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An Overview of the scientific significance of Botanical Gardens in plant conservation

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Abstract
The solution to the lack of functional data for underrepresented plant taxa could be found in botanical gardens. It is possible for researchers to access thousands of species from all over the world with a variety of life histories and living collections kept in botanic gardens, which house about thirty percent of all plant species.
There is currently an unparalleled loss of plant diversity, which is leading to a decline in ecosystem services. The threat of extinction affects about one-third of the world's vascular plant species. These activities include excessive harvesting and exploitation, unfavorable forestry and agricultural practices, urbanization, pollution of the environment, changes in land use, exotic invasive species, global climate change, and more. Thus, in order to save plant species, we must work harder to create integrative conservation strategies. Plant research, conservation, and public education about the richness of plant species worldwide are the main goals of botanical gardens. Additionally essential to sustaining human necessities and well-being are these gardens.
Scientists are able to get around many of the infrastructure challenges involved in gathering functional trait data for tropical forest species in-situ because botanic gardens frequently feature on-site laboratories and are affiliated with universities and other research institutes. A catalog of the scientific research, in-situ conservation, plant resource exploitation, and citizen science components of the botanical gardens' integrated missions is presented in this mini review.
Despite their potential benefits, botanic gardens are still incredibly underutilized for researching the functional ecology of plants, as express in this paper. For academics and researchers, the review addresses the advantages and possible biases of botanic gardens.

Keywords: In-situ, ex-situ, plant spices, Botanic gardens, researchers, scientific research, global environment

Introduction

In a botanical garden, the native flora of the area is the subject of botanical research, conservation, teaching, and display. Apart from that, a botanical garden is a place where plants are cultivated for public display and scientific research. A contemporary botanical garden includes a herbarium, library, space for photographic studies, lecture hall, laboratory, and leisure areas, according to Rakow and Lee (2011). Nevertheless, it may also feature specialized plant collections, like those of succulents and cacti, herb gardens, plants from specific regions of the world, and so forth. Other examples could be greenhouses and shade rooms filled with unique collections of plants, such as exotic species or alpine or tropical plants.
There is currently an unparalleled loss of plant diversity, which is causing a decline in ecosystem services. Due to a number of destructive activities, such as over-harvesting and over-exploitation, harmful agricultural and forestry practices, urbanization, environmental pollution, changes in land use, exotic invasive species, global climate change, and more, about one-third of the world's vascular plant species are in danger of going extinct. Thus, we must work harder to create integrative conservation strategies for the preservation of plant species. Botanical gardens dedicate their resources to plant research and conservation, as well as educating the public about the diversity of plant species found across the world.
Additionally, these gardens are essential to sustaining human needs and well-being. A paradigm for the integrated missions of botanical gardens—which include citizen science, in-situ and in situ conservation, scientific research, and plant resource utilization—is outlined in this article.
In the review, the future responsibilities and challenges facing botanical gardens in a changing world are discussed. These include the detrimental effects of depression caused by out breeding and/or inbreeding, raising awareness of, studying, and conserving the diversity of plant species, speeding up global access to information about plant diversity, and stepping up capacity building and training initiatives.
Plant collections kept in enclosed spaces for scientific research, leisure, conservation, botany and horticulture teaching, and public landscape aesthetics are known as botanical gardens. Botanical gardens can play important roles in plant sciences and agricultural studies because of their facilities and wide range of plants. Furthermore, botanical gardens are crucial for the creation of green areas in cities, as well as for their roles as tourist destinations, commercial enterprises, and places where people may go to feel better about themselves. Thus, the functions of botanical gardens in terms of research and instruction were examined in this study.
Regarding these subjects' application to plant science and agriculture research, there was additional discussion. Additionally, botanical gardens' scientific potential has been considered for upcoming research.

Evolution and History

The history of botany is deeply entwined with that of botanical gardens. In order to study medicinal plants, European colleges constructed the first physical gardens, which later became known as botanic gardens. Early gardens from the Renaissance period were discovered close to Pisa, Italy (1543). Originally created as medicinal

gardens in the 16th and 17th centuries, botanical gardens eventually came to represent displays of exquisite, exotic, rare, and sometimes highly valuable plant species that were returned from European colonies and other distant locations. Without a doubt, the first garden was discovered rather than created, since the biosphere is a global garden. A belt of trees, plants with flowers, and fruits enhanced the beauty of a natural area. This garden grows on its own without any care from anyone. According to the earliest stories, these locations are the gardens of the Gods or the homes of those who are blessed by them, therefore extra care doesn't need to be taken to maintain the area tidy.

The first of them, called physic gardens, were established in the 16th century in Italy during the Italian Renaissance. The gardens are the source of current botanical gardens.

The 17th century marked a shift from this early interest in therapeutic plants to one in the new plants brought in from excursions outside of Europe.

Botanists working in herbaria and universities connected to the gardens developed systems of categorization and naming in the eighteenth century; these systems were frequently on display in the gardens as instructive "order beds." The late 18th century saw the fast expansion of European imperialism, leading to the establishment of botanical gardens in tropical regions. Economic botany gained prominence, with its center being at the Royal Botanic Gardens, Kew, close to London.

Later, in the 19th and 20th centuries, there was a shift toward a variety of specialized and eclectic collections that showcased numerous botany and horticultural disciplines (Hill, 1915). Municipal or civic botanical gardens were founded in significant numbers during the 19th and 20th centuries. There were strong horticultural traits and frequent labeling of the plants, despite the lack of scientific infrastructure or programs. While they maintained plant collections and shared seeds with other gardens worldwide, they were not botanical gardens in the traditional sense; instead, the daily policies of the people in charge determined what material might be collected. In most cases, they were run by general park administrations and tended to become little more than well-kept parks.

Education, tourism, and interpretation services all saw significant advancements in the second half of the 20th century. A wide range of interests was catered to by botanical gardens, and this was reflected in their displays, which often included specialist glasshouse collections of tropical plants, alpine plants, cacti, and orchids, as well as the traditional herb garden. Horticultural displays included beautiful flowerbeds and herbaceous borders, plants from all over the world, and special collections of plant groups like roses or bamboos. Specialized gardens have been quite popular, such as the Palmengarten in Frankfurt, Germany (1869), which is home to one of the most significant collections of orchids and succulent plants in the world (Heywood, 1987) [5].

Botanical gardens have evolved over time to meet the needs of horticulture and botany as cultural and scientific institutions. Today's botanical gardens showcase a variety of the aforementioned themes as well as others. Because they have a close relationship with the public, they can inform visitors about the environmental challenges of the early 21st century, particularly those that have to do with plant sustainability and conservation.

In the twenty-first century, botanic gardens are concentrated repositories of amazing information in taxonomy, ethnobotany, and horticulture, and this knowledge is still growing. In addition to studying species for their potential medical uses, scientists are also exploring evolution through the creation of DNA banks, ex/in-situ conservation, and seed banks.

For What Reason Was the Botanical Garden Founded?

Plant species are protected in and out of their natural habitats through the establishment of botanical gardens.

The number of botanical institutions in existence now is roughly 3,765 (BGCI, 2023) globally. Over 41 percent of known threatened species have been conserved by the 3,269 botanical institutions spread over 180 nations, and at least 30 percent of all plant species' variety is thought to have been preserved.

According to Mounce *et al*. (2017) [8], 93% of the plant species kept in the botanical garden are from the temperate zone, despite the tropical region having a large and wide variety of plant species. Accordingly, 76% of species thought to have vanished from collections still in existence are tropical in origin (Mounce *et al*., 2017) [8]. Plant conservation organizations like Botanical Gardens Conservation International (BGCI) and the construction of botanical gardens are crucial for overcoming these obstacles and saving plants all over the world through accessions. According to Krishnan and Novy (2017) [7], among many other benefits, botanic gardens provide the chance to maintain plant diversity outside of their natural habitats, or "ex-situ conservation services," and they significantly contribute to preventing the extinction of species by coordinating conservation efforts.

The significance and goals of a botanical garden should be carefully considered before it is established, according to Patzelt and Anderson (2016) and Rakow and Lee (2011). The following are a few uses and importance of botanical gardens

1. Growing a limited number of plants in the area so that locals are familiar with their names, attractive qualities, and suitable cultural practices.
2. To display an extensive assortment of all the woody plants that are deemed most beautiful from an aesthetic perspective (if it's an arboretum, or among the perennials, annuals, and bulbs as well, if it's a botanical garden).
3. To serve as a method of bringing in new plants to the region, from wherever they may come
4. To provide a lab for horticulture, botany, and nature study students.
5. In order to boost output, economic relevance, and aesthetic appeal, new plants that have never been grown there should be introduced, and planting areas should be done strategically.
6. To develop the excitement of finding new species that are appropriate for planting on private property and to inspire the public's interest in recreation through walks, drives, beautiful displays, flower shows, and other events.

Spread of Exotic Species

The number of botanical gardens and arboreta worldwide has increased to over 1800, with the majority of them located in temperate zones across 150 nations, including

roughly 400 in Europe, 200 in North America, and 150 in Russia, and an increasing number in East Asia. About 150 million people visit these gardens annually; therefore it is not unexpected that many individuals were initially enthralled with the wonders of the plant world in a botanical garden.

The publishing of seed lists allowed botanical gardens to trade plants in the past. Between botanical gardens, this was a way to transfer plants and knowledge. Despite increased awareness in recent years regarding the potential for genetic piracy and the spread of exotic species, this system nevertheless exists today.

As a global organization connected to the International Union of Biological Sciences, the International Association of Botanic Gardens was established in 1954. More recently, Botanic Gardens Conservation International (BGCI), whose goal is to "mobilize botanic gardens and engage partners in securing plant diversity for the well-being of people and the planet," has also supplied coordination. In addition to creating a variety of resources and publications, arranging international conferences, and implementing conservation projects, BGCI, which has over 700 members—mostly botanic gardens—in 118 countries, is a prominent supporter of the global strategy for plant conservation.

Regional communication is also possible. There is the Botanic Gardens of Australia and New Zealand (BGANZ) in Australasia and the American Public Gardens Association in the United States.

Botanical gardens: Their Purpose and Role

Botanical gardens provide four primary purposes, according to Ocak and Kurtaslan (2015)

The purpose of botanical gardens has changed throughout time. Originally intended to research and cultivate plants with therapeutic qualities, they have served a variety of purposes throughout history, including as gardens for pleasure. It might be argued, however, that because their collections are essentially scientific, they are always changing to meet the demands of their societies as they encounter new difficulties.

As time goes on, they will play an increasingly important role in both plant conservation and helping visitors learn about them.

They are also beginning to lessen the effects of climate change, and given their ideal location for facilitating the movement of species and the adaptation of ecosystems to new climatic conditions in many parts of the world, they may be crucial to the planet's survival.

The following are the several responsibilities that botanical gardens serve.

1. Research conducted by Scientists

An outdoor laboratory is provided by the botanical garden. Undertake research on a range of plant species, species interactions, vegetation, ecological dynamics, and the impact of climate change on national, regional, and local socioeconomic development.

Scientific study can be conducted in many different fields at botanical gardens. Botanical gardens are important sources of data collection for plant ecology, including phenological indicators of climate change, plant physiology and growth strategies, and plant–animal interactions. They also serve as centers for taxonomic and systematic research. Botanical gardens can offer a wide variety of species for the purpose of studying functional trade-offs between species attributes and plant performance.

2. Preservation of Plants

A botanical garden can enhance the conservation of biodiversity by acting as a refuge for endangered species, offering ecological models, promoting genetic and species diversity, and supporting international efforts to conserve plant germplasm. Additionally, it maintains genetic variety and conserves endangered species.

Genetics for plant conservation offers useful instruments for successful restoration and conservation, for measuring and tracking procedures, and eventually for lowering the likelihood that endangered plant species would go extinct in the wild.

Everyone agrees that plants are an important component of biological variety on Earth and a critical resource. Many thousands of wild plants have enormous economic and cultural significance and potential, in addition to the few crop species utilized for basic food and fibers. These plants provide food, medicine, fuel, clothing, and shelter for countless numbers of people worldwide. Additionally, plants are essential to the planet's basic environmental balance, ecosystem stability, and the provision of a significant portion of animal habitats.

Botanical Gardens Conservation International (BGCI) estimates that there are 6.13 million accessions in botanical gardens, including more than 80,000 species. The primary contribution of botanical gardens is their collections of live plants. There is a long history of preserving live plants in botanical gardens, particularly those that are endangered in the wild. This practice has significantly advanced our knowledge of endangered species. Ex situ conservation, according to the Convention on Biological Diversity, is the preservation of biological diversity's constituent parts away from their native environments. Botanical gardens are typically linked with ex situ conservation, which is a crucial aspect of preserving endangered plant species.

Developing and sustaining native taxon collections, as well as cultivating and maintaining plant stocks for ex situ conservation and the sustainable use of plant resources worldwide, are some of the key goals of botanical gardens.

Within and amongst garden collections, many methods for preserving live plants are used. It is challenging to determine the conservation value of an ex situ collection directly.

For ex situ botanical populations of endangered species, it is crucial to comprehend an efficient sampling strategy that enables the acquisition of large variation for living plant conservation collections.

Many species that have been introduced from other regions are grown in botanical gardens; nevertheless, the majority of cultivated taxa are kept in small collections, and most of them are only in small populations with inadequate genetic diversity. Due to stochastic dynamics and a lack of genetic exchange, small populations are vulnerable to harmful genetic consequences.

Consequently, for the preservation of some plant species in their natural environments, in situ ecosystem management and in situ conservation are crucial. For instance, due to the greater number of native species that are dispersed there, Universities, research institutes Botanical Garden plays a leadership role in conservation.

In the living collections of the botanical garden, almost 10,000 plant species are conserved. In modern botanical gardens, of course, the traditional roles of the garden should not be overlooked, namely the development and usage of plant resources.

3. Use for Recreation

Those who have turned gardening into a hobby are drawn to the botanical garden. The development of nature-based leisure and tourism destinations for both domestic and foreign visitors can thus be greatly facilitated by botanical gardens.

4. Role of Education

In order to develop a concept of nature-sensitive citizenship, organized attempts to explain how natural environments work—more especially, how humans may regulate ecosystems and behavior to live sustainably—are collectively referred to as environmental education, a multidisciplinary field of study. In order to bridge the gap between environmental issues and moral principles and stop new environmental issues from developing, environmental sensitivity and awareness should be employed. Thus, to help people reach good living standards, environmental education needs to help create a high-quality environment.

5. Popularization of Flora Through Citizen Science

Botanical gardens around the world have various essential goals, including conservation and research, as well as public education and garden displays. Botanical gardens have long been linked to citizen science, which is the process by which citizens do scientific researches as researchers. The emphasis of contemporary citizen science is on "citizens as scientists" rather than "scientists using citizens as data collectors". As a matter of fact, policymakers and non-governmental organizations are increasingly utilizing volunteers to augment their capacity to oversee and manage ecological assets, evaluate species that are vulnerable, and safeguard natural habitats.

In western North America, for example, volunteers were able to present proof of sharp decreases in the population of monarch butterflies during the previous 36 years. Utilizing a citizen science initiative to look into how invasive plant species are spreading among locals may help to increase awareness and alter local residents' behavior. The creation and execution of public data gathering programs, in reality, frequently results in scientific and educational consequences, including scientific education, biodiversity monitoring, and biological research.

Collaborating between local community volunteers and scientific researchers can enhance the breadth of study and facilitate the collection of scientific data. Due to their greater familiarity with the area, local residents may provide insightful information. Botanical gardens that display plant species are collection-based and hence have a unique relationship with nature. At botanical gardens, citizen science initiatives include research on population patterns, reproduction, and genetic and ecological reactions to habitat fragmentation. A recent study on how citizen science and environmental education interact with climate change and botanical gardens found that participants' knowledge, attitudes, and opinions are influenced. For example, through pollination in botanical gardens, citizen scientists could assist young people in moving from perceiving nature as they are to doing so from a scientific perspective.

Role of Botanical Gardens

An excellent location for a variety of scientific investigations is a botanical garden. (2017) [7] Krishnan and Novy. According to Herben *et al*. (2012), it is a significant source of data for the study of plant ecology, including phonological markers of climate change, plant physiology and growth strategies, and interactions between plants and animals. A wide variety of species are available at botanical gardens for the research of functional trade-offs between species traits and plant performance (Dawson *et al*. 2009) [3]. Moreover, botanical gardens are the perfect place to conduct research on the ecology of pollination, seed distribution, and other plant-animal interactions (Wang *et al*. 2018). The following functions of botanical gardens in the twenty-first century are based on the review of Krishnan and Novy (2017) [7]

1. Despite being taken out of their natural habitat, exotic plants from all over the world coexist in open air in botanical gardens, which are special acclimation settings.
2. Modern taxonomic investigations in morphology, ecology, genetics, systematics, and evolution are based on the rich and unique collections of living plants. For use in scholarly investigations into cytology, embryology, anatomy, photochemistry, and related subjects, they offer living plant resources.
3. They cover information on culinary plants, decorative plants, therapeutic plants, and many relevant subjects.
4. Plants grown in botanic gardens provide seed for hybridization, which allows for the commercial production of superior varieties of fruits, vegetables, and flowers.
5. Many endangered species are protected and unique plants can be propagated thanks to the numerous glasshouses, greenhouses, and other facilities found in botanical gardens.
6. Botanical gardens all throughout the world have served as acclimatization hubs and provided adequate facilities for the preservation of commercial plants. Numerous significant plants, native to one region but introduced to other nations, like tea, rubber, coffee, cotton, teak, cinchona, hemp, vanilla, and so forth, have become commercially important due to the efforts of numerous individuals.
7. In order to promote the introduction of some exotic, practical, and affordable plants, botanical gardens also exchange seeds and saplings of significant plants with other gardens.
8. In addition to practicing and instructing people in environment conservation, botanical gardens are helpful in teaching people how to produce horticultural plants and maintain landscapes and gardens.
9. They serve as a hub for leisure and artistic attractiveness.

Botanical Gardens' Upcoming Obligations and Problems in an Evolving Global Environment

Several human endeavors are reuniting previously isolated populations and species, such as horticultural hybrid procedures in botanical gardens and in situ/ex situ conservation studies (Kramer and Havens, 2009; Blackmore

et al., 2011) [13, 19]. Nonetheless, the induced artificial gene flow could result in the loss or decline of plant species due to depression caused by out breeding. In fact, recent research (Fenster and Galloway, 2000; Edmands, 2007) [14] has shown that out breeding depression negatively affects population persistence. As such, with those accessions produced in botanical gardens, caution must be exercised to prevent both inbreeding and out breeding.

The purpose of botanical gardens is to advance knowledge, research, and preservation of the diversity of plant species. Studies on the species variety of botanical gardens itself, however, are scarce.

According to Pautasso and Parmentier (2007) [15], there is no correlation between the species richness patterns found in natural ecosystems and the living collections found in botanical gardens across the globe. The authors demand more funding for scientists in underdeveloped nations and for botanical gardens located in areas with a high species diversity. Furthermore, it is imperative that botanical gardens assume a pivotal role in the establishment of a plant information database aimed at tracking dynamic environmental elements within gardens (Stevens, 2007; Paton, 2009) [16]. Managers from various botanical gardens need to have faster global access to information about plant diversity (Lughadha *et al*., 2009) [17].

According to Kay *et al*. (2011) [18], staff members in botanical gardens are particularly well-suited for conservation horticulture research. Horticultural activities play a significant role in in situ and/or ex situ plant conservation at botanical gardens. According to Blackmore *et al*. (2011) [19], numerous researchers have overlooked the beneficial impact that horticulture in botanical gardens has on plant conservation in recent decades. We therefore recommend that horticulturists working in botanical gardens interact with scholars studying systematics, genetics, taxonomy, and environmental education.

Further, the success of conservation in botanical gardens depends on research such as conservation effect assessments, which should be carried out by staff members in these scientific centers using their vast field knowledge and experience. Failure to do so may prevent the goals of scientific plant species conservation from being met.

Given the large number of visitors to the botanical gardens both in person and virtually, citizen science offers a unique opportunity for them (Donaldson, 2009) [20]. But while designing a citizen science program, it's important to take into account possible conflicts between scientific research, educational initiatives, and participants' motivation (Jordan and Ehrenfeld, 2011; Chen *et al*., 2015a) [21]. Basic guidelines for citizen science initiatives in botanical gardens should be established. These guidelines should state that data gathered by members of the public must be verified by various experts, that data collection techniques must be standardized, and that volunteers must be given feedback regarding their involvement in the botanical gardens.

Botanical gardens are excellent places to study plant diversity and resource use. However, studies carried out in botanical gardens are frequently disregarded in mainstream plant science.

It is rare for scientists working at botanical gardens to rise to positions of leadership in the field of plant science (Blackmore *et al*., 2011) [19]. To train future botanists and horticulturists in botanical gardens, capacity building and training activities (plant collection and identification, species registration and evaluations, horticulture and conservation practices, public education and citizen science) must be carried out.

The world is entering the Anthropocene, hence it is necessary to explore the idea of "new conservation." Additionally, researchers at botanical gardens may have new chances in the post-GSPC 2020 era due to new technology (Heywood, 2017) [22]. A thorough collection policy for living collections is essential for a scientific botanical garden that prioritizes science and conservation. Plants of wild origin, representative populations, sufficient sample sizes, clear provenance and other collection details, and a direct connection between collections and botanical project design are a few examples of what this would take into account.

To improve capability and scientific inquiry Chinese botanical gardens should: i) create specialist gardens and support corresponding research; ii) enhance and expand facilities for molecular biology-based research; and iii) create digitalized botanical gardens.

Conclusion

Botanical gardens have been preserved and passed down to future generations as one of humanity's greatest contributions to the planet. These gardens have benefited the area's scientific advancements, economic growth, cultural advancement, and commercial development over the course of history. In order to fulfill the aforementioned purposes, these botanical gardens need to be expanded, renovated, and protected in line with scientific findings. This is the only way that rapidly diminishing natural resources can be preserved and environmental issues can be swiftly addressed.

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