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Review Paper

Assessment of Challenges and Strengths of Sustainable Architecture in the Medicinal Plant Gardens

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Abstract
Medical plant gardens are locations that primarily focus on the preservation, cultivation, research, and education of plant species that are utilized for medicinal purposes. These gardens could further achieve objectives such as creating tranquil and pleasant conditions for visitors, as well as developing the local economy and raising citizen awareness. Hence, it is imperative that the architectural style of successful herbal botanical gardens reflects a comprehensive comprehension of botany and fosters innovative thinking in garden design and interpretation. It seeks a design that will maintain the virtuous cycle of medicinal plants and maintain the spatial equilibrium of the dynamic development of urban landscapes, to achieve good ecological and urban functions. The purpose of this study is to explore the design methods of plant landscaping in urban medical plant gardens under the concept of sustainability that focuses on select principles that are adapted to sustainability and how to promote biodiversity and improve the quality of life of urban residents through eco-design approaches. We found that effective sustainable design includes not only the selection of the right areas, but also the rational management of water resources, energy conservation, environmental impact reduction, creating a calm space, and increasing the awareness of citizens. This study also identifies the socio-cultural challenges and strengths of these gardens. In conclusion, this work conducts a detailed analysis of the sustainable assessment framework for medicinal plant landscaping design in urban green spaces and empirically confirms that the sustainable architecture style is superior in general when compared to alternative styles.

Keywords: *Medicinal plant garden, Architecture style, Biodiversity, Sustainability, Energy conservation.*

INTRODUCTION

medicinal plants have played an important role in human healthcare as essential ingredients in traditional medicines. According to studies, more than 80% of the world's population still uses medicinal herbs for primary treatment. (Fitzgerald et al., 2019). In the modern period, natural chemicals produced from medicinal plants have also played an important role in medication discovery and development (Atanasov et al., 2015; Newman & Cragg, 2020). Meals, spices, cosmetics, aromatherapy, and perfumes all use medicinal and aromatic plants. Phytochemicals produced from plants are increasingly being used as food preservatives, colorants, sweeteners, and in other applications (Sarkic & Stappen, 2018; Voon et al., 2012). Out of roughly 46,000 plant species worldwide, at least 28,187 have been used for medical purposes, but only 4,478 of these therapeutic plants were mentioned in regulatory documentation (Willis, 2017). Many medicinal plants, on the other hand, are on the verge of extinction as the global plant population declines due to climate change and anthropogenic perturbations (Marnish, 2021).

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Unsustainable collection and commerce, as well as changes in land use and socio-culture, accelerate plant extinction (Schirpke et al., 2023). Therefore, it seems necessary to use sustainable places for the conservation, cultivation, research, and education of these species. This significant function can be handled by the medicinal plant gardens. These gardens provide services related to plant species whose primary use is not therapeutic (Devkota & Watanabe, 2020). Ex-situ conservation is crucial for medicinal plant gardens (Havens et al., 2006) as it can help preserve ecosystems and is essential to ensure the survival of rare and endangered plant species.

Even though living collections often contain only a few individuals of each species, they are of limited value for genetic conservation, botanic gardens have several distinguishing qualities (Yuan et al., 2010). They frequently contain taxonomically and ecologically diverse flora, with a large diversity of plant species coexisting in normal conditions (Cheng et al., 2018). By developing propagation and cultivation techniques, as well as domestication and variety breeding programs, botanic gardens can make a significant impact on medicinal plant conservation (Yuan et al., 2010).

The history of medicinal plant gardens is extensive, as the primary objective of early botanic gardens was to cultivate and examine medicinal plants (Wyse Jackson and Dennis, 1998) Currently, there exist more than 2,500 botanic gardens in 150 nations worldwide, containing over six million accessions of living plants, comprising approximately 80,000 species (Hawkins, 2008) They are well-positioned to address the distinct local conservation requirements of medicinal plants and the individuals who rely on them for their well-being and livelihood in a particular region. They are also likely to be the most important organizations for conserving native medicinal plants, as plants are rarely a top priority for other conservation organizations and agricultural government agencies. The second component, the architecture of these gardens, may be less discussed.

The other component, the architecture of these gardens, is maybe less discussed. In other words, botanic gardens can help conserve medicinal plants and ensure their long-term use in a variety of ways by combining botanical, agricultural, and architectural knowledge (Hawkins, 2008). With the sustainable design of these gardens, in terms of ecology, energy efficiency, aesthetics, etc., we can have an ideal location for research, development, education, and attracting tourists. As a result, this article examines various studies on the challenges and strengths of designing Medicinal Plants Gardens (MPGs) in different dimensions, including energy, climate, environment, and totalitarianism.

METHODOLOGY

Identification and articles collection procedure

An online search was conducted in three databases: the Web of Science, Scopus, and Google Scholar. These three databases were selected for their broad inclusion of multidisciplinary topics within the architectural and plant sciences domain.

Each database was searched for all years included in the respective databases, with the most recent search completed in 2023. The selection criteria for the selected articles were developed based on the purpose of the systematic review, to examine sustainable architecture in medicinal plant gardens. we tried to collect the existing research were used from keywords on medicinal plants and botanic gardens, design of MPGs, sustainability in MPGs, sustainable architecture in MPGs, socio-cultural challenges and strengths in MPGs and health in the MPGs design. From all the databases, 270 references in total were extracted. The publications' titles, abstracts, and keywords were screened based on the inclusion criteria, and 90 articles were left for full-text review. About 180 articles were excluded due to lack of focus on the topic, unavailability of full text, or redundancy. Finally, after a careful reading, 75 articles were selected for final review (Figure 1). Table 1 outlines the process of analyzing, interpreting, and summarizing these selected findings.

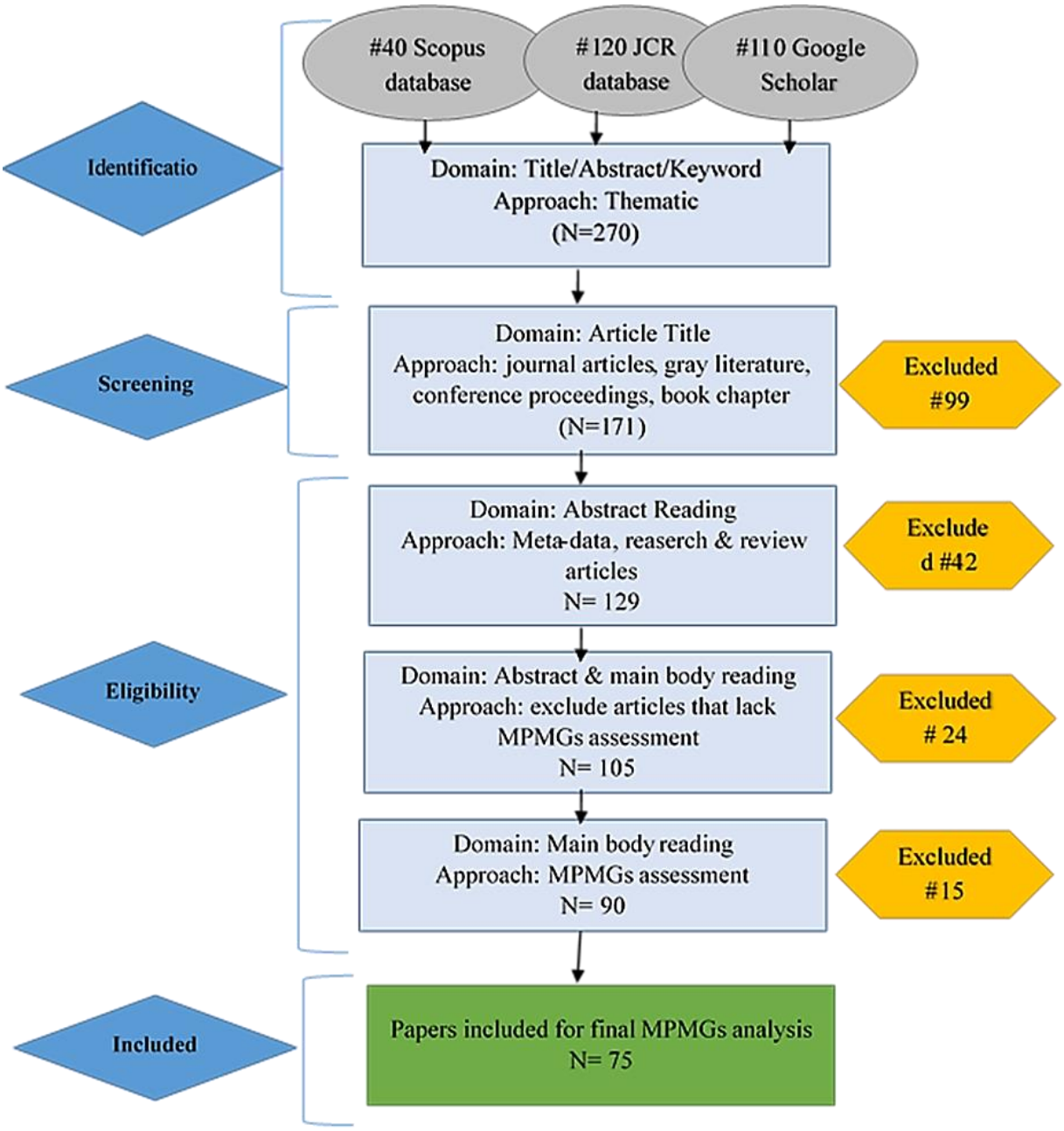

Fig 1. The Flow Chart of the Database Search of Publications (Source: Authors)

Table 1. Description of Previous Studies on the MPGs Design

Relevant Articles Title	No of Articles	Year of Publication	Findings
Medicinal plants and design of MPGs	31	From 1998 to 2023	The incorporation of human-centered landscape design with an environmentally sustainable approach can enhance the livability of cities and green spaces. Researchers assess the quality of existing landscape design both in natural and man-made environments.
Sustainability in MPGs	15	From 2000 to 2019	Human activities should be carried out in conjunction with the sustainability of environmental resources, and skills in accordance with social values and to strengthen human relationships. Attention to climatic and natural conditions and the location of the building in the definition of architecture
Sustainable architecture in MPGs	12	From 1998 to 2019	These gardens explore the interplay between people, plants, and civilization across cultures and stages of development It is an opportunity to emphasize and demonstrate a commitment to sustainability and environmental stewardship through sensitive and appropriate construction methods and environmental protection measures, including existing vegetation, topography, topsoil, and groundwater.
Socio-cultural challenges and strengths in MPGs	9	From 2002 to 2017	Botanical gardens can affect the behaviour of local and international tourists. Gardening, especially in urban areas, promotes ecological services and human sustainability
health and the MPGs Design	8	From 2003 to 2021	The importance of medicinal plants in primary healthcare and their commitment to fostering sustainable livelihoods. These gardens can both assist treat diseases and create a tranquil and interactive environment for people's mental and social health by producing helpful medicinal plants

HISTORY OF HERBAL MUSEUM GARDEN

The design history of medicinal plant gardens is sparsely documented. Botanical gardens, for example, were the first step toward modernizing garden design, because the design was based on practical ideas for producing medical and uncommon plants rather than aesthetic and decorative grounds (Tomasi, 1991). Following that, the study has concentrated on changing the purpose and role of botanical gardens in contemporary urban landscapes, as well as design knowledge that can aid improve botanical garden design quality (van den Toorn, 2010). The first gardens and zoos appeared in Mesopotamia and Egypt around 10.000 years ago, following the domestication of plants in the eastern Mediterranean basin (Foster, 1999). Even though only a few photographs have survived, it is fascinating to see how early on the practice of collecting (abnormal) flora and animals was established. The Lyceum in ancient Athens was the first major center for collecting foreign plants, animals, and artifacts as well as advancing modern scientific thought.

During his conquests of many places, Alexander the Great collected plant and animal specimens for Aristotle's studies, allowing Aristotle to establish the world's first zoo and botanical Park. As head of the Lyceum between 322 and 266 B.C., An Aristotelian pupil named Theophrastus continued Aristotle's foci of observation, description, collaborative investigation, and documentation. His classification system for plants was based on the causes associated with various plants; in fact, it was linked to the use of plants for medicinal purposes. The first Hortus Medicus was built in 1543 by the University of Pisa. Plant collections were originally primarily used for medicinal purposes. The basic ground plan of the gardens was square or circular, with four sections. Other functions gradually began to emerge (Conan, 2005).

Since the Renaissance, botanical gardens have played an important role in scientific advancement by disseminating and popularizing botanical knowledge. In the nineteenth century, botanical research focused on plant physiology and cell biology. Botanical research centers shifted from the botanical garden to the laboratory as a result. According to Robin (2008), when planning and designing botanical gardens, three criteria should be co The design history of medicinal plant gardens is sparsely documented. Botanical gardens, for example, were the first step toward modernizing garden design because the design was based on practical ideas for producing medical and uncommon plants rather than aesthetic and decorative grounds (Tomasi, 1991). Subsequently, the focus has been on changing the purpose and role of botanical

gardens in contemporary urban landscapes, as well as enhancing design knowledge to improve botanical garden design quality (van den Toorn, 2010). The first gardens and zoos appeared in Mesopotamia and Egypt around 10,000 years ago, following the domestication of plants in the eastern Mediterranean basin (Foster, 1999). Although only a few photographs have survived, it is fascinating to see how early the practice of collecting (abnormal) flora and animals was established. The Lyceum in ancient Athens was the first major center for collecting foreign plants, animals, and artifacts, as well as for advancing modern scientific thought.

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Since the Renaissance, botanical gardens have played an important role in scientific advancement by disseminating and popularizing botanical knowledge. In the nineteenth century, botanical research focused on plant physiology and cell biology. Botanical research centers shifted from the botanical garden to the laboratory as a result. According to Robin (2008), when planning and designing botanical gardens, three criteria should be considered: scientific, didactic, and aesthetic. After Darwin, phylogenetic systems emerged, which were based on the evolutionary history of a taxon or group of plants. A botanical garden's identity is defined by sections and structures for herbaria, education, and research, as well as medicinal, systematic, and aquatic sections and structures (Van den Thorn, 2017). After Darwin, phylogenetic systems emerged, which were based on the evolutionary history of a taxon or group of plants. A botanical garden's identity is defined by sections and structures for herbaria, education, and research, as well as medicinal, systematic, and aquatic sections and structures (Van den Toorn, 2017).

Gardens architecture that dates back to medieval and Renaissance Europe continues to strongly influence modern herb gardens. In the 13th century, early herbal gardens emphasized elements we still associate with our own ornamental herb gardens: proper location, enclosure, intimacy, and fragrance. Therefore, the information that exists about medicinal plant gardens shows a relatively high sustainability in their design (Larkin, 2023).

DESIGN OF THE MEDICINAL PLANTS GARDENS (MPGs)

Professional competence is essential when designing a garden to address these concerns, encompassing the evaluation, planning, design, management, and monitoring of both constructed and natural environments. Hopper (2012) asserts that professionals in the field of medicinal plants, in collaboration with those in architecture, urban planning, and civil engineering, are essential to the preservation of the natural environment. This can be accomplished through developing and carrying out programs that conserve the environment while meeting human needs.

Another view of the botanical gardens is as a place where city people can go to breathe some fresh air. They contain a wide range of plants that have been planted and kept in their original habitat, in addition to plants that have been examined, documented, and displayed to shed light on their individual characteristics. According to Oldfield (2008), Ballantyne et al. (2008), and Sharrock & Chavez (2013), the garden needs to be connected to the surrounding ecosystem ecologically. Galbraith et al. (2011) state that botanical gardens ought to function as a living museum that promotes public awareness of the interdependence of plants, humans, and the rest of nature, while also serving the local community. Combining an environmentally friendly strategy with human-centered landscape design can make cities and green places more livable. Through landscape design, people feel a sense of belonging and pride (Vuchic, 1999). By using this technique, individuals can actively participate in green places, enhance neighborhood social interaction, and gain an understanding of the significance of nature stewardship (Middle et al., 2014; Rasidi & Jamirsah, 2012; Mahdavinejad & Abedi, 2011).

The gardens, according to Buta et al. (2014), could help protect green spaces and habitats from the negative effects of unmanaged landscape planning and labor. Three components work together in the Human-Oriented Design method to affect how visitors view the overall design and landscape setting. Needs motivation, or the desire to take action in order to satisfy one's own needs is the first component. This idea was applied to determine the preferred landscapes

and frequency of visits by park visitors (Nordh et al., 2011; Mohamed et al., 2012; Othman et al., 2015).

The second concept is Landscape Visualization Theory. It has been used by many researchers and practitioners to assess the quality of existing landscape design in both natural and man-made environments (Oguz, 2000; Özgüner & Kendle, 2006; Mohamed et al., 2012; Othman et al., 2015; Özgüner & Kendle, 2006). According to the literature, this theory has been instrumental in evaluating the visual aspects of landscapes and has been widely applied in various studies.

Findings suggest that natural elements such as waterfalls, foliage, landforms, and well-maintained landscapes can attract users' visual attention positively. The Theory of Flow is another theory that provides landscape designers with principles for developing a site that effectively engages individuals and holds significance (landscape-based experiences) (Clements & Dorminey, 2011; Othman et al., 2015). Ultimately, this theory contributes to the concept of Human-Oriented Design by highlighting the appropriate approach to identifying site characteristics that align with the activities and demographics of site visitors.

SUSTAINABILITY IN MPGs

Sustainability is defined as the effective and efficient use of resources, such as nature, humanity, and technology, in a manner that meets current needs while also ensuring the fulfillment of future needs. In essence, "sustainable" denotes a world where humans and nature can coexist, considering the needs and rights of future generations, and safeguarding the environment without compromising it. Sustainable development involves tackling life-threatening physical and social trends (Martins, 2019).

A sustainable system integrates housing, people, plants, energy, and water with financial and political structures to design fertile systems. Permaculture originates from two Latin words: agriculture and permanent, signifying stable and long-lasting farming. Sustainable development not only considers basic needs like food, clothing, and shelter but also aims to provide a comfortable and moderate way of life. It emphasizes adjusting the demand for technological resources and social organization to meet current and future needs within environmental limits. The objective of sustainable development is to alter people's perceptions of the relationship between humans and nature. However, the solutions proposed for environmental and architectural sustainability primarily involve technological solutions and changing human perspectives and ideologies. They do not fully define the relationship between man and nature accurately (Botkin, 2003). According to urban planners, a sustainable city is one that can fulfill citizens' needs for economic growth, income generation, and employment, and also address health concerns, air and water pollution, sewage, green spaces, and recreational areas (Zarkesh et al., 2019). Ecological sustainability aims to preserve primary resources at levels that do not endanger future generations and to maintain and enhance the ecosystem's capacity, quality, and resilience. Strategies such as reducing resource and energy consumption, waste generation, pollution, and promoting recycling contribute to strengthening sustainability by maintaining a balance between resource exploitation and production capacity. Environmental sustainability objectives include preserving biodiversity, hydrological processes, climate enhancement, and environmental utility (Zarkesh et al., 2019).

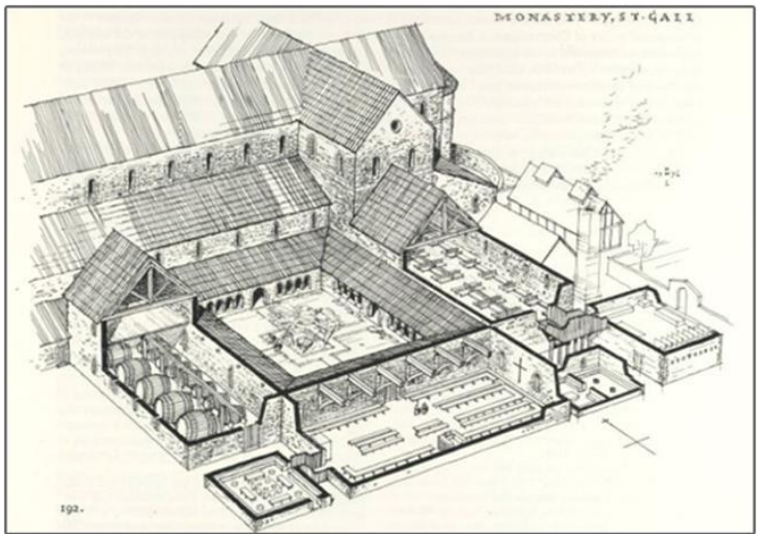


Fig 2. Illustration of a 13th-Century Monastery Herb Garden (Blackcreek, 2022)

The concept of sustainability in architecture, along with attention to climatic and natural conditions and the building's location in architectural design, is crucial. It involves reducing nonrenewable resources and energy consumption by promoting environmental and architectural harmony. Sustainable architecture also encourages the use of recyclable materials and renewable energy sources. Ultimately, sustainable architecture focuses on the environment, energy, and ecology. Therefore, human activities should align with environmental sustainability, skills should reflect social values, and relationships should be strengthened. In sustainable architecture, the interior space, as interconnected and integrated components, possesses its unique identity. Together, they shape the characteristics of sustainable architecture through a coordinated process that complements the building's form. This architectural approach minimizes negative environmental impacts and is environmentally friendly. Consequently, designing sustainable architecture is a complex and well-thought-out process (Barkoosaraei & Moshiri, 2017).

Effective environmental education bridges the gap between science and personal experiences, resulting in a shift in social behavior in favor of environmental protection (Littledyke, 2008; Ballard et al., 2017). As a result, raising citizen awareness is critical to achieving long-term social change. Museums and botanical gardens, for example, contribute to the development of an informed and engaged citizenry concerned with preserving and valuing cultural and natural heritage (Knudson et al., 1999). Plant gardens and museums ought to give up on replicas of nineteenth-century exhibits (Krishtalka & Humphrey, 2000). Of course, a successful design has certain differences. Research on standard guided tours given by staff members of natural history museums reveals high levels of visitor pleasure, but little long-term behavioral or educational impact on pupils (Cox-Petersen et al., 2003). Compared to visitors to natural history museums, zoos, aquariums, and natural places, those who visit botanical gardens are less driven by environmental concerns (Ballantyne et al., 2008). These flaws are addressed by a unique amalgam of an interactive museum, a plant garden, and a permaculture site, which provides visitors with a positive, memorable experience as well as a behavioral change outcome. Preliminary visitor surveys revealed high levels of satisfaction and genuine commitment to change (Qumsiyeh et al., 2017).

Totally, the challenge of sustainable architecture is to find a comprehensive solution to environmental concerns while maintaining a high standard of living and cultural, economic, social, and comfort values. Sustainable development is an excellent impetus for architectural innovation. Ecosystem architecture emerged in the last years of the twentieth century as an architecture that designed forms of communication and the foundation of life cycles or ecosystems as the starting point for research as well as the final destination and point of departure. On the one hand, sustainable architecture comes with all of the requirements for maintaining and sustaining it, and on the other hand, all of the knowledge about how each person interacts with the natural world in their own unique way (Madanovic & Jadresin-Milic, 2020). Sustainable design aims to meet basic needs without depleting remaining natural resources for future generations (Barkoosaraei & Moshiri, 2017). Reason 2: Improved readability and correct punctuation and grammar errors.

SUSTAINABLE ARCHITECTURE PRINCIPLES IN MPGS

Newer botanical gardens frequently bridge past, present, and future plant uses by interpreting traditional knowledge within the context of contemporary issues (Yerli et al., 2019). These gardens delve into the interaction among people, plants, and civilizations across various cultures and developmental stages. Modern gardens are also more inclined to advocate for addressing humanity's relationship with the environment (Hoversten & Jones, 2002). The opportunity to emphasize and exhibit a commitment to sustainability and environmental stewardship through thoughtful and appropriate construction methods and environmental protection measures, such as those for existing vegetation, topography, topsoil, groundwater, and other elements, is a frequently disregarded aspect of the construction process. Likewise, the design team needs to incorporate eco-friendly supplies and sustainable construction methods into the construction and tender documentation (Chang et al., 2008).

Energy conservation, climate adaptation, environmental impact reduction, totalitarianism, and respect for visitors are all characteristics that can predict the success of sustainable architecture in MPG's design. Sustainable architecture can also pursue a well-defined goal, concentrate on its visitors, make use of site and institution resources, create a learning environment, and adapt over time (Jones & Hoversten, 2004).

Energy conservation

Every structure in a medicinal plant garden must be designed and constructed to reduce the use of fossil fuels and other energy sources. Wood was the primary energy source before the widespread use of fossil fuels, and it still provides about 15% of today's energy. When wood became scarce, many people turned to the sun to generate heat, reducing their reliance on wood. Given the method of construction, the necessity of accepting this principle in the past is undeniable. Perhaps it is only because of the vast array of new materials and technologies available in today's world that such a principle has been forgotten in architecture. This time, buildings must change the environment according to users' needs and consider sustainability indicators by using different materials or combinations of them. Buildings constructed in response to the local climate and to reduce reliance on fossil fuels provide unique experiences not found in today's ordinary botanical garden and are thus considered half-completed attempts at green architecture. Medicinal plant garden design and construction can benefit from various solutions.

As a practical example, the orientation of the buildings helps well for the position of any block is positioned on its northern or southern face to prevent (or emission) as much light as possible due to the space's functional requirements. Bamboo is also one of the materials that is now the most sustainable. When used as a supplementary material in the external facade, bamboo siding and boards serve as a barrier against heat and ultraviolet light. The use of bamboo sidings for projects because of its hardness, resistance to decay, and renewable qualities when used as cladding, made it a sustainable and desirable material. In a variety of areas that link to the outside, compressed bamboo planks can also be utilized as louvers.

Adaptation to Climate

Garden buildings should be designed to take advantage of the climate and energy sources available in the area. The shape and location of the building, as well as its interior spaces, can significantly impact the comfort level inside the building based on the climate. Proper insulation of the structure can also reduce fuel consumption. There are many similarities and overlaps between these two processes. For instance, cities in Greece, like those in the Pyrénées, were relocated to prevent flooding. They adopted a rectangular grid layout with east-west streets to allow buildings to face south and make the most of the sun. The Romans further developed solar design principles, incorporating transparent windows, an innovation from the first century A.D., to enhance heat retention (Kasmaei et al., 2012). These historical insights should be considered in the design of modern garden buildings. The use of suitable plants on the exterior of buildings, according to the weather conditions of the region, can be effective in adjusting the temperature, using less fossil energy, and also eye-catching outer space. Additionally, building roof design should take into account the region's rainfall amount to maximize precipitation in the roof, which can be transferred by a water storage source for use in garden irrigation.

Environmental Impacts Reduction

Each structure in an MPG should be designed to use as few new resources as possible while also serving as a source for other structures. However, it should be noted that the current artificial environment has consumed the majority of the world's resources, and repairing and upgrading existing structures to reduce environmental impact is just as important as building new ones. It should be noted that there are insufficient resources to create artificial environments that can be used to renovate each new generation of buildings. This reuse can take the form of recycled materials or repurposing spaces. for example, an alternative to conventional concrete that uses fly ash is called AshCrete. This alternative is made up of fly ash, borate, bottom ash, and a specific chemical that belongs to the chlorine family. It is approximately 97% recycled material. In place of cement, fly ash, also referred to as pulverized ash, is to be utilized in concrete. In addition to making concrete more durable, fly ash can be used to ensure environmental preservation as it is a waste product that needs to be properly disposed of. Moreover, the main benefit of utilizing ashcrete is its decreased susceptibility to water and harsh chemicals. Alternatively, High Density Polyethylene (HDPE), is a thermoplastic polymer made from ethylene monomer. Its remarkable strength-to-density ratio is what makes it most famous. Up to 120 degrees is the maximum temperature this material can tolerate. Because all of these materials are 100% recyclable, they can also be regarded as environmentally beneficial. In a similar vein, it is low maintenance and resistant to UV radiation, extreme temperatures, and different types of abrasions. It also doesn't release volatile organic chemicals into the atmosphere, which is beneficial to human health.

The recycling of buildings and the elements within them is a part of architecture's history. The ruins of a nearby Roman building were used to rebuild Santa Alba in 1077 and 1115. In the Middle Ages, wooden

frames were made up of pieces of wood that were cut and joined together in a carpentry workshop, coded, and then transported to buildings. If necessary, parts of the ancient building can be converted into a museum garden using this method. If the cost of changing a building is less than the cost of demolishing and rebuilding it, these changes should be welcomed. However, this does not imply a lack of respect for the structure's historical significance. There's also the possibility that these structures have other values to consider. These issues are manifested in the transformation of existing buildings to adapt to new needs, particularly in the improvement of the building's condition in terms of greater performance and efficiency, which may result in changes in its appearance. Modifications to old buildings for new uses, such as a museum garden, can come with a price tag and a slew of issues. However, the advantages of repurposing these large buildings in an urban setting can outweigh these issues and costs. Renovation of buildings in large and small cities can also save resources that would otherwise be used for demolition and reconstruction (Kasmaei et al., 2012).

Totalitarianism

To create an artificial environment, all green principles necessitate participation in a holistic process. Finding buildings that adhere to all the principles of green architecture is a challenging task because green architecture is still a work in progress. Green architecture should encompass more than a single structure; it should consider the long-term urban environment. The medicinal plants garden is more than just a collection of structures; it is a network of interconnected systems designed for visiting and recreation, with a structure composed of constructed shapes. By closely examining these systems, we can envision the future.

Respect to visitors

As garden administrators are well aware, visitors are a botanical garden's most valuable resource (Greenhouse & Socolofsky, 1997; Yu & Shih, 2018). Spending time in the garden is a pleasurable aesthetic experience that nourishes both the spirit and the mind, which is essential for their psychological and physical well-being (Kaplan et al., 1998). Botanical gardens should challenge designers to create environments that provide a close relationship between plants and people in botany, history, ecology, and other fields of human knowledge through experiential learning opportunities in medicinal plants, botany, history, ecology, and other fields of human knowledge. Gardening and interpretive education should incorporate multiple learning styles, which are the various ways in which people acquire and process information in a learning situation. Because most visitors only have a limited amount of time to spend in a garden, the ethnobotanical garden's size and the number of exhibitions must be carefully planned (Shackley, 2009).

All individuals utilizing the building within the medicinal plants garden are honored by green architecture. This principle seems to have minimal impact on pollution caused by global warming and ozone depletion. Nevertheless, the green architectural process does not exclude individuals from this intricate system, which involves valuing all shared resources in constructing a holistic building. While humans are responsible for constructing all buildings, some structures acknowledge the importance of human presence, while others strive to eliminate the human element from the construction process.

The building should gently connect with the ground, as stated by Australian architect Glenn Murcutt. This concept involves the building's integration with its surroundings, which is crucial for sustainability and involves intricate considerations. A building that inefficiently consumes energy, pollutes the environment, and fails to resonate with its occupants, never truly harmonizes with the ground. Thus, creating seating areas for visitors, bike lanes, sidewalks, and coffee shops is effective for the enjoyment of these gardens and increasing sustainability.

CASE STUDIES OF SUSTAINABLE ARCHITECTURE IN MPGs

The gardens with the aforementioned plants overseas were selected for analysis and research in order to better understand the plant landscape design in medicinal plant gardens and to achieve their implementation with sustainable principles. Specific examples of sustainable architecture include the Zeytinburnu Medicinal Plants Garden in Turkey and the Research Facility and Garden of Medicinal Plants in Nepal (Tables 2 and 3).

Table 2. Medicinal Plants Garden and Research Facility in Nepal

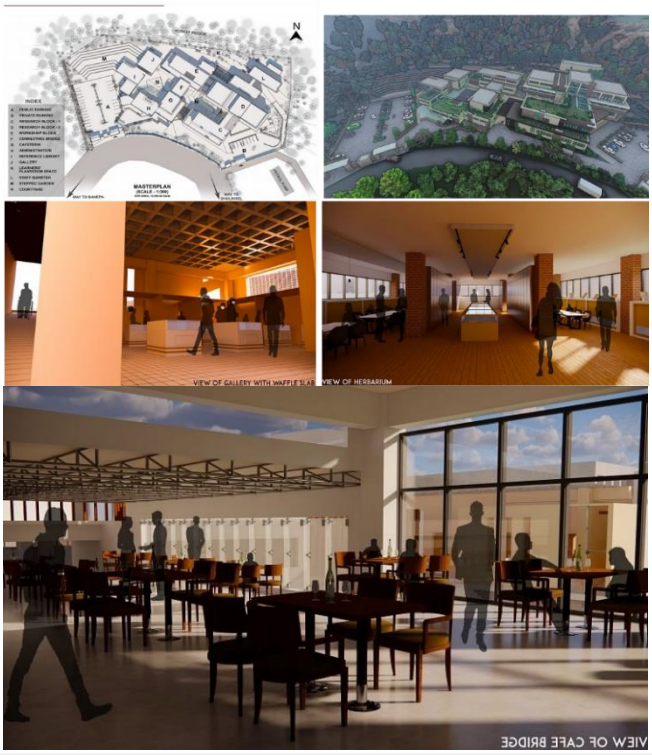
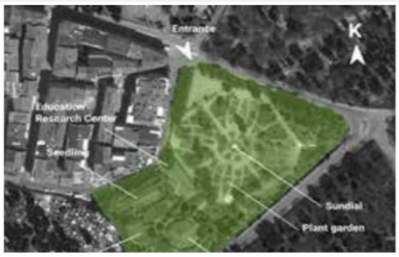
Outline	Creating a sustainable design strategy to ensure that the project improves the site's area and, as a result, contributes to the creation of a better environment for everyone. The site would be minimally affected by the adoption of a sustainable strategy that is nicely incorporated into the design. Furthermore, the design reduces the amount of artificial energy needed for ventilation and lighting. The areas that needed mechanical ventilation have been managed to have the least negative environmental impact possible. It gives users a unique space and unites architecture and nature. The goal of the design is to incorporate architectural elements into the site while maintaining its natural beauty.
Plant species	750 medicinal, ornamental and aromatic plants, including trees, perennial plants (herbs) and native, and vegetation. Some plants are collected when flowering, dried, and kept in herbarium cabinets. Some others are used in the phytochemistry laboratory.
Photograph (inspireli.com)	
Sustainable Architecture	Energy conservation: The building consists of a research center, workshop block, gallery block, water services block, laboratory, herbarium, library, and cafe. The building form is oriented along the slanted east-west axis, with the facades and openings oriented southward to maximize the amount of sunlight that enters the structure. People feel cool and invigorated in the two large courtyards filled with healing plants. The blocks climb northward from southward such that each block receives the necessary amount of sunlight. Additionally, buildings are designed to allow for optimal ventilation and sunlight throughout the blocks. Natural ventilation can enter and exit buildings using a variety of design techniques in addition to mechanical ventilation. Natural ventilation in labs is significantly aided by the interstitial space. These areas have open louvers that allow ventilation outlets to release filtered air into the surrounding air, greatly reducing pollutants and promoting thorough air circulation. Environmental impact reduction: From an architectural perspective, the integration of universal design, green design principles, rainwater harvesting, and wastewater management has enhanced the design. An alternative to conventional concrete that uses fly ash is called ashcrete and is made up of around 97% recyclable materials. Pulverized ash, also referred to as fly ash, is substituted for cement in concrete. The main benefit of utilizing ashcrete is its decreased susceptibility to water and harsh chemicals. Additionally, bamboo became a sustainable and desirable material for the project due to the use of bamboo sidings as cladding and its toughness, resistance to decay, and renewable qualities. Education: It offers native knowledge related to the customary application of medicinal herbs, which can directly benefit the community in terms of production and advancement of scientific endeavors. The goal is to improve the atmosphere needed for research for both students and researchers, as well as to establish a place where people may connect through various activities. Totalitarianism: This collection is made up of an interconnected network that uses a single structure including education, visiting and recreation, energy reduction, air spectrum, etc. with the design of green architecture.

Table 2. Zeytinburnu Medicinal Plant Garden in Turkey

Outline	The planting of medicinal native plants and the creation of sustainable design for environmental impact reduction, energy conservation, and adaptation to Climate. It, in addition to being a place for training researchers, provides a recreational space close to nature for its visitors.
Plant species	Over 700 medicinal, ornamental and aromatic plants, including perennial plants (herbs), trees, and vegetation. Plants are collected when flowering, dried, and kept in herbarium cabinets.
Photograph (Özdamar & Caymaz, 2022)	 
Sustainable Architecture	Energy conservation: There is a seed bank, laboratory, education and research center, greenhouse, and library. Buildings are designed to save energy. Environmental impact reduction: Considering that it is in an urban area with intensive construction and in an area with air pollution, it can be effective in adjusting the temperature of the area and reducing air pollution. Education: to disseminate the culture of medicinal plants in health environments, schools, home treatment, foods, plants, art, workshops, volunteer gardening, and documentaries and educational events are done in the garden. Herbarium is also a place for training researchers in the field of plants.

SOCIOL-CULTURAL CHALLENGES AND STRENGTHS IN THE MPGs DESIGN

Botanical gardens are designed with a practical purpose, both historically and now. The organization of plants seems to have become increasingly intertwined with other types of use, resulting in a broad set of design concepts. The second aspect of all designs is the site's form and layout. The collection and its spatial organization are influenced by the site's climatic and geological surroundings. The most notable difference in the architectural style of modern botanical gardens is the multifunctional agenda of research, green space, biodiversity resources, and culture. The use of a framework, whether existing or constructed from scratch, is an important general design principle. Bordeaux is the most fascinating proposal in terms of expressing the link between the environment and culture in a contemporary urban context (van den Toorn, 2017). Medicinal plants and natural history garden museums are essential for long-term economic development, research, culture, education, and natural and historical preservation (Silvestro & Alexander, 1980; Suarez & Tsutsui, 2004). Museums now serve as emblems of national identity (Hitchcock, 2002). These institutions are essential for studying and protecting biodiversity, as well as addressing pressing concerns such as overcrowding, political instability, and climate change (Johnson et al., 2011; Cook et al., 2014; Paknia et al., 2015).

Botanical gardens play a crucial role in influencing the behavior of both local and international tourists through the preservation of flora (Ballantyne et al., 2008). They are also essential for biological conservation and contribute to the variety of green spaces in urban areas (Powledge, 2011). These venues and herbaria offer practical applied research with immediate social advantages, ranging from knowledge about medicinal plants to

information on climate change (Schipmann et al., 2005; Ward et al., 2010). Gardening, particularly in urban settings, promotes ecological services and human sustainability (Miller et al., 2015; Elmqvist et al., 2015; Miller et al., 2016). Spending time in a lush garden can significantly impact the human soul and mind after being confined to tight indoor spaces for hours. Further exploration of the significance of these services in developing countries is necessary (Qumsiyeh et al., 2017). Therefore, the creation of a natural botanical garden can enhance the cultural and social connections within the community.

THE RELATIONSHIP BETWEEN HEALTH AND THE MPMS DESIGN

Agriculture, forestry, and fisheries are just a few of the industries that rely on biodiversity. Nearly half of the world's population survives on natural resources, and many of the world's poorest people rely on biodiversity to meet their fundamental needs. Ecosystem protection, restoration, and long-term use are all necessary for sustainable development. Food security and improved nutrition are also dependent on biodiversity. Animals evolve by adapting to changing environments and acquiring stress tolerance, which is facilitated by food crops with a broad genetic diversity. Healthy ecosystems also play a role in water transportation and protecting people from water-related risks, while wood, coal, and charcoal provide energy for cooking and heating to over 3 billion people worldwide. Integrating biodiversity considerations into urban design can help in creating more sustainable communities in cities. In urban areas, strategically placed trees, for instance, can reduce air temperatures by 20 to 80 degrees Celsius, reducing the need for air conditioning and saving energy. Medicinal plant gardens engage in various activities aimed at enhancing our understanding, conserving, and utilizing plant diversity sustainably, as well as promoting environmental awareness (Sharrock, 2018).

The use of medicinal plants for human health has a direct impact on botanic garden policy at all levels and in all locations. In 2003, for example, participants at the first Indian Botanic Gardens conference underlined the importance of medicinal plants in primary healthcare and their commitment to fostering sustainable livelihoods (Richardson, 2003). The meeting resulted in the release of the Lucknow Statement on Botanic Gardens of India, which underlined "the fundamental importance of plants as the foundation for all life on Earth and as a key resource for human well-being." Botanic gardens serve a variety of functions related to human health. The establishment of the Botanic Garden "ORSTOM" in the Democratic Republic of Congo, for example, was motivated directly by the 1992 Rio Summit's ideas of sustainable development (Cudjoe et al., 2019). This garden looks at domestication in order to provide useful species for agriculture, helping residents meet their food and healthcare demands more easily while also sparing trees that would otherwise be cut down. The Earth Ethnobotanical Garden (at Earth University in Costa Rica) focuses on medicinal plant conservation, explores potential plant uses, and disseminates that information to local populations, reflecting the university's overall goal of balancing "environmental consciousness" and "social commitment" (Proulx et al., 2021). On the other hand, these gardens can both assist in treating diseases and create a tranquil and interactive environment for people's mental and social health by producing helpful medicinal plants. As a result, building design is crucial to achieving these goals.

TRAINING PROGRAMS FOR MPGs

Education is an essential component of any effort to educate and empower individuals to make meaningful life changes. For instance, the Makerere University Botanic Garden in Uganda taught women and children about the advantages of different plant species through talks and exhibits. Consequently, these organizations have created nurseries for trees and herbs in order to promote valuable species, especially those that are multipurpose and take a long time to mature. Every program studied in this research comprises at least one (and often numerous) type of communication, ranging from formal lectures and brochures to workshops and 'hands-on' learning, to transfer skills and knowledge to people in the community. These initiatives rely on the teaching capacities of botanic and medicinal plant gardens, which have grown in response to global processes in recent decades and are now ideally positioned to play a unique role in the education of conservation and sustainable development (Borsch & Löhne, 2014). Botanic garden educators need to be equipped with the skills and training required to effectively impart the knowledge and abilities that will encourage the utilization of plants for health (Waylen, 2006).

Plant studies and investigations provide the data needed to enhance people's lives. Many gardens, particularly in agriculture and healthcare, place a strong emphasis on research related to the development of beneficial plants. This research is often associated with crop improvement and domestication. For instance, the Wuhan Botanical Garden in China has successfully developed ten new

kiwi (Actinidia spp.) cultivars and indigenous remedies known as "Yikanjiaolong." Another study aims to identify plant species with antiviral or antimicrobial properties, hepatoprotective effects, immunomodulatory functions, or anti-tumor properties, as seen at the Russian Academy of Sciences' Komarov Botanical Institute (Tkachenko et al., 1997). Similar initiatives are undertaken by the Ceará Botanical Park in Brazil, the Research Institute of Medicinal Plants in Poland, and the Guangxi Botanical Garden of Medicinal Plants in China (Waylen, 2006). In contrast, gardens like Mexico's "Fundación Xochitla" Botanic Garden focus on nurturing and cultivating native species with ornamental potential, while gardens in northern regions concentrate on identifying plant varieties that can thrive in harsh conditions. Many studies generate information that residents can immediately apply to improve their living conditions. For example, in the Democratic Republic of Congo, the Botanic Garden "ORSTOM" is working on domesticating locally beneficial species like a fodder plant suitable for local cultivation, which will help improve pasture nitrogen content. Similarly, the Kisantu Botanic Garden in the Democratic Republic of Congo has researched the popular fruit mangosteen to assist local farmers in prolonging the shelf life of harvested fruit, thereby expanding their market (Verdcourt, 2004).

To provide a straightforward and comprehensive guide to safe-to-eat nightshades that also match consumer taste preferences, the Radboud University Botanical and Experimental Garden in the Netherlands investigations the characteristics of its African Solanum accessions, such as taxonomy, morphology, nutritional qualities, and alkaloid attributes. The study's findings could have implications for local healthcare. For instance, in Senegal, the Garden for Useful Plant Experimentation (JEPU) is cataloging, cultivating, and assessing indigenous medicinal plants and management techniques to establish a sustainable medical system that caters to local needs. It is crucial to sustain this research and utilize the findings in actual well-being programs.

Finally, and briefly, the design of the building for such gardens should be:

• A building with all the standards of energy conservation, environmental impact reduction, respect for visitors, totalitarianism and so on.

• Creation of a natural botanical garden by enhancing the cultural and social connections within the community.

• both assist in treating diseases and create a tranquil and interactive environment for people's mental and social health by providing helpful medicinal plants.

• enough to meet the research, educational, and recreational needs of users.

CONCLUSION

As this study shows, botanic gardens use biodiversity in a variety of ways to improve human well-being. These include improved healthcare and nutrition, financial assistance, and cultural and social benefits. Many of these characteristics of happiness are interwoven, and a well-designed project can improve overall quality of life greatly. The design of medicinal plant gardens has an impact on urban dwellers' jobs, daily activities, leisure, and entertainment. Therefore, when planning these initiatives, it is crucial to take people's health and way of life into account.

By incorporating sustainable urban principles into MPG designs, it is ensured that the city will fulfill the daily demands of its residents. This is accomplished by reducing the negative effects of urbanization on the environment, offering a crucial change in the way green space designs are created, and, lastly, implementing a strategy for the sustainable growth of urban planning. In order to continue to link biodiversity to human well-being, the key competencies of education and researching medicinal plant gardens with a new design be encouraged and directed. These studies, for example, increase the awareness of citizens and encourage new discoveries.

It's also critical to educate and publicly disseminate information regarding the design of these projects so that future efforts are based on best practices. Medicinal plant gardens can boost global prosperity, even though various aspects of well-being and project types are more significant to some locations than others. This can include collaboration amongst gardens, and in many cases, partnerships with non-botanical garden groups can help botanical gardens fulfill their mission. The importance of strong ties and networks between the botanical garden and the design and development community is emphasized by this. Although human needs and preferences regarding nature and biophilia are typically the same, people in different countries have different cultures, economies, and interpersonal connections. As such, the design of these gardens, due to the implementation of the concept of sustainability, can reflect the culture and general well-being of the intended audience. In general, this study scrutinizes the various botanic gardens located in different cities, compiles detailed plans for transforming green spaces according to sustainable design principles, and arranges the

harmony between landscape aesthetics and environmental preservation according to the urban landscape's unique design scheme. Thus, to adhere to the fundamental tenet of sustainable garden theory, it is advised that the design of these gardens take into account how the general public lives while preserving the cycle of nature.

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