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The University of Bologna Botanical Gardens: proposal for a tech-savvy walk throughout history

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Abstract

Botanical gardens in Italy are facing a severe crisis and many of them are under risk to disappear. The Botanical Gardens of the University of Bologna (UBBGs) contains one of the eldest germplasm collections in the world. Currently, the ageing of the living arboreal collection poses typical problems associated with senescence, with some specimens already being lost. Furthermore, social recognition and emotional attachment from the local citizens are weak. In the present paper, a proposal for the recovery and regeneration of the UBBGs is structured in three subsequent phases. Primarily, the detection of physiological and mechanical issues in arboreal collection occurs by visual and instrumental analyses. A GIS-based system links the data to each tree and allows to upload them in digital databases. In the second phase, iconic "totem" trees are selected to host GPS-triggered interpretive features available to users via digital application on mobile devices. To make use of them, people are asked to log in and supply basic information, including (I) age class, (II) provenance, (III) time for visiting, and (IV) reasons for visiting. Extemporary quizzes, digital puzzles, and themed treasure hunts are also delivered during the tour basing on visitors' information and played features. At the end of the tour, personal satisfaction is assessed by a star-rating system, besides the selection of the most and least enjoyed features. In the last phase, satellite gardens are newly established, in neglected or abandoned urban sites, and users are also involved in data collection; therefore, fostering participatory citizen science. Hence, a long-term management plan for the arboreal collections is defined. Technological features improve the accessibility and intelligibility of UBBGs to visiting people, reviving their educational and recreational roles.

Keywords: ex situ plant collection restoration, interactive learning, plant genetic resource conservation, citizen science

INTRODUCTION

The Botanical Gardens Conservation International (BGCI) defines botanical gardens as "institutions holding documented collections of living plants for the purposes of scientific research, conservation, display and education" (Ward et al., 2010; Gratzfeld et al., 2016). This general statement blurs the boundary lines between the different styles that botanical gardens (BGs) have been acquiring in time. In 1989, a 12-classes list was drawn up in agreement with other institutions (Vernon, 1989) where several mixtures of undertaken roles and activities were considered. Though, some botanical gardens have hybrid characteristics and do not match fully to any of the listed classes (Wyse Jackson and Sutherland, 2013). Perhaps historical factors help to explain such a high level of heterogeneity, in fact many botanical gardens were established or underwent renovations over the last three centuries (Wiegand et al., 2013; Martins-Loução and Gaio-Oliveira, 2017), consistently with contemporary fashions and needs. In a recent report, it was also observed that more than 50% of the existing BGs were built no longer than 60 years ago (Wyse Jackson and Sutherland, 2013). All in all, it is possible to work out general definitions of botanical gardens, but the high levels of heterogeneity in modern BGs inherited characteristics currently does not allow to find one fitting all.

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Drivers of changes in living trees collection setting and utilization

Among the drivers, the anthropic impact and its side effects are the most cited in literature. They threaten to destroy several ecosystems (Volis, 2017) along with all the beneficial services we ourselves benefit from them. Focusing on plants, the number of endangered species steadily grows, and some 100 are already found exclusively in BGs (Dixon and Sharrock, 2009). During the last decades, the situation made “conservation and restoration” the mantra for scientific and political agenda concerning the global loss of biodiversity. In connection with this, scientific research frequently stresses the importance of seed banks and living plants collections in biodiversity conservation and restoration programs. Moreover, the role of BGs in plant conservation is widely acknowledged (Raven, 1981), having them great and longstanding strength in the exploration and documentation of plant diversity (Crane et al., 2009). Several garden networks through which BGs coordinate different activities all over the world have already been established (Schnelle and Volkert, 1974; Wyse Jackson and Sutherland, 2013; O’Donnell and Sharrock, 2017). In addition to data management, BGs could materially assist the migration of the major plant groups lacking of long-distance/short-time dispersal capacity (Dixon and Sharrock, 2009), hence take the chance to test their responses to global change (Crane et al., 2009) and identify drought- and temperature-sensitive species that are experiencing increased mortality rates in BGs (Primack and Miller-Rushing, 2009). Eventually, they could also serve as biodiversity hotspot for the local fauna (Bazzocchi et al., 2017). In spite of these efforts to build a solid and real network, some BGs are in crisis and risk to turn into public parks (Hurka, 1994), with their plant collections dismissed because not actively used and costly (Raven, 1981). Other institutions already experienced turnovers due to calamities and/or abandonment (Nath et al., 2018). The financing of these institutions is one of the main problems driving the crisis (Heywood, 2017) but not the only one. In fact, since they do not aptly fit their current social role, threatened BGs could benefit more than others from a deep paradigm shift, and their collections should therefore be compliant with the latest needs, in order to promote both their social and scientific relevance.

Technological drivers: data gathering and digitization

Data accessibility through digital media is a great opportunity but also a major thrust for research institutions like botanical gardens. Not only the huge volume of materials requiring digitization must be considered but also the need for an agreement on data standards, use, quality, and limitations (Lughadha and Miller, 2009). Anyway, digitization is in progress, and trends in technology are expected to speed the process up making more information available online (Crane et al., 2009; Lughadha and Miller, 2009). Several factors are involved. First of all, the huge amount of data gathered from the research activities makes desirable to develop an international computerized information retrieval system through which garden’s holdings, collecting activities and research programs may be coordinated (Raven, 1981; Wyse Jackson and Sutherland, 2013; O’Donnell and Sharrock, 2017). Moreover, the data collection in scientific research is increasingly outputted in digital format (Heberling and Isaac, 2018) and makes use of sophisticated tools and software. Secondly, as long as BGs are popular places, they might serve to collect and share reliable data for multidisciplinary research projects concerning technological, environmental, educational and, especially, social sciences (Martins-Loução and Gaio-Oliveira, 2017; Sanyé-Mengual et al., 2018). Involving citizens and people from different strata is fundamental to work out strategies and solutions to significantly improve research activities, data gathering/sharing, and cultural awareness. Comprehensively, digitization and data accessibility to different levels allow science to virtually cross the physical borders of institutions committed to confront global challenges, thus promoting a positive perception in the public opinion.

Social and educational drivers

Botanical gardens are turning into shared, technological and multidisciplinary centers of research, education, conservation, social services, and commercialization (Lughadha and Miller, 2009; Kuzevanov and Gubiy, 2014). Without such renewal, gardens will face the possibility of becoming little more than enjoyable parks or urban green areas (Ballantyne et al., 2008). As public learning institutions, they gain a major role in providing medium through which people can acquire information, develop ideas and build new visions for themselves and the civil society (Wassenberg et al., 2015). Botanical gardens should also highlight the effects of environmental change on the loss of cultural and linguistic diversity (Dunn, 2017), that is a very urgent criticality we are called to confront with. A recent study found that any reduction in nature connection is not because of a lack of biodiversity in urban areas, but because of lifestyle factors, including parental limits and the attraction of electronic media over natural play spaces (Hand et al., 2017). A drastic renovation in research and educational approach could be arguably useful to mitigate modern detrimental phenomena (Hinds and Sparks, 2008) like the "green blindness" (Oldfield, 2009) and the "extinction of experience" (Samways, 2007; Soga and Gaston, 2016).

Scope of the research

The experimental design is expected to provide useful guidelines to restore the connection between the place and the people, but also and above all to create a privileged space where the scientific research and the people continuously meet each other. This work focuses on UBBGs re-modernization both by promoting research activities and fostering citizens participation. Restoration and monitoring programs of the arboreal collections are targeted through the implementation of technological assets. User's participation is then mandatory to identify and understand their communication preferences, their proneness to be informed in science outcomes and also their real interest in being involved in reviving neglected urban areas (Gasperi et al., 2016). At the same time, basic recreational activities (including strolling up and down the botanical gardens, enjoying shade in warm days, smelling flowers or sitting quietly on a park bench) are preserved since the use of the technological media is not compulsory to visit the place. Afterwards, the rearrangement of paths, signage and local furniture, will occur consistently with the outcomes.

MATERIALS AND METHODS

Study area description

The University of Bologna Botanic Gardens (UBBGs) were established in 1568, on the initiative of Ulisse Aldrovandi (Zanotti and Mossetti, 2008). In 1803, the University of Bologna took possession of a rural area, near and within the city walls, comprising the "Palazzina della Viola" 15th-century building. Since then, the location is still the same but the design significantly changed over time and currently consists of a 2-ha area falling under nine sectors (Figure 1). They include several woody and herbaceous plants widely cultivated in European botanical gardens, thematic collections, an example of "Garden of the Simples" and some reconstruction of natural environments with typical shrubs and evergreen trees from Emilia and Mediterranean regions.

Currently, the 20th century buildings within the area host the Department of Biology offices and laboratories where research and academic educational activities occur all year round. The Ulisse Aldrovandi Herbarium (Mossetti, 1990) is fully digitized and available online. To visitors, besides bookable guided tours, UBBGs currently provide text-rich pamphlets illustrating different themed paths, and QR codes can be played via smartphones while exploring the garden. Walkable paths inside the area are often dead ends and not plainly visible The starting steps in UBBGs renovation are here described and discussed. Furthermore, both social recognition and emotional attachment from the local citizens are weak. Accordingly, the design questions targeted by this preliminary study are the following:

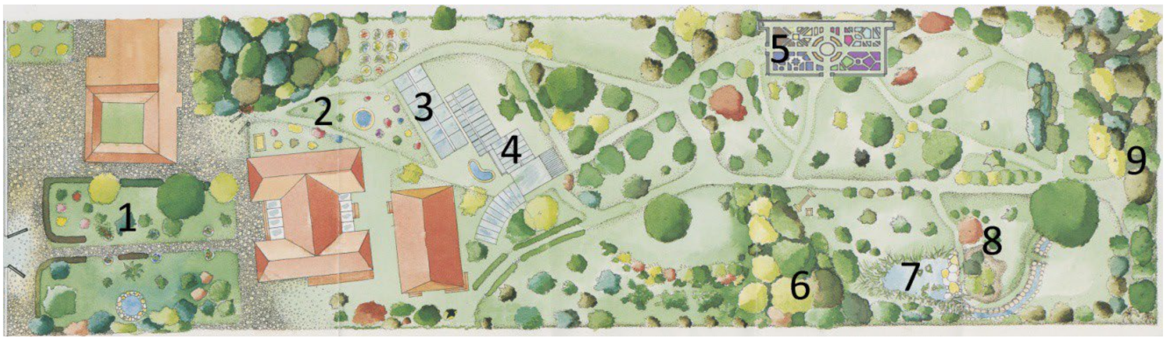

Figure 1. Map of the University of Bologna Botanic Gardens. 1) The front garden; 2) The back garden; 3) The tropical plants greenhouse; 4) The succulent plants greenhouse; 5) The herb garden; 6) The reconstruction of the submerged forest of the plains of the Po river; 7) The pond; 8) The rock garden (Gessi Bolognesi's vegetational pattern reconstruction); 9) The city walls.

1) How data may be gathered on appropriate arboreal management in BGs?
2) How should be designed an efficient and cost-effective learning HUB for appropriate data collection in BGs through citizen-science?
3) How can an effective citizen involvement be achieved in BGs improvement?

Accordingly, a proposed three-steps procedure will be described in the following paragraphs (Figure 2).

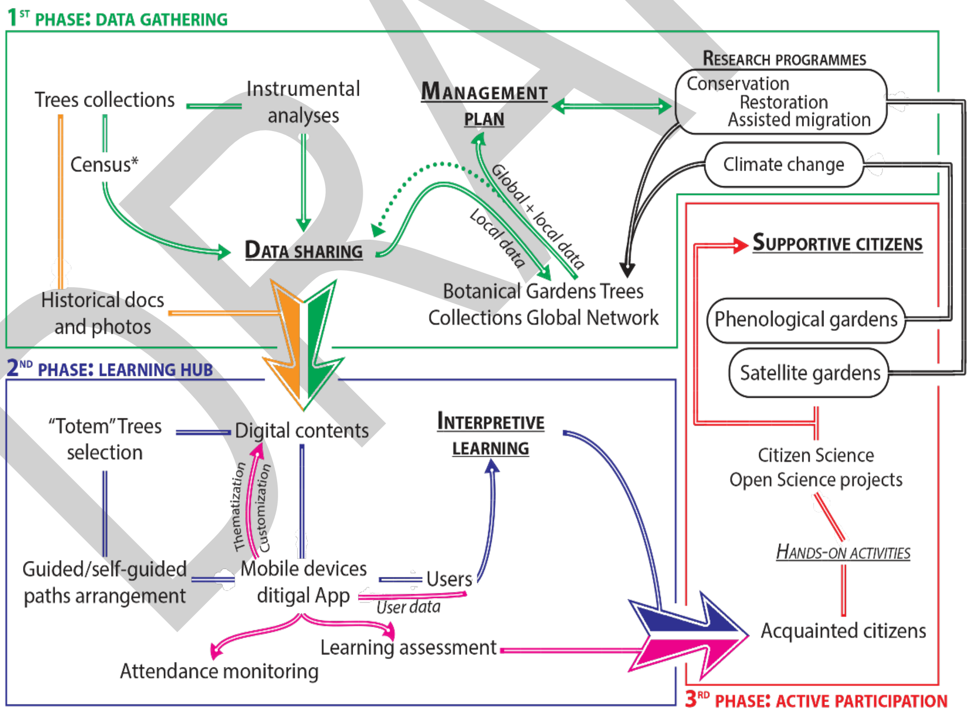

Figure 2. Flowchart showing the connections both within and between the phases.

1st phase: starting the data gathering

Nowadays, the monitoring and stability assessment of arboreal specimens are quite widespread practices meant to keep acceptable levels of risks in urban environment and plan effective long-term management as well. Since the living arboreal collection poses typical senescence problems, a preliminary investigation is conducted to assess the overall health status of the standing trees. The latest non-destructive technologies are used: i) sonic and electric tomography (Rust et al., 2008); ii) multispectral analysis (Caturegli et al., 2020); iii) analysis of leaf gas exchanges (net photosynthesis, stomatal conductance and transpiration); iv) pulling test. Data and metadata from instrumental and visual investigations are provided by a digital medium and are virtually attached to each specimen by a GIS-based geotag system. Beside the analysis of current situation, historical documentation related to the management and the changes in trees collection is implemented. The whole data are then processed and set to be uploaded to a comprehensive database storing and sharing information with and from other institutions continuously over time, so they can be compared and studied. On the one hand the results will be considered to map out the future directions in arboreal collection management and on the other they will provide functional materials to the next phase of the experimental design.

2nd phase: learning hub

The presence of iconic and representative trees is expected to emerge at the end of diagnostic analyses. These individuals, hereafter named "totem", will be used as digital hotspots. The features will include interpretive media, such as graphs, photos, videos, recorded sounds, and audio guides. Basically, all of them will be put into an augmented-reality environment that the users will explore by mobile application. When starting the app, users will anonymously select few multiple-choice parameters corresponding to their personal situation: i) age class; ii) provenance; iii) time for visiting; and iv) reasons for visiting. Then, a themed map unfolds on the screen for the selection of the path to go, consistently with the users' parameters. Hence, the tour starts and the app virtually leads the player through the place in search of GPS-triggered totem trees and plant items. The digital environment integrates the latest interpretive biology data and history notions concerning the UBBGs trees collection. Extemporary quizzes, puzzles and themed treasure hunts are also administered via digital application basing on visitor interaction with the items. Just before leaving, people are asked to rate their experience and select both the features they enjoyed the most and the least. Users who want to stay up-to-date and get involved in further educational activities can also subscribe by their e-mail address at the end of the tour. Eventually the data collected from the initial and final survey are processed to characterize different clusters of users visiting the UBBGs, their reasons for visiting and their appreciation of digital and real features. For users providing their e-mail address, the completion of the digital tasks gives the opportunity to personalize the digital tour time by time, as well as to assess their learning advancement, hence reasonably increase the complexity of the challenges they face.

3rd phase: the UBBGs renewal plan and the satellite gardens network establishment

Once the emotional and recreational connection is re-established, the UBBGs could act as a bridgehead for the creation and the management of phenological and assisted-migration gardens strategically placed within the city. The sites are chosen among obsolete public parks and gardens, dismantled areas waiting for restoration but also institutional gardens (e.g., school gardens) (Sanyé-Mengual et al., 2019). Before the interventions start, the citizens who expressed their intention to be involved in further activities are asked about their willingness to physically take part to the management of the new green area. The number of users involved varies with the needs of the proposed experimentations and the tasks' complexity. Only digitally-trained citizens who allowed data profiling through e-mail address are contacted, because their level of preparation can be roughly predicted basing on the results of digital tasks. Once the workgroup is set, the UBBGs staff provide few simple and necessary instructions to correctly carry on the activities and supervise the first attempts. The staff of the UBBGs eventually check the "satellite data" before the upload to the database. Digital features are developed and become available to common users similarly to those regarding the botanical gardens. The collected "satellite-data" are used to extend the digital learning interpretive features beyond the UBBGs boundaries.

DISCUSSION

The proposal affects topical facets of modern botanical gardens activities, so the expected results are very complex and ambitious. Firstly, data gathering and sharing is fundamental to the institution to gain a wider range of influence in scientific and social fields. Beyond all the existing literature stating this as a basic assumption, the development of national and international data networks is a good gauge to assess the truthfulness of this statement. Among the several networks that have been established, some examples are the Botanical Gardens Conservation International (BGCI), the USA National Phenology Network (USA-NPN) and its affiliate, the International Phenological Gardens of Europe (IPGE) (Wyse Jackson and Sutherland, 2013; O'Donnell and Sharrock, 2017).

As new interest raises for biodiversity collections, their study, celebration and utilization for human benefit (Crane et al., 2009), the role of botanical gardens in education and biodiversity conservation is particularly consolidated. But that is not enough to keep them safe from dismission. Actually, some researchers found that these are no longer the driving factors for the BGs social significance (Ballantyne et al., 2008; Ward et al., 2010). Thanks to technological development, botanical gardens have the chance to tackle their re-modernization before being completely overcome and obsolete. The trees collection management is a very complex issue that will not be extensively discussed here. In short, different stakeholders calls for different and heterogeneous solutions to tackle several criticalities. Thus, some argue that BGs should establish proper ex situ collections including local wild flora, rather than exclusively focus on threatened and endangered species (Hurka, 1994). Others heighten the educational role of BGs, asserting that prioritizing the conservation of ornamental plants rather than other species could be essential to raise public awareness and restrain detrimental cultural phenomena (Lughadha and Miller, 2009). Then some state that priority should be given to the high scientifically and economically interesting species (Raven, 1981). Arguably, neither of these initiatives can be effectively taken until a synced global network is set to concertedly manage the trees collections over the world as one and comprehensive collection (Volis, 2017), and whatever the strategy is, anything but a very small percentage of the world's flora could be ever preserved in botanical gardens (Raven, 1981). From this angle, the proposal aims to usher the UBBGs into the global network, benefitting from the latest technologies to manage the arboreal collection through a long-term vision prospect. Once this is done, both conservation and renovation plans can simultaneously occur, providing a possible solution to the problem of plant conservation along with the current needs of scientific research. Actually, the arrangement of the collections should also reflect the new organizational goals, resulting in an attractive and suitable environment for educational and recreational purposes. Even though the former aspect is prominent in academic perception, botanical garden visitors are often interested in recreational activities rather than learning per se or pure horticultural information (Martins-Loução and Gaio-Oliveira, 2017; Wassenberg et al., 2015). Hence, the digital features will provide entertainment and also gather data that will give the opportunity to better understand this aspect and make botanical gardens more and more attractive to general public. Furthermore, visitors rarely come on their own and the environment should encourage and enhance social interaction among different age groups (Ballantyne et al., 2008). That is why it is important to investigate user's motivation in combination with age class and other socio-cultural parameters. The provision of digital contents via personal mobile devices is meant to be a non-invasive learning tool that let visitors choose whether, when and which digital features they want to play with, as moving at their own pace. This approach is in line with recent studies stressing out that people wish to decide whether or not to access to interpretive contents when in proximity (Wolf et al., 2013) and also that free-choice learning setting is more effective than a fixed one (Ballantyne et al., 2008). Preventing the unpleasant sense of compulsion and inviting people to make free choices, preserves the recreational aspects while providing educational activities. According to Martins-Loução and Gaio-Oliveira (2017) if botanical gardens need to promote their social relevance, a good collaboration with social sciences, humanities and communication professionals is needed (Martins-Loução and Gaio-Oliveira, 2017). The better the coordination of the reciprocal connections and circulation of resources between nature and society, the greater the environmental, social and cultural role of BGs in the community and market economy (Kuzevanov and Gubiy, 2014). Since the commitment to conserve world's biodiversity is largely dependent on public opinion and public pressure, the greatest effort required will be those aimed to directly involve the general public in scientific research and tackle social, economic, and political issues (Hurka, 1994; Primack and Miller-Rushing, 2009). The whole process of establishing satellite gardens aims to promote citizens responsibility toward the common good and make them involved in scientific research. Promoting projects such as the greening of schools and surrounding urban areas through the establishment of satellite gardens could impart a sense of community and set natural environments off within urban areas, preserving and maintaining green spaces along with educating citizens of all ages (Ballantyne et al., 2008). Eventually, these places can be used for several subsidiary activities, such as out-of-school learning projects, events, temporary exhibitions and so on. Indeed, botanical gardens skills and expertises could be used in our increasingly managed and 'gardened' world, also to prevent the complete loss of basic knowledge about plants and their uses, especially at the local and regional level (Krasny and Tidball, 2009; Martins-Loução and Gaio-Oliveira, 2017). In the end, BGs are also presented with a great opportunity to develop ways in which the awareness of cultural diversity is increased, as part of their conservation mission (Volis, 2017).

CONCLUSIONS

Global changes in society, technology and environments pose complex challenges that botanical gardens in large cities can help to investigate, providing useful insights into both climatic and social contexts. The proposed steps are the starting line for a long-term process leading to greater and deeper innovation. Further investigations are needed to assess the effectiveness in learning process along with the possibilities to extend the BGs activities beyond their physical boundaries, promoting social cohesion and culture dissemination. Accordingly, the experimentation of the model hereby proposed is ongoing and will lead in the coming seasons to comprehensive data collection and implementation of a model for participatory botanical garden management.

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