

The Future Role of Botanical Gardens

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Abstract

Historically, botanic gardens have used their living collections of plants for a wide variety of purposes and those purposes have evolved through time to continue to meet the changing needs of society. I argue that, building on and going far beyond their success to date, the future role of botanic gardens should be nothing less than shaping and contributing to a sustainable future for humanity. A sustainable future can only be one in which plants are placed at the heart of the web of life and recognised as our life support system. Botanic gardens, as popular places in which people chose to spend their time, are better placed than other kinds of institutions to engage with society and mobilise support for the protection of plant diversity through powerful, positive messages that empower citizens to be involved in shaping the future. Botanic gardens already work together through national, regional and international networks but need to achieve a step change in the level of the strategic action they take together. Of the Post-2015 Development Agenda, the UN Secretary-General has said, “Our goal is simple but daunting - prosperity and dignity for all in a world where humankind lives in harmony with nature.” Botanic gardens have a key role in delivering this vision of the future.

Key Words: global change, sustainable development agenda, Anthropocene

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We live in a world that is changing more rapidly than ever before in human history, confronting a set of interconnected challenges arising from the growing demands we make on the biosphere (see, for example, Rockström *et al.* 2009; Mooney 2010; Ellis 2011; Brook *et al.* 2012; Ellis *et al.* 2013). Botanic gardens, with their living collections, expertise and close engagement with wider society, have the potential to be key players in meeting the major challenges of the times and contributing to a sustainable future (Blackmore 2001, 2009, 2016; Blackmore & Paterson 2005; Marris 2006).

Before making the case for botanic gardens in the Anthropocene as agents for change and pathfinders into the future I will briefly consider the origins and historical roles of botanic gardens. My purpose in do-

ing this is to show that botanic gardens are evolving entities, capable of adapting their mission and roles to meet the changing requirements of the communities they serve.

The Evolutionary Nature of Botanic Gardens

Neither the origins nor the earliest history of plant collections that would today be considered botanic gardens can be known with certainty. We can, however, speculate that organised, purposeful collections of plants began to be made around the time when people made the transition to practicing settled agriculture. The early recorded history of botanic gardens

was reviewed by Hill (1915) in an excellent account, proceeding from the garden of Shen Nung, Emperor of China in 28th Century BC, to the Royal Garden of Thotmes III at the Temple of Karnak, to Aristotle's Garden at Athens and onwards into modern times. In Europe, botanic gardens arose as off-shoots of medicine, as physic gardens, for the provision of medicinal plant materials and the training of physicians (Hill 1915; Stearn 1962; Stafleu 1969). The scope of botanic gardens, their collections and their work expanded enormously as they embraced the Linnean endeavour of classifying and documenting diversity. In the eighteenth and nineteenth centuries, in particular, a strong emphasis was placed on utilitarian plants other than medicines and botanic gardens became important as institutions of colonial power (Prain 1925; Holtum 1970; Radding 2005). Botanic gardens also came to be regarded as important cultural institutions, expressions of a civilised society, and this was an important motivation for the establishment of many public botanic gardens in America (Coulter 1917; Brockway 1979; O'Malley 1996). Writing on the history of botanic gardens in America, O'Malley (1996) described them as "... the quintessential expression of both garden art and scientific inquiry" embodying "...the fundamental belief in the perfectibility of man and the optimism of the founders in the future they were creating for the new republic." The justification for regarding botanic gardens as cultural institutions alongside the great museums and galleries of the world has been strengthened by their growing commitment to public education and outreach. Education now plays an important part in almost every botanic garden, including many that do not sustain their own research programmes (Wyse Jackson & Sutherland 2000).

Perhaps the greatest redefinition of role in botanic gardens has been the focus on plant conservation which emerged as a major concern during the twentieth century (Heywood 1990; Barthlott *et al.* 2000; Heywood & Iriondo 2003; Powledge 2011) especially since the introduction of the United Nations Convention on Biological Diversity (CBD) (Williams *et al.* 2003). A further impetus was provided by The Global Strategy for Plant Conservation (GSPC) (Blackmore

2005; Wyse Jackson & Kennedy 2009; McNeely 2011) which exerted considerable influence of the development of the strategic plans of many botanic gardens (see, for example, Hopper 2010). Initially, the main responses of botanic gardens focused on *ex-situ* conservation (Havens *et al.* 2006; Li & Pritchard 2009). Botanic gardens, with their living collections and seed banks for threatened plants have come to be seen as 'modern-day arks' (Oldfield 2010; Pennisi 2010). They have also led the development of protocols for the reintroduction of plants from botanic gardens into the wild (see, for example, Akeroyd & Wyse Jackson 1995). More recently the ability of botanic gardens to contribute to ecological restoration, coupled with growing recognition of the urgent need to restore degraded landscapes has led to the launch of the Ecological Restoration Alliance of Botanic Gardens (Havens *et al.* 2006; Aronson 2014) under the auspices of Botanic Gardens Conservation International (BGCI).

The conclusion I draw from this brief historical introduction to botanic gardens is that they are resilient and persistent institutions capable of changing through time and adapting to continue to meet the needs of the society they serve.

The Geographical Distribution of Botanic Gardens

Before turning to explore what it is that society might require of botanic gardens in the future, I want to consider the global distribution of botanic gardens. The GardenSearch Database developed by BGCI currently holds records on 3392 botanic gardens in around 150 countries (Fig. 1). It is clear that the vast majority of botanic gardens are situated in the temperate regions of the world, with a preponderance in Europe and the United States (Chen *et al.* 2009).

It has been well known since the observations of Alexander von Humboldt that plant diversity is much greater in the tropics (Humboldt 1845-1858; Dobzhansky 1950; Barthlott *et al.* 2007) than at higher latitudes and a variety of hypotheses have been developed to explain this marked gradient in plant

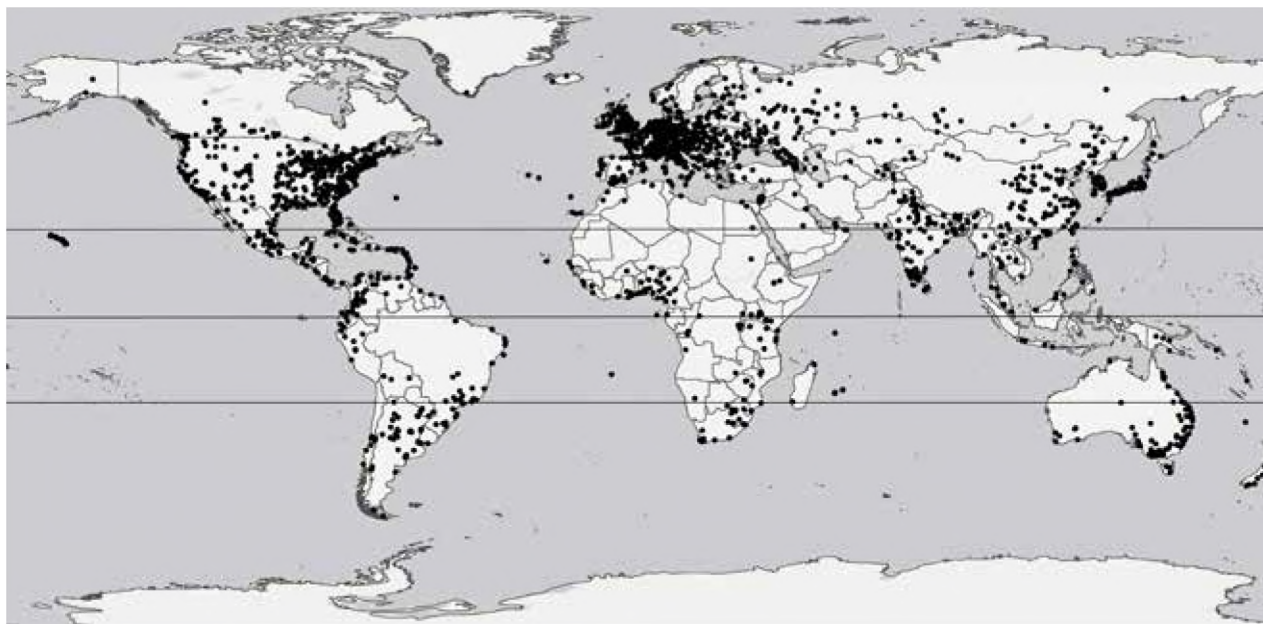


Fig. 1. Global distribution of botanic gardens based on the GardenSearch Database of Botanic Gardens Conservation International (BGCI in 2015).

biodiversity (Davies *et al.* 2004; Fine & Ree 2006; Hawkins *et al.* 2011). There is therefore a marked discrepancy between the distribution of botanic gardens and the distribution of plant diversity which reflects the historical development of formal, scientific botanic gardens in Europe discussed earlier. Barthlott *et al.* (2000) made the point that, "... the earth's Botanic Gardens are distributed inversely to the natural phytodiversity". The consequences of this for the patterns of diversity within the living collections of botanic gardens have been analysed by Parmentier and Pautasso (2010). In this symposium which focusses on tropical collections, it is clear that, in order to conserve and restore plant diversity for the future, many more botanic gardens need to be established in the tropics. More tropical botanic gardens are also needed in order to correct the imbalance in the delivery of the educational and wider social programmes which are much more readily available to people in temperate regions. There are, as will be mentioned later, other societal benefits to be realised through the creation of more botanic gardens in the tropics. It is important, however, to recognise that there are important

botanic gardens in the tropics, a number of which have long and distinguished histories. Holtum (1970) presented a review of the significance of tropical botanic gardens in South East Asia, emphasising the gardens of Calcutta (established 1786), Bogor (established 1817), Peradeniya (established 1821) and Singapore (established 1874). Other important examples include the Sir Seewoosagur Ramgoolam Botanic Garden at Pamplemousses in Mauritius, (established 1770, the earliest botanic garden in the Southern Hemisphere) and Rio de Janeiro Botanical Garden which was founded as an acclimatisation garden in 1808. Mexico and China, two megadiverse countries which include tropical regions within their territories, have increasingly well-networked botanic gardens delivering coordinated, strategic work programmes. The Mexican Association of Botanic Gardens includes 40 partners (Dávila *et al.* 2011) while the botanic gardens of China are working together on a shared vision for conservation and sustainable use of plants (Huang 2011). Of course, in correcting the mismatch between the distribution of plant diversity and the distribution of botanic gardens, it is not simply a

question of where in the world the collections are. As Gibson and Raven (2013) point out, tropical research exhibits a similar pattern of historical legacy with European researchers carrying out most of the research in the former colonies of the Old World tropics and scientists from the US dominating research in the Neotropics (Clark 1985). An analysis by Fazey *et al.* (2005) showed that fewer than half the papers on conservation biology in the Caribbean, Central America and South America had first authors from countries in those regions. Similar findings were reported by Griffiths and Dos Santos (2012), who highlighted both the need to build capacity in developing countries and the difficulties of doing so.

The development of human capacity within tropical, and subtropical, botanic gardens is therefore a priority for the future. It is likely that for more botanic gardens too be developed in the tropics, they will need to be seen to contribute directly to national development plans, as those of Mexico and China clearly do (Dávila *et al.* 2011). Furthermore, tropical botanic gardens are increasingly engaged in wider conservation efforts (Chen *et al.* 2009), also at the *in situ* ecosystem management. As will be discussed later, an even wider, universal agenda, to which botanic gardens can contribute, will be provided by the 2030 Sustainable Development Goals (SDGs).

The Future

If botanic gardens have evolved to meet the changing needs of the communities they serve and if, as I imagine they will, they continue to evolve, what directions might they be expected to take in the future? Different answers suggest themselves at the local level and the global level.

Meeting the Needs of the Local Community

When it comes to meeting the needs of their local community, botanic gardens, in common with many cultural institutions and visitor attractions, generally use visitor footfall as a simple measure of their rele-

vance. In addition, many use surveys and questionnaires to determine what it is that visitors value most and what they would like to see more of in the future. Often it is simply the peaceful, green ambience of the botanic garden that visitors value most highly. Although it is the *raison d'être* for most botanic gardens, the presence of a diverse, well-interpreted collection of plants, displayed in an attractive manner, tends to come lower on the list of priorities for visitors. At the Royal Botanic Garden Edinburgh I encountered one regular visitor who insisted that they did not come to look at the plants, but only to see grey squirrels and to watch tractors at work. I was asked where else, in the city, could their grandchildren see working tractors? What I found helpful about this interaction was the salutary reminder that what botanic gardens value most about themselves (the richness of their living collections or the vigour of their research programmes) might seem unimportant to some visitors but that even those with little appreciation of plants can find interest in the place, its wildlife and its work. Simply existing as pleasant and interesting place might not be sufficient justification for the existence of a botanic garden, but it is much more important than it may seem and in ways that will become more significant in the future. Botanic gardens, by their very existence, provide significant benefits to the health and well-being of their visitors. And although displaying agricultural machinery at work is unlikely to feature as an objective in the corporate plan, we should cherish the opportunity to show and celebrate the working skills of botanic garden staff. In an increasingly urban world (Victor 2006; Elmqvist *et al.* 2013a), with more than half of humanity already living in cities, experiences of urban green space are of growing importance. Elmqvist *et al.* (2013a) refer to both the hardware of cities, their physical infrastructure, and their software, their cultural life. They point out that less emphasis has been placed on recognising the ecological infrastructure of cities: their parks, gardens, open spaces and water catchment areas. Given that many botanic gardens are situated in cities, they are perhaps unique in that they contribute to both the hardware and software of the city. At the same time,

albeit on a relatively small scale, they even contribute ecosystem services, including fresh air, carbon sequestration, groundwater management and reducing the urban heat island effect. Most importantly, an urban botanic garden can communicate with and influence a large number of people and serve as source of expertise and plant material to enrich the planted landscape within and beyond its boundaries. The opportunities to do this are increasing. People are continuing to move into cities and the trend of urbanisation is accelerating in many regions. As Seto *et al.* (2013) pointed out, the geography of urbanisation has shifted, with the fastest growing urban centres now being in Asia and Africa (in particular in China, India and Nigeria) rather than in Europe or the Americas. The predicted growth in cities and megacities is yet another argument in favour of the development of more botanic gardens in tropical and subtropical centres of urban expansion.

The fact that many botanic gardens are urban oases, engulfed by the city they serve, makes them of enormous value, offering contact with nature and bringing mental and physical health to citizens. A growing body of research makes it increasingly possible to document and quantify these benefits (see for example, Maller *et al.* 2005; Bowler *et al.* 2010; Keniger *et al.* 2013). The idea that gardens are, in themselves, places of healing (Hartig & Cooper-Marcus 2006) rather elegantly reflects that earlier chapter in history when, as physic gardens, they provided medicines. Some botanic gardens still do produce medicinal plants for consumption, but almost all could now claim to improve the health of their visitors. Furthermore, the fact that gardening is, in itself, both a leisure activity and a source of mental and physical health benefits to its practitioners, especially the elderly (Milligan *et al.* 2004), suggests an increasingly important role for botanic garden outreach programmes in response to the demographic changes of an aging society. In Tokyo, currently the world's largest megacity, Takano *et al.* (2002) found an increase in longevity associated with access to walkable greenspace such as parks and gardens and argued for the importance of greenspace in city masterplans. Keni-

ger *et al.* (2013) grouped the benefits of contact with nature under four headings: psychological well-being benefits, cognitive benefits, physiological benefits and social benefits. Little wonder then that in many cities, including both London and New York, the most expensive real estate is next to, or has views over, a botanic garden or park. A growing number of botanic gardens offer programmes, from mindfulness to horticultural therapy, which promote and deliver health benefits to their audiences.

Such programmes already deliver real benefits to botanic garden visitors but urbanisation is creating new, unprecedented challenges for humanity. As Maller *et al.* (2005) and others have pointed out, humans have only lived in urban environments for a small number of generations, having previously become adapted to natural ones over many thousands of years. Botanic gardens have, it seems to me, the opportunity to be at the frontline of discovering how it is possible for humans to live healthy and satisfying lives in cities of increasing size and population density. There are many challenges to be addressed because cities will be heavily affected by global climate change (World Bank 2010), changes in sea level (McGranahan *et al.* 2007), pollution and other environmental impacts. The urban heat island effect, for example, is even more intense in tropical cities than temperate ones, and can create temperatures as much as 10 °C higher than in the surrounding countryside (Kovats & Akhtar 2008). Urban green spaces, including green roofs and walls, provide practical forms of ecosystem-based adaptation (EBA) (Colls *et al.* 2009) that can benefit greatly from the involvement of botanic gardens. Botanic gardens can, for example, promote the use of native species in urban greens spaces and facilitate the provision of suitable plant material, as in ecological restoration efforts (Aronson 2014). In developing this wider impact on the landscape of cities, botanic gardens may need to forge new partnerships, beyond their traditional alliances, such as engaging with the efforts emerging from the Mayors' Climate Protection Agreement (Bulkeley 2013). It would not be as novel as it may seem for botanists and botanic gardens to engage actively with architects, engineers

and city planners. The botanist Patrick Geddes (1854–1932) was a pioneer of social improvement in cities and one of the founders of modern city planning (Geddes 1915; Meller 1993). Geddes lived in a world with two billion human inhabitants, there are now more than seven billion of us, with a projected 9.5 billion by 2050 (Ehrlich *et al.* 2012). Consequently, there is a greater need than ever for plant-based solutions to feeding humanity, sustaining ecosystem services and maintaining the ecological resilience that comes from a biodiversity rich biosphere (Cardinale *et al.* 2012). In these matters, botanic gardens have much to offer (see for example, Maunder 2008; Donaldson 2009).

Urban agriculture, including the growing of food in city tenements, was promoted vigorously by Patrick Geddes (Meller 1993) and has seen a great resurgence in recent years (Katz 1986; DeKay 1997). Botanic gardens, in their efforts to develop wider social roles (Vergou & Willison 2013), have been significant contributors, teaching people who are increasingly remote from the production of food how they can grow their own. Many botanic gardens now have programmes to support home gardening. When I joined the Royal Botanic Garden Edinburgh at the turn of the millennium, carrots and cabbages were nowhere to be seen. Now, a popular programme of ‘Growing your own food’ attracts volunteers, external sponsorship and course participants. A less chauvinistic attitude prevails towards growing the full diversity of plants. Vegetables and crop plants, precisely those plant species most essential for our daily lives, now flourish alongside systematic collections for research and threatened plants in conservation programmes. This is a healthy mix, offering a broader spectrum of opportunities to engage with and support the local community and removing a false dichotomy between plants used in agriculture and plants not used in agriculture.

The city of Chicago, described by Wang and Moskovits (2001) as “... a microcosm of some of the greatest challenges to the survival of Earth’s biological diversity and to the quality of human life”, provides outstanding examples of urban regeneration and urban farming. Since 1996, the Chicago Wilder-

ness programme has brought together a large and diverse coalition of partners to document natural remnants of vegetation and then restore and reconnect them through greenways and wildlife corridors to create a regional nature reserve covering 81,000 hectares (Wang & Moskovits 2001; Moskovits *et al.* 2002). Chicago Botanic Garden, a key participant in the initiative, developed ‘Plants of Concern’ a state-wide citizen science programme to monitor threatened plants (Havens *et al.* 2012). Going far beyond its own boundaries, Chicago Botanic Garden also runs an impressive programme of rural agriculture called ‘Windy City Harvest’ (www.chicagobotanic.org/urbanagriculture) as well as programmes in horticultural therapy and a wide range of educational activities. To my mind, Chicago Botanic Garden’s Strategic Plan (<http://strategicplan.chicagobotanic.org/homepage>) is a model for the botanic garden of the future. Chicago Botanic Garden states, “Our mission is clear: We cultivate the power of plants to sustain and enrich life.” This mission is founded on three beliefs:

- “The future of life on Earth depends on how well we understand, value, and protect plants, other wildlife, and the natural habitats that sustain our world.
- Beautiful gardens and natural environments are fundamentally important to the mental and physical well-being of all people.
- People live better, healthier lives when they can create, care for, and enjoy gardens”.

These core beliefs embody principles that are universal in their applicability to the botanic gardens of the future. At Chicago Botanic Garden they are matched by the ambition and leadership that makes the Garden one of the city’s most influential institutions. It is perhaps ironic that these forward-looking initiatives are taking place in a city where, in the 1920s and 1930s, the Chicago School of urban sociology promoted a modernist perspective in which urban life was considered to be quite distinct from rural life (McDonnell 2011 cited by Elmqvist *et al.* 2013b) so that cities were essentially thought of as detached from their broader

life-support systems in the hinterland. The growth of Chicago as a major hub in the US railways allowed the rapid expansion of the city and pushed its dependence on agricultural production further away. Today's green renewal shows the potential of botanic gardens to help to shape the quality of life in the future. No doubt, as they work to increase their impact, botanic gardens will need to extend the range of disciplines and skills they can draw on, either by direct recruitment of specialist staff or by developing new partnerships, for examples, with organisations with medical healthcare expertise.

Given our focus on tropical collections, I will take Singapore as another microcosm of the future. Established as an independent state in 1965 with five million people in just 580 square kilometres the national development strategy focused on creating 'a city in a garden' (Hean 2010). Singapore has no natural reserves of fossil fuels and limited land for the generation of renewable energy. Similarly, spaces for reservoirs of drinking water are limited and the government has therefore promoted energy efficiency, recycling and desalination of sea water. In developing the Marina Bay area, adjacent to the central business district, incentives were provided to encourage greenery and an inland reservoir captures and recycles the cities run-off (Hean 2010). The architecture of the Gardens by the Bay reflects these considerations (Davey 2011) with recycled vegetation providing biomass to combined heat and power energy plants that cool and dehumidify the substantial glasshouses (Davey *et al.* 2010; Koh 2012). Interpretation of these features raises the consciousness of visitors to sustainable technologies and the role of plants in the life of the city, becoming a source of civic pride to local inhabitants. The Gardens by the Bay also houses a rich and well-interpreted collection of plants in an exciting setting with futuristic 'supertrees', elevated walkways and the spectacular Flower Dome and Cloud Forest glasshouses. The latter houses a world class exhibit focussing on global change, setting out practical steps every visitor can take to reduce their own ecological footprint. Where better than the relaxing, yet stimulating, en-

vironment of a botanic garden to learn about and reflect upon the future of the planet?

Meeting the Needs of the Global Community

Above and beyond the contribution botanic gardens make to the life of the immediate communities they serve, it is possible to consider how, collectively, they meet the needs of the global community through their relevance to the international development agenda (Blackmore 2016). At the Millennium Summit in 2000, the largest ever gathering of world leaders agreed to reduce poverty through the Millennium Development Goals (MDGs), eight ambitious targets running to 2015 (<http://www.unmillenniumproject.org/goals/>). These targets are, I would argue, the closest thing we have had to an internationally agreed agenda for the future of our planet. I regard them, therefore, as a proxy for what the world wants for the future. This is not to say that the MDGs provided an optimal or even an adequate vision for the future of the planet. They were, in effect, concerned only with those aspects of the future on which 191 world leaders could reach agreement. And although Millennium Development Goal 7 refers to environmental sustainability there is, for example, no specific goal concerning the condition of nature itself. The emphasis was firmly on what was referred to as the human environment. MDG 7 had three specific targets, to:

- "integrate the principles of sustainable development into country policies and programs and reverse the loss of environmental resources,
- Halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation, and
- Have achieved by 2020 a significant improvement in the lives of at least 100 million slum dwellers".

It might be argued that the United Nations addresses biodiversity and the natural environment elsewhere, through the UN Convention on Biological Diversity (CBD). But the CBD contains no specific targets for

action. The Global Strategy for Plant Conservation (GSPC) on the other hand, does have explicit targets (Blackmore 2005; Wyse Jackson & Kennedy 2009; McNeely 2011). However, as the Secretariat of the Convention on Biological Diversity (2009), McNeely (2011), Sharrock *et al.* (2014) and others have pointed out, progress towards these targets has been mixed and has undoubtedly been constrained by the lack of dedicated financial resources to support the strategy. The GSPC is now into its second term, but it remains the case that few governments have allocated funding to support it. Although the fundamental importance of plants to humanity is often stated (see for example, Sharrock *et al.* 2014), it seems that the message has not yet been taken to heart. One of the major challenges has been, and continues to be, establishing the links between biodiversity and poverty alleviation (Sachs *et al.* 2009). The links are there, whether recognised or not. But bringing about a wider understanding of this point is one of the most important contributions botanic gardens can try to make to wider society for the benefit of the future. Of the eight MDG targets some were more obviously connected with our dependence upon plants than others. Goal 1, to eradicate extreme poverty and hunger, and Goal 7, to ensure environmental sustainability, depend directly upon the state of the world's plants and vegetation. Other goals, concerned with human health, have a tangible but less direct connection with plants, especially given the importance of plant-derived medicines. These include Goal 4, to reduce child mortality, Goal 5, to improve maternal health and Goal 6, to combat HIV/AIDS, Malaria and other diseases. Arguably, however, none of the MDGs could be achieved in places where plant-derived ecosystem services have broken down completely (Blackmore in press). Now that we have passed the deadline for the achievement of the MDGs progress towards them has clearly been mixed, with the UN reporting that, "Despite many successes, the poorest and most vulnerable people are being left behind" (United Nations 2015).

As the deadline for the Millennium Development Goals drew closer, discussion on the Post 2015 Development Agenda began (see, for example, Griggs *et al.*

2013). One important document, The Future We Want (<http://www.uncsd2012.org/thefuturewewant.htm>), emerged from a wide consultation exercise and a summit in Rio de Janeiro in June 2012, twenty years after the 1992 Earth Summit. The Future We Want called for "...holistic and integrated approaches to sustainable development which will guide humanity to live in harmony with nature and lead to efforts to restore the health and integrity of the Earth's ecosystem." It introduced a new draft set of 17 Sustainable Development Goals (SDGs) which were put forward for agreement in September 2015, at the 70th session of the General Assembly of the United Nations in New York. The 2030 Agenda for Sustainable Development (<https://sustainabledevelopment.un.org/post2015/summit>) came into effect from the start of 2016. As with the earlier MDGs, achieving many of the 17 SDGs will require the careful conservation and stewardship of the Earth's botanical diversity. I identify five of them as having particular relevance to the future work of botanic gardens and to issues discussed earlier in this chapter:

- Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture.
- Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
- Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable.
- Goal 13. Take urgent action to combat climate change and its impacts.
- Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

Of the SDGs, Goal 15, is most directly connected with the traditional work of botanic gardens and to their more recent aspiration to contribute to ecological restoration (Aronson 2014; Aronson & Alexander 2013). However, all five are worthy of review and consider-

ation by botanic gardens when developing their plans for the future. By adapting their mission and roles to contribute to meeting the challenges of the global agenda defined by the SDGs, especially the goals highlighted above, botanic gardens can meet the needs of both the local and global communities and play a pivotal part in shaping the future.

Conclusions

Thinking of botanic gardens as agents of change recognises the importance of both their advocacy and outreach programmes and of the direct actions they undertake in working with plants. A botanic garden is an ideal place in which to learn about and reflect upon global change and to become more aware of the UN's 2030 Sustainable Development Agenda. Securing the integrity of the biosphere and achieving the SDGs will depend not just on governments but upon the engagement of individual citizens around the world understanding how they personally can make a positive difference to the future. Recognising this, the role of botanic garden education and outreach programmes should be to focus on positive and practical messages that empower their visitors to live healthier and more sustainable lives. Botanic gardens can also build movements for change in society to replace the currently widespread perspective that there is little the individual can do to influence the future of the planet (Blackmore 2009). The United Nations' vision of "prosperity and dignity for all in a world where humankind lives in harmony with nature" requires changes in individual behaviour in addition to governmental programmes. Botanic gardens can contribute to creating such a world, especially if, and this will be my main conclusion about their future, they work together even more effectively than hitherto.

The direct action I refer to includes the research undertaken in botanic gardens, especially in the fields of taxonomy, systematics, conservation biology, ecology and other fields of biodiversity science. There is, of course, a real urgency to this research. As others in this conference have emphasised, the objects of this research are disappearing steadily in the biodiversity

crisis. Our present efforts are inadequately resourced and, as a result, too slow. Fortunately, there is also good news. The internet enables rapid communication around the world and, with the digitisation of collections, is enabling the disproportionately rich herbaria housed in the temperate world to be accessible to all nations. Countries with emerging economies, including China and Brazil in particular, are expanding their workforces in the biodiversity sciences.

Nevertheless, applying our knowledge of biodiversity to the task of reversing the tide of environmental degradation in order to restore the health and integrity of the Earth's Ecosystems is an enormous challenge. Botanic gardens are now beginning to see their relevance to this task. The Ecological Restoration Alliance of Botanic Gardens is in its infancy, but it is clear that botanic gardens have a unique contribution to make. This special role reflects their rich collections of plant diversity coupled with their horticultural expertise to grow a wide spectrum of plants, including many that are rarely cultivated outside botanic gardens (Aronson 2014; Aronson & Alexander 2013). The scientific and technical skills available in seed banks and living collections represent essential knowledge for a sustainable future. Inappropriate, exotic plants continue to be used in reforestation programmes, often because native species are not readily available in commercial nurseries and seed stocks. Botanic gardens are perhaps the only agencies likely to be able to change this situation by providing native plant material. Doing so will build on the many successful programmes of ex-situ conservation carried out by botanic gardens in response to Target 8 of the Global Strategy for Plant Conservation (Blackmore *et al.* 2011). Such programmes focus on bringing locally threatened plants into the security of the living collection and, ultimately, using them to re-establish wild populations and to contribute to restoration projects.

Most importantly, for the future, we need to be better organised and more strategic if our actions are to be coordinated and scaled up in order to have a significant impact. We need what Paul Smith, Secretary General of Botanic Gardens Conservation Inter-

national (BGCI), calls “a rational, cost-effective global system for plant conservation” (Smith 2017). He makes the point that such a system already exists for plants in agriculture, with an International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) (www.planttreaty.org), a global plan of action, a network of international ex-situ collections, a global portal to accession data, advanced bioinformatics tools, and an endowment fund (The Crop Trust, www.croptrust.org) to conserve crop diversity in perpetuity. BGCI, as the global network of botanic gardens, is well placed to frame the debate and facilitate the establishment of an equally strategic approach to conserving plant species which are not necessarily important for food and agriculture. BGCI is developing its own strategic plan accordingly (www.bgci.org/about-us/mission).

Individually and, especially when working together collectively, botanic gardens have the opportunity to be agents for change transforming lives and pointing the way to a more sustainable relationship with the planet.

Acknowledgments

I am grateful to BGCI for Figure 1. The symposium recognised the vital importance of local field assistants for scientists from temperate regions working in tropical countries. I dedicate this paper to Antonio ‘Mazarin’ Constance (1935–) who’s knowledge of nature in the Seychelles is worthy of honorary doctorates in several disciplines.

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