amazon. *Biodivers. Conserv.* **20**: 429–439.

Kramer, A.T. and Havens, K. (2009). Plant conservation genetics in a changing world. *Trends Plant Sci.* **14**: 599–607.

Küchler-Krischun, J. (ed.) (2007). National strategy on biological diversity: adopted by the Federal Cabinet on 7 November 2007. Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), Public Relations Division, Berlin.

Kusari, S., Zuhlke, S., Borsch, T. and Spiteller, M. (2009). Positive correlations between hypericin and putative precursors detected in the quantitative secondary metabolite spectrum of Hypericum. *Phytochemistry* **70**: 1222–1232.

Lack, H.W. and Haas, I. (2000). Botanisches Museum Berlin: Adolf Engler - Die Welt in einem Garten. Prestel, Munich.

Leadley, E. and Green, J. (1998). **The Darwin Technical Manual for Botanic Gardens**. Botanic Gardens Conservation International, London.

Leiva Sánchez, A.T. and Hernández Monterrey, N. (2009). A new Botanic Garden for St. Kitts-Nevis. *Rev. del Jardin Botánico Nacional* **30-31**: 29–31.

Li, D.-Z. and Pritchard, H.W. (2009). The science and economics of *ex situ* plant conservation. *Trends Plant Sci.* **14**: 614–621.

Lobin, W. and Barthlott, W. (1988). *Sophora toromiro* (Leguminosae): The lost tree of Easter Island. *Botanic Gardens Conservation News* **1** (3): 32–34.

Löhne, C., Friedrich, K. and Kiefer, I. (2009). Natur und Nachhaltigkeit: Innovative Bildungsangebote in Botanischen Gärten, Zoos und Freilichtmuseen – Naturschutz und Biologische Vielfalt 78. Bundesamt für Naturschutz, Bonn-Bad Godesberg.

Martinez, S.I. and Biber-Klemm, S. (2010). Scientists - Take action for access to biodiversity. *Curr. Opin. Environ. Sust.* **2**: 27–33.

Masefield, G.B. (1967). Crops and livestock. In: **The Economy of Expanding Europe in the Sixteenth and Seventeenth centuries** (Rich, E.E. and Wilson, C.H., eds.). Cambridge University Press, Cambridge.

Maunder, M., Culham, A., Alden, B., Zizka, G., Orliac, C., Lobin, W., Bordeu, A., Ramirez, J.M. and Glissmann-Gough, S. (2000). Conservation of the Toromiro tree: Case study in the management of a plant extinct in the wild. *Conserv. Biol.*

14(5): 1341–1350.

Meyer, M.H., Hokanson, S., Galatowitsch, S. and Luby, J. (2010). Public gardens: Fulfilling the university's research mission. *Horttechnology* **20**: 522–527.

Mittermeier, R.A., Robles Gil, P., Hoffmann, M., Pilgrim, J., Brooks, T., Mittermeier, C.G., Lamoreux, J., and da Fonseca, G.A.B. (2004). Hotspots revisited: Earth's biologically richest and most endangered terrestrial ecoregions. CEMEX, Mexico.

Oldfield, S. (2007). **Great Botanic Gardens of the World**. New Holland, London.

Oldfield, S.F. (2009). Botanic gardens and the conservation of tree species. *Trends Plant Sci.* **14**: 581–583.

Padilla, R. (ed.) (2008). Jardim Botânico do Rio de Janeiro, 1808-2008. Artepadilla, Rio de Janeiro.

Paton, A. (2009). Biodiversity informatics and the plant conservation baseline. *Trends Plant Sci.* **14**: 629–637.

Patzelt, A., Morris, L., Al Harthi, L., Al Rashi, I., and Spalton, A. (2008). The Oman Botanic Garden (1): The vision, early plant collections and propagation. *Sibbaldia* **6**: 41–78.

Patzelt, A., Al-Farsi, K., Morris, L. and Spalton, A. (2009). The Oman Botanic Garden (2): Collections policy, nursery construction, expanded plant production and initial tree translocation. *Sibbaldia* **7**: 83–98.

Pendergrast, M. (1999). **Uncommon grounds: The History of Coffee and How it Transformed our World**. Basic Books, New York.

Primack, R.B. and Miller-Rushing, A.J. (2009). The role of botanical gardens in climate change research. *New Phytol.* **182**: 303–313.

Rae, D. (2011). Fit for purpose: The importance of quality standards in the cultivation and use of live plant collections for conservation. *Biodivers. Conserv.* **20**: 241–258.

Rappe, E. and Kivela, S.L. (2005). Effects of garden visits on long-term care residents as related to depression. *Horttechnology* **15**: 298–303.

Rauer, G., von den Driesch, M., Ibisch, P.L., Lobin, W. and Barthlott, W. (2000). Beitrag der deutschen botanischen Gärten zur Erhaltung der biologischen Vielfalt und genetischer Ressourcen - Bestandsaufnahme und Entwicklungskonzept. Bundesamt für Naturschutz, Bonn-Bad Godesberg.

Rucińska, A. and Puchalski, J. (2010). Molecular studies on *ex-situ* conservation of rare and endangered Polish plants. Proceedings of the Fourth Global Botanic Gardens Congress, Dublin, 13-18 June 2010.

Sanders, D.L. (2007). Making public the private life of plants: The contribution of informal learning environments. *Int. J. Sci. Educ.* **29**: 1209–1228.

Scoggins, H.L. (2010). University garden stakeholders: Student, industry, and community connections. *Horttechnology* **20**: 528–529.

Sebsebe Demissew (2010). The Ethiopian Flora Project: Lessons learnt. Proceedings of the Fourth Global Botanic Gardens Congress, Dublin, 13-18 June 2010.

Secretariat of the Convention on Biological Diversity (2002). Global Strategy for Plant Conservation. Secretariat of the Convention on Biological Diversity, Montreal.

Sharrock, S., Hird, A., Kramer, A. and Oldfield, S. (2010). **Saving Plants, Saving the Planet: Botanic Gardens and the Implementation of the GSPC Target 8**. Botanic Gardens Conservation International, Richmond, UK.

Sharrock, S. and Jones, M. (2011). Saving Europe's threatened flora: Progress towards GSPC Target 8 in Europe. *Biodivers. Conserv.* **20**: 325–333.

Smith, P., Dickie, J., Linington, S., Probert, R. and Way, M. (2011). Making the case for

plant diversity. *Seed Sci. Res.* **21**: 1–4.

Torres-Santana, C.W., Santiago-Valentín, E., Leiva Sánchez, A.T., Peguero, B., Clubbe, C. (2010). Conservation status of plants in the Caribbean Island Biodiversity Hotspot. Proceedings of the Fourth Global Botanic Gardens Congress, Dublin, 13-18 June 2010.

UN – United Nations, Department of Economic and Social Affairs / Population Division (2010). World Urbanization Prospects: The 2009 Revision – Highlights. United Nations, New York.

UNESCO (2010). The UNESCO Man and Biosphere Reserves Directory. Online database available under: http://www.unesco.org/mabdb/br/brdir/directory/database.asp. [information on Yayu and Kafa reserves accessed on 15 March 2011].

Van Bel, A.J.E. and Hess, P.H. (2008). Hexoses as transport sugars in the phloem. The end of a dogma? *J. Exp. Bot.* **59**: 261–272.

Van den Wollenberg, L.J.W. (2011). The future prospects of electronic seed lists. *Biodivers. Conserv.* **20**: 277–286.

Von den Driesch, M., Lobin, W., Helminger, T., Gröger, A. and Van den Wollenberg, B. (2006). The International Plant Exchange Network (IPEN): An instrument of botanic gardens to fulfil the ABS provisions. In: **Access and Benefit-Sharing of Genetic Resources BfN-Skripten 163**, pp. 31–44 (Feit, U., Von den Driesch, M. and Lobin, W., eds.). Bundesamt für Naturschutz, Bonn-Bad Godesberg.

Wandersee, J. H. and Schussler, E. E. (2001). Toward a theory of plant blindness. *Plant Sci. Bull.* **47**(1), 2-9.

Ward, C.D., Parker, C.M. and Shackleton, C.M. (2010). The use and appreciation of botanical gardens as urban green spaces in South Africa. *Urban For. Urban Green.* **9**: 49–55.

Willison, J. (2006). **Education for Sustainable Development: Guidelines for Action in Botanic Gardens**. Botanic Gardens Conservation International, Richmond, UK.

Willison, J. and Greene, J. (1994). **Environmental Education in Botanic Gardens: Guidelines for Developing Individual Strategies**. Botanic Gardens Conservation International, Richmond, UK.

Wyse Jackson, P.S. and Sutherland, L.A. (2000). **International Agenda for Botanic Gardens in Conservation**. Botanic Gardens Conservation International, Richmond, UK.

Wyse Jackson, P. and Kennedy, K. (2009). The global strategy for plant conservation: A challenge and opportunity for the international community. *Trends Plant Sci.* **14**: 578–580.