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A Study on Establishing an Ecosystem Service Evaluation System in Response to Climate Change Focusing on Garden Value Evaluation Indicators

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Abstract The importance of ecosystem service such as green spaces has risen due to restrictions on outdoor activities amid the climate crisis and COVID-19. While gardens significantly impact economic development, quality of life, and social well-being, comprehensive studies on their multidimensional values are lacking. This research categorizes garden values into social, cultural, environmental, and health dimensions and proposes an integrated assessment framework that introduces detailed elements and evaluation methods. An empirical assessment of carbon storage index in two Korean gardens, Semiwon and Juknokwon, reveals Semiwon's higher carbon storage per unit area. The proposed framework, emphasizing a quantitative approach, enables cross-national and regional comparisons, contributing to a broader understanding and evaluation of garden values beyond specific facilities.

Keywords ecosystem service, multidimensional valuation, service assessment index, integrated framework

I. Introduction

Amid the prolonged challenges posed by the COVID-19 pandemic and the climate crisis, contemporary society grapples with various issues, encompassing declining physical and mental health and social disconnection. Recognizing the healing effects of gardening activities, the British Royal Horticultural Society is

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piloting gardening as a prescription program to address mental health issues like depression and anxiety linked to the pandemic (Baek, 2022, December 6). Simultaneously, the Sejong Government Complex has implemented a rooftop garden and indoor wall greening project, utilizing plant functions to absorb fine dust and carbon for carbon neutrality (Ha, 2021, February 22). Research from the Rural Development Administration highlights the efficacy of introducing plants, approximately 2% of indoor space volume, in reducing air pollutants and addressing climate change (Park et al., 2021).

Over time, gardens have transcended the notion of being confined to residential spaces, assuming a broader significance as common areas like National Gardens, Local Gardens, and Community Gardens (Woo et al., 2016). And their role and significance in fostering economic development continue to expand. The growing number of local governments expressing their intent to establish National Gardens is notable, accompanied by the enactment of related laws, including ordinances specifically addressing gardens. This trend underscores the recognition that defining the diverse impacts of gardens and precisely measuring their value is crucial for anticipating shifts in the national environment. Such efforts are seen as pivotal contributors to enhancing the quality of life for the populace.

Presently, the assessment of a garden's value is confined to the ecosystem service foundation, primarily focusing on green space. This approach represents an indirect evaluation lacking a comprehensive, objective, and quantitative analysis across various fields, including humanities, society, environment, health care, and education. In response to the growing concern and increasing demand for gardens, there is a necessity to propose an objective and quantitative analysis of their value. This involves integrating evaluation indicators that span various dimensions.

Therefore, this study introduces an integrated framework capable of objectively defining and evaluating the multi-faceted value of gardens. Such an approach aims to contribute to the establishment of diverse garden policies and the revitalization of the associated garden industry.

The study's flow is as follows: First, the multifaceted value of gardens is defined through a review of previous studies, seeking an appropriate evaluation method. Subsequently, a Focus Group Interview (FGI) is conducted based on the developed draft of evaluation elements. The final evaluation indicators are selected by validating the representativeness and validity of the multi-faceted value evaluation elements and suggesting supplementary points. Among the final evaluation indicators, a pilot evaluation is conducted on Local gardens for a Greenhouse gas control indicator, considering data security and the applicability of the evaluation method.

II. Study area and method

1. Conceptual scope of gardens and similar facilities

In the context of domestic law, the term 'Garden' is specifically defined by the "Act on The Creation And Furtherance Of Arboretums And Gardens" (Abbreviation: Arboretum and Garden Act). According to Article 2, Section 1 of this Act, a 'Garden' encompasses a space (inclusive of facilities and land) where various elements such as plants, soil, stones, and facilities (including sculptures) are exhibited and continuously managed through cultivation. It is important to note that certain spaces specified by the Presidential Decree, including cultural properties (under the Cultural Heritage Protection Act), natural parks (as per the Natural Parks Act), and urban parks (regulated by the Act on Urban Parks and Green Areas), are explicitly excluded from this definition. Consequently, under the "Arboretum Garden Act," a garden is characterized as a natural space composed of plants and stones. It serves as a platform for expressing aesthetic value through the exhibition, arrangement, and cultivation of these elements. Additionally, it functions as a place where flowers, fruits, and food can be cultivated and harvested. The notion of exhibition implies that the role of the garden has expanded beyond a private space, transforming into a public forum (Woo et al., 2016).

According to the "Arboretum and Garden Act," gardens are categorized into different types, including 'National Gardens,' 'Local Gardens,' 'Private Gardens,' 'Community Gardens,' and 'Living Gardens,' based on their creation and operation. In this part, gardens established and managed by national and local governments, such as National Gardens and Local Gardens, serve as exemplars of the evolution of the garden concept from private spaces to public facilities.

In parallel, 'Urban parks,' akin to gardens, are defined in the "Act on Urban Parks And Green Areas (Abbreviation: Parks and Green Spaces Act)" as spaces or facilities strategically positioned or designated within urban areas. These spaces aim to contribute to the preservation of the urban natural landscape while enhancing the health, recreation, and emotional well-being of citizens.

On the other hand, a 'National Park,' as defined in the "Natural Parks Act," refers to a park designated as an area representing the natural ecosystem landscape. Facilities classified as natural parks include provincial parks, county parks, and geological parks. Unlike gardens, the objective of natural parks is 'nature conservation and management,' which involves considerations for the conservation status of the natural ecosystem, the presence or absence of cultural assets and historical relics, and the conservation value of the landscape (Enforcement Decree of the Natural Parks Act [attached table 1]).

Ideas akin to gardens encompass the concept of ‘Green space,’ which is directed towards the conservation and enhancement of the natural environment in urban areas. This involves activities such as pollution and disaster prevention, aligning with the objectives specified in Article 2 of the Parks and Green Spaces Act. Additionally, the term ‘Woodland Garden’ is introduced as a space that shares characteristics of both a forest and a garden, as outlined in the research conducted by Hong et al. (2021).

Therefore, from a legal and institutional standpoint, natural parks can be delineated as spaces ‘For protecting’ beautiful landscapes and cultural properties. In contrast, urban parks and green spaces can be characterized as areas and facilities ‘For creating a better urban environment.’ Gardens are further classified as spaces ‘For exhibiting and cultivating’ plants, earth, and stone natural objects and facilities. Furthermore, the contemporary garden, as deduced from prior research, has evolved from private to public spaces. It functions as a space that showcases and nurtures nature and facilities, offering residents and citizens a sense of repose and aesthetic stability and contributing to internal stability and psychological health through visual and emotional satisfaction.

2. A Previous Study on the Value of Garden

In previous studies, evaluations of gardens and similar facilities have been approached from diverse perspectives, including the economic, environmental, and social aspects. From an economic standpoint, researchers have explored various facets, encompassing the direct and indirect impacts of gardens, job creation through tourism, willingness to pay for facility maintenance, and the valuation of tangible assets owned by gardens. An exemplary study assessed the annual direct and indirect economic contributions of three botanical gardens in Australia, evaluating their social and economic value in monetary terms (Deloitte Access Economics, 2018). Methods for assessing the economic value of gardens include industry-related models based on tourist expenditure, conditional valuation (CVM) examining users’ perceived value, and investigations into the value of tangible assets such as land and buildings (Lee et al., 2019).

Gardens have also been analyzed in terms of their environmental value. This includes quantifying the carbon sink of garden vegetation and assigning a value in terms of carbon credits (Choi et al., 2019). Some studies have focused on quantitative evaluations of microclimate and ecological value (Daniels et al., 2018), while others have adopted an Ecosystem Services Perspective (Mo, 2021; Lee & Choi, 2021; Lim & Xenarios, 2021). Ecosystem services evaluate the benefits that the environment provides to humans by categorizing the value provided by the natural environment into supply, culture, and control services, and sometimes including the concept of support services that bolster other services. In Korea, the National Institute of Ecology and the Korea National Park Research Institute regularly conduct research on valuation and conservation measures using the concept of ecosystem services for natural environments, including National Parks.

Furthermore, the value of gardens has been explored concerning public facilities, social aspects, and policy considerations. Evaluations have encompassed safety, accessibility, social sustainability, and inclusion for various demographic groups (Malek et al., 2018; Lee & Min, 2019). Satisfaction with usage and the evaluation of the value of recreational offerings have also been explored (Lee, 2017b; Chen et al., 2019).

Although gardens have been examined from diverse perspectives, such as economic and environmental considerations, there is a contrast with overseas cases where comprehensive evaluations encompass various values like economic ripple effects and social contributions. In domestic research within Korea, there is a relative lack of active pursuit in comprehensively evaluating diverse values associated with gardens.

III. METHODOLOGY

1. Selection of garden valuation factors through FGI

In the process of developing a comprehensive valuation framework for gardens, we initially categorized garden functions derived from prior research into four main groups: social, cultural, environmental, and health functions. Subsequently, we organized evaluation factors for each function, forming a draft valuation framework. To refine and validate our approach, the draft underwent expert consultation using the Focus Group Interview (FGI) technique—a qualitative investigative methodology involving experienced experts in the field.

nalysis of legislation and previous research	
The value of gardens	Derivation of value through analysis of prior studies related to the value of the garden
The value of a similar facility	Derivation of value through analysis of legislation and previous research of similar facilities

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Keywords derived from prior studies of value evaluation	
Social value	Strengthen public interest, revitalize local communities, crime prevention, community, regional economic development, garden industry, create small-scale regional specializations, create jobs, and social sustainability such as disaster, health, poverty, inequality, etc.

Cultural value	Cultural Heritage and historical, identity value, aesthetics, landscape, leisure, recreation, inspiration, tourism, recreation, religious value, etc
Environmental value	Flood control, storm damage reduction, soil erosion prevention, greenhouse gas control, water quality control, noise prevention, dust proofing, pollination, species diversity preservation, waste disposal, chemical control, water purification, food production, freshwater supply, etc.
Health value	Absorption of air pollutants, provision of places for physical activity, physical and mental health, stress reduction, disease control, pest control, etc.

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Draft Derivation of Multifaceted Value Evaluation Elements of Garden

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Based on the FGI results, the final draft

Figure 1. The process of deriving multifaceted evaluation factors for the garden

During the FGI consultation, emphasis was placed on ensuring the hierarchy, representativeness, and suitability of the evaluation elements. Particularly, importance was given to considering ‘Representativeness’ in addressing potential ‘Trade-off’ relationships in garden valuation, where an increase in one value might lead to a decrease in others. This consideration aimed to avoid the risk of overestimation when summing individual values.

Both experts engaged in the consultation possessed doctoral degrees in landscape architecture and had extensive experience in studies related to National Gardens conducted by the Korea Forest Service. The expert consultation revealed that the initial classification of social, cultural, environmental, and health values lacked clarity due to functional similarities. Consequently, the values were redefined as social and cultural values and environmental and health values. Suggestions from experts included the addition of flood control functions.

Post-consultation, the garden evaluation framework was refined to ensure its applicability to diverse garden characteristics. Definitions of values were succinctly summarized to provide a universally clear understanding, enhancing the consistency, comprehensiveness, and adaptability of the framework across various garden types. Furthermore, to streamline the evaluation factors for each item, a systematic reorganization was carried out, considering the availability of evaluation data and the necessity of the evaluation. This strategic refinement is designed to offer a more straightforward and efficient framework for evaluating the multifaceted value of gardens.

Table 1. Draft evaluation indicators (left) and first revision reflecting FGI results (right) A Final Proposal Considering Evaluability

Group	Class
Social value	Sustainability
	Improving the quality of life of local residents
	Local Economy Revitalization
Cultural value	Health, healing, landscape
	Identity support
	Recreation, leisure, tourism
	Inspiration
Environmental value	Species diversity
	Erosion control
	Pollination
	Water quality
	Greenhouse gas control
	Habitat provision
Health value	Air pollution control
	Disaster safety management
	Health indicator

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Group	Class
Social·Cultural value	Community
	Sustainability
	Local Economy Revitalization
	landscape
	Identity support
	Recreation, leisure, tourism
Environmental·Health value	Species diversity
	Habitat provision
	Water quality
	Greenhouse gas control
	Erosion control
	Flood control
	Pollination
	Air pollution control
	Heat island reduction
	Disaster safety management
	Health indicator

Table 2. A Final Proposal Considering Evaluability

Group	Class	Definition
Social·Cultural value	Community	Local community consciousness, utilization of places such as events and festivals, improving the quality of life of residents
	Sustainability	Management. Continuous operability
	Local Economy Revitalization	economic growth and the overall well-being of the community, such as job creation
	landscape	Aesthetic elements and diversity to enjoy visual pleasure
Environmental·Health value	Habitat provision	Stability of spatial structure according to land coating
	Greenhouse gas control	Greenhouse gas absorption volume provided by ecosystems
	Flood control	Flood prevention by calculating the amount of penetration of land coating
	Pollination	Pollination of vegetation by pollinators
	Health indicator	Improvement of users' physical and mental health

2. Multi-Partial Value of Gardens and Evaluation Methods

2.1 Social·Cultural value

Social value extends beyond economics, encompassing outcomes that benefit the public and advance communities across society, economy, environment, and culture (Ministry of Employment and Labor & Korea Social Enterprise Promotion Agency, 2021). Key areas include human rights promotion, safety, community well-being, support for disadvantaged groups, job creation, citizen participation, and regional revitalization (Ministry of Public Administration and Security & Korea Institute of Public Administration, 2019). The Korea Forest Service's 2nd Basic Plan for the Promotion of Gardens (2021) underscores gardens' social value with terms like contributions to national welfare, economic stimulation, local revitalization, environmental improvement, and support for urban regeneration. These terms underscore the comprehensive impact that gardens can have on society, reflecting their role as dynamic contributors to various facets of community life. Indicators of these social functions include aspects such as tourism and recreation, improvement of residents' quality of life, educational opportunities, and contributions to industrialization (Park et al., 2017c).

The term "culture" stems from the Latin word 'cultura,' evolving over time from denoting human achievements to encompassing care for agriculture, the body, and the mind (Baldwin et al., 2005, as cited in Suh, 2015). This evolution is examined from macro and micro perspectives, representing group systems and individual expressions of aesthetics and emotion (Suh, 2015). A garden centered on plants serves as a natural canvas for exhibition and cultivation, expressing nature and culture through ecological structure, lifestyle, and thought (Park, 2015). The cultural value of a garden is seen in expressing identity through display and management, promoting physical and mental well-being.

In previous studies, cultural evaluation indicators for gardens encompass aesthetic beauty, recreation and healing, spiritual and religious inspiration, the value of cultural heritage and uniqueness, and regional identity. These indicators collectively depict gardens not only as visually pleasing spaces but also as repositories of historical, spiritual, and regional identities, showcasing their diverse cultural contributions.

In summary, the social and cultural values of gardens lie in their ability to act as catalysts for positive change and development across various dimensions of society. Their impact extends far beyond economic considerations, shaping communities, fostering cultural enrichment, and contributing to the overall well-being of individuals and the larger population.

a) Community

Article 1 of the “Arboretum and Garden Act” emphasizes the conservation and resource utilization of nationally valuable tree genetic resources, managing gardens systematically to enhance people's quality of life and contribute to the national economy. To achieve these goals, the development of National Garden evaluation indicators needs to follow principles such as ‘Inclusiveness,’ ‘Publicness,’ and ‘Sustainability.’ The key focus on ‘Publicness’ facilitates the implementation of social values for common interests, while ‘Inclusiveness’ ensures consideration for class, region, generation, and space, fostering symbiosis among people (Park et al., 2021).

Various studies highlight the role of gardens in addressing contemporary societal challenges such as community breakdown and environmental pollution by providing green spaces and fostering community awareness. Gardens serve as places for residents to connect with nature, build a living community, and contribute to urban regeneration by cultivating economically valuable community spaces (Lee, 2017a, as cited in Lee & Min, 2019; Lee & Park, 2018).

Given this context, for the public function of gardens, the community was selected as an evaluation indicator. Previous studies evaluated the community function based on resident participation, policy sharing, usage levels, and accessibility of urban forests (Lee et al., 2008). The method of analyzing the value of a place for residents to exchange, using the ratio of the population within a radius to the number of visitors (Hong et al., 2021), proposed in another previous study, is believed to be highly useful for evaluation because it uses easily accessible visitor and demographic data.

b) Sustainability

Garden sustainability includes economic and environmental aspects, and ongoing user satisfaction through management. From an economic and environmental perspective, sustainability involves development that meets current needs without compromising the abilities of future generations (Gowdy et al., 2010). This development ensures vital environmental, economic, and social services while preserving ecological stability, fostering economic growth, and achieving social equity. In this regard, Gardens enhance the environment, serve as retreats, improve residents' lives, and act as communal spaces.

Studies on the sustainable value of gardens analyze their impact on cities through theoretical frameworks and cases (Park et al., 2017b; Kim, 2021a). In a different context, the research aims to analyze stable sustainability for facilities by analyzing the characteristics and evaluation system of disaster prevention functions (Jang & Park, 2019; Hang & Lee, 2020). Other studies assess satisfaction with urban parks, willingness to pay for maintenance, and associated costs (Kim & Park, 2014). In New York Central Park (NYC), sustainability is approached through facility maintenance and environmental aspects (Sultana, 2022).

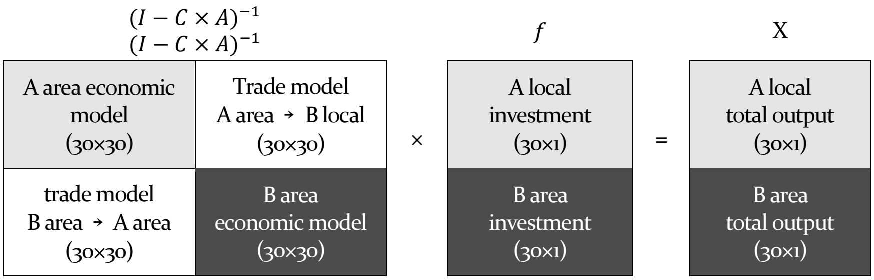
The concept of sustainability covers such a wide range. Considering its role as one indicator in the value evaluation framework and its relationship with other evaluation indicators, maintenance and management of facilities are deemed the most appropriate indicators. In this regard, there is a study that analyzes users' Willingness to Pay (WTP) for park management status and comfort using the Conditional Valuation Method (CVM)(Kim & Park, 2014).

c) Local Economy Revitalization

Research on the economic impact of gardens encompasses various dimensions, including job creation, fostering the garden industry, and enhancing local economies by linking with local initiatives. Previous research has explored the effect of the green business of community-based social enterprises on the Green New Deal goals, particularly in creating eco-friendly jobs and addressing social inequality (Kim, 2021b). Another study (Jeon & Lee, 2020) aimed to contribute to revitalizing the local economy and alleviating social stress among modern individuals by examining cases of developing potential therapeutic rural tourism products.

In the analysis of the economic ripple effect of National Gardens (Park et al., 2021), industry linkage analysis was employed. This methodology assesses the economic activities of a specific region by analyzing the interdependence and network relationships between industries in a simple matrix through production and trading activities, providing a quantitative understanding of economic feasibility.

Conventional IO Models often grapple with the risk of over- or underestimating ripple effects due to fixed coefficients, restricting the scope for accurate long-term assessments. The Flex IO Model emerges as a valuable methodology to overcome these challenges (Park et al., 2017a; Park, Park, 2020).



Source: Park et al. (2021)

Figure 2. Example of Flex IO Model

By introducing adaptability into industry linkage analyses, the Flex IO Model provides a more comprehensive understanding of the economic impact of gardens over time. This strategic shift in methodology contributes to the refinement and precision of economic assessments, ensuring a more accurate representation of the gardens' influence on local economies.

d) Landscape

The "Landscape Act," designed to preserve and manage the national landscape, defines landscape as encompassing the local environmental features comprising both natural and artificial elements, intertwined with residents' lifestyles.

A garden, holds a unique position as the space closest to a residence, providing an opportunity to admire the scenery and appreciate beauty. Characterized by mirroring natural topography and landscapes, gardens hold cultural and scenic value through intentionally crafted hills, structures, and the overall human environment (Park et al., 2017c; Ryu & Cho, 2015). They additionally serve as expressions of regional identity, history, and culture, incorporating unique construction techniques and local characteristics (Hong et al., 2021). As an illustrative example, Hyogo Prefecture in Japan leverages the distinctive landscapes of farmhouse gardens, which authentically capture the characteristics of rural areas, as a valuable tourism resource (Hirata & Son, 2015). This underscores the transformative potential of gardens in not only enriching the visual landscape but also serving as cultural repositories and tourism assets.

Table 3. Landscape Aesthetic Evaluation index

landscape evaluation index		content
Horizontal landscape Aesthetic	Variety of landscape patches	Divide the study site into grids and evaluate the diversity of landscape patch types on detailed land cover.
	Landscape Patch Nature	Divide the study site into a grid and evaluate the naturalness of the landscape patch type on the detailed land cover.
Vertical landscape Aesthetic	Index of Greenness	The ratio of the leaves of a plant from the point of view of a person standing at a certain point
	Evaluation of landscape conversion	Trends on rust rate results and frequency of visual changes in rust rate through inflection points

Source: Joo et al. (2018)

Previous studies related to scenic value evaluation include a study that estimated changes in the non-market value of cultural heritage resources based on landscape quality changes through a hypothetical travel cost model (Han, 2006). Another study evaluated perceived scenic beauty by users while walking, using horizontal and vertical landscape indicators (Joo et al., 2018). Considering the possibility of securing data and conducting quantitative evaluation, vertical landscape evaluation based on the diversity of landscape patch types and the greenness ratio on the detailed land cover map was deemed appropriate as a method for evaluating the landscape of the garden.

2.2 Environmental· Health value

The diminishing green space due to development results in the loss of crucial ecosystem benefits, such as food, water purification, and air purification. Recognizing the need to evaluate the environment, the Korea National Park Research Institute and the National Institute of Ecology are actively assessing the environmental value of domestic resources using the concept of ecosystem services. Additionally, numerous studies and strategy collections, both domestic and foreign, utilize ecosystem service evaluation methodologies.

Table 4. Detailed functions of control services by major reports on ecosystem services

MA (2005)	TEEB (2010)	UKNEA FO (2014)	CICES 5.1 (2018)
Atmospheric purification	Atmospheric purification	Air purification	Atmospheric composition, conditions
Climate regulation	Climate regulation	Climate regulation	Climate regulation
Water resources control	water flow adjustment	Water quality	Water quality
Water purification and waste disposal	Waste disposal	Noise control	Mediation of waste, toxins, and other nuisances by non-living processes
Prevention of erosion	Prevention of erosion		
Soil formation	Maintenance of soil fertility	Soil quality	Soil quality
Pollination	Pollination	Pollination	
Disease control	Biological Control	Disease and pest control	Control of Harmful Organisms and Diseases
Pest control			
Natural disaster control	Prevention of disturbance	Risk Control	Lifecycle maintenance, habitat, and gene pool protection

Source: Authors, based on Joo et al. (2016, 2020), Na et al. (2018), CICES.EU.

Ecosystem services, defined as the advantages people derive from the ecosystem, encompass functions such as supply, regulation, culture, and support services. Although support services, which aid functions like primary production and material circulation, are sometimes excluded to prevent estimation errors and double counting, they play a pivotal role in sustaining the overall ecosystem. This study focuses on control services and habitat functions as the defining environmental values of gardens (Table 1), differentiating them from social and cultural values.

Previous research suggests that gardens and similar facilities yield direct benefits like psychological recovery, stress reduction, and mitigated mental disorders. Indirect effects include providing opportunities and spaces for physical activity and enhancing thermal comfort (Sultana, 2022; Daniels et al., 2018). In line with this, the health value of gardens, as defined in this study, encompasses both direct and indirect effects on health and safety.

a) Habitat provision

'Habitat' denotes an area with resources and conditions conducive to the survival and reproduction of living organisms, while 'Habitat quality' signifies an ecosystem's ability to fulfill the needs for sustaining specific biological species (Na et al., 2018).

In an urban ecosystem, a garden functions not only as a habitat but also as an ecological steppingstone, supporting various ecosystem services like biodiversity. Stable habitats established by gardens form the basis for biodiversity, contributing to enhanced pest and disease control (Stiling, Cornelissen, 2005; Cardinale et al., 2006, as cited in Joo et al., 2018) and facilitating the discovery of new species (Mo, 2021).

Methods for evaluating the value of a garden as a habitat include assessing its role as an ecological steppingstone through distance and structural connectivity (BC index) with adjacent green spaces (Lee et al., 2008; Kim et al., 2017b), evaluating habitat considering biotope (Kim et al., 2006; Daniels et al., 2018; Cabral et al., 2017), assessing three-dimensional structure such as layers (Tzoulas & James, 2010), observing wildlife presence (Lee et al., 2008), assessing plant diversity (Zhang & Jim, 2014), and utilizing the InVEST model.

Given the relationship between habitat quality and biodiversity, biodiversity assessment becomes a means to indirectly evaluate habitat quality. The Shannon index is a common method for measuring biodiversity, with some studies supplementing it by evaluating the ratio of native to exotic species in the garden and assessing the suitability of tree species to the geographical environment (Lee & Choi, 2021).

$$H' = -\sum pi \ln pi \qquad \text{(1)}$$

pi: The proportion of individuals corresponding to a species among all individuals

The Shannon index measures the uncertainty of predictions for random species in the target area by calculating the ratio of individuals of a specific species to the total population. An increase in the index value indicates higher uncertainty, signifying an augmentation in species diversity within the target region (Magurran, 2004, as cited in Lee et al., 2018).

b) Greenhouse gas control

Amid the pressing concerns of climate change, South Korea has identified strengthening carbon absorption as a pivotal strategy for achieving carbon neutrality by 2050. A SWOT analysis of National Gardens has revealed promising external opportunities, including the ‘Realization of carbon neutrality through securing green space,’ ‘Increasing the economic value of the environment,’ and ‘Achieving realistic measurement of environmental value’ (Park et al., 2021). Strategies to leverage these opportunities involve ‘Operating a sustainable garden by promoting a spatially functional carbon emissions trading system’ and ‘Evaluating the contribution to realizing carbon neutrality by expanding the garden function.’

Various methods exist for evaluating greenhouse gas absorption in gardens, encompassing the stock change method, which calculates biomass carbon storage (Joo et al., 2018), and a formula for determining net carbon dioxide absorption by vegetation (Choi et al., 2019). Additionally, methods include carbon storage calculation considering vegetation cover area, greening area by layer, carbon storage by tree species (Lee & Choi, 2021), and the InVEST model. The quantified absorption and storage data can be translated into monetary terms through environmental cost analysis or cost-benefit analysis, offering a tangible measure of the environmental impact.

In this study, we propose utilizing the InVEST Carbon model to evaluate the carbon storage value of gardens. The model has been employed in numerous reports by the National Institute of Ecology and the National Park Research Institute, with ongoing updates in related research. Considering ongoing research updates, the InVEST Carbon model was deemed a highly valuable evaluation method.

c) Flood control

The intensifying impacts of global warming are leading to increased flood damage globally. A notable instance occurred in August 2022, when Gangnam experienced a daily rainfall of 380 mm, resulting in an estimated loss of around 127.4 billion won (Kim, 2022, August 11). Experts attribute the surge in impervious areas as a primary cause of flooding, emphasizing the importance of improving water circulation through green spaces as a viable mitigation measure (Yeon & Kim, 2022, August 9).

Studies indicate that artificial environments like dense urban areas, industrial zones, and roads have a rainwater infiltration rate of 10 to 14%, while green spaces such as parks, wastelands, and farmlands boast a significantly higher rate of 30 to 38% on average (Pauleit & Duhme, 2000). In a study assessing the flood control function of gardens, a 7.4 ha garden demonstrated a potential stormwater runoff reduction of approximately 7,018.9 ㎥. Notably, planter-structured gardens outperform general land cover in water storage, making them more effective in flood control (Mo, 2021).

To evaluate flood damage reduction, a method involves calculating the runoff and infiltration storage amount by land cover using the Runoff Curve Index (CN) and comparing it with the target rainfall amount for disaster prevention (Choi et al., 2020). The economic value of flood reduction can be quantified by considering the unit price required for constructing and maintaining a multipurpose dam (969.5 won/ton, Choi et al., 2020) or the associated flood control benefits (28.67 won/ton, Joo et al., 2018). This approach not only provides a tangible measure of the flood control function but also allows for economic assessments to emphasize the value of green spaces in mitigating flood-related risks.

d) Pollination

IPBES reports that over 90% of plants in nature rely on animal pollinators, with 71% of the world's top 100 crops depending on bee pollination (Joo et al., 2018; Choi, 2022, March 20). Urbanization poses a threat to honeybee habitats, and gardens emerge as potential spaces to attract and protect pollinators, especially honeybees, in small green areas.

Mo (2021) defined pollination as agricultural production, diversity, and observation of pollinated species, as well as pollen movement through the analysis of previous research. Quantitative evaluation methods encompass the assessment of the abundance and diversity of honey plants and the consideration of whether crops are cultivated within the habitat range of the captured bees, among other factors.

A method for evaluating the pollination function through the colony of pollinating insects includes assessing the community of pollinating parasites using indices such as the Species Diversity Index(H'), Evenness Index(J'), Margalef Index(R_1), and Dominance Index(DI), and the total number of pollinator levels (Joo et al., 2018). Pollination of plants is a key component factor of ecosystem services (Daniels et al., 2018), which was first evaluated in IPBES (2016) as the theme evaluation element of ecosystem services (Joo et al., 2018).

$H' = -\sum (n_i/N) \times \ln(n_i/N)$	ni: number of individuals in the species N: total population	(2)
$J' = H'/\ln(S)$	H': species diversity S: number of species	(3)
$R_1 = (S-1)/\ln(N)$	S: number of species	(4)

N: total population

$$DI = (n1 + n2)/N \qquad (5)$$

n1: first dominant species
n2: second dominant species
N: total population

Source: Joo et al. (2018)

The InVEST crop pollination model, incorporating factors like bee distribution, honeycomb suitability index, seasonal bee activity index, and average bee movement distance, offers a tool to evaluate bee population density and seasonal moisture supply. From an economic standpoint, the value of pollination can be calculated by multiplying the area of the target site by the cost of artificial pollination, recommended at KRW 39,630.6 per hectare by the Rural Development Administration (Na et al., 2018).

e) Health indicator

Article 4 of the "Arboretum and Garden Act" delineates a healing garden as a subset of theme gardens, emphasizing its therapeutic attributes. Gardens contribute significantly to physical and mental well-being by providing spaces for physical activity. Research indicates physiological effects, including impacts on blood sugar levels, cortisol levels, heart rate variability (HRV), blood lipids, and body mass index (Howarth et al., 2020). Additionally, psychological benefits are observed, such as a reduced incidence of stress-related diseases like obesity, type 2 diabetes, osteoporosis, depression, heart disease, and improved overall mental health (Ulrich et al., 1991; Mitchell, Popham, 2008, as cited in Rajput, 2021). Moreover, studies demonstrate that mere appreciation, independent of physical activity, can lead to reduced blood pressure, heart rate, and stress (Kang et al., 2020).

The health advantages provided by gardens are particularly pertinent in contemporary society, marked by a growing prevalence of obesity due to the COVID-19 pandemic and an increased occurrence of diabetes among individuals in their 20s and 30s. These benefits not only have the potential to decrease medical costs but also function as a form of welfare for vulnerable populations, such as low-income individuals (Lee, 2020).

While studies on the mental impact of gardens have used objective indicators and evaluation tools, the challenge of observing the same subjects over time introduces complexities (Kim & Lim, 2021; Korea National Arboretum, 2022). Similar challenges are encountered in assessing the physical effects of gardens. In this study, the focus is on evaluating the absorption function of plants for air pollutants.

The formula for air pollutant absorption is determined based on various land cover types (e.g., broad-leaved forest, coniferous forest, mixed forest), considering factors such as land cover area, gross primary production, temperature, and air pollutant concentration (Korea National Park Research Institute, 2021). Temperature data can be sourced from the Korea Meteorological Administration's Meteorological Data Open Portal, while air pollutant concentration values (unit: ppm) can be acquired from the Korea Environment Corporation's Air Korea. The specific formulas for calculating air pollutant absorption (Formula 6) and unit conversion (Formula 7) are as follows.

$$U_{SO_2} = 18.6 \times C_{SO_2} \times Pg$$
$$U_{NO_2} = 13.9 \times C_{NO_2} \times Pg \qquad (6)$$

U_X= Air pollutant absorption(ton/yr)
C_X= Air pollutant concentration(ug/cm3)
Pg= Total primary production(ton/yr)

$$Air\ pollutant\ concentration(ug/cm^3) = \frac{(44 \times Air\ pollutant\ concentration(ppm)/1000 \times 10^{-6})}{[22.4 \times 10^{-6} \times (273 + Temperature)/273]} \qquad (7)$$

Source: Korea National Park Research Institute (2021)

Ahn et al. (2019) quantified the impact of 1 ton of emissions on PM2.5 concentration for each pollutant and assessed the reduction in pollutants in terms of the Value of Statistical Life (VSL). VSL was estimated using the Statement Preferred Method, reflecting the willingness to pay for a specific reduction in mortality risk. Despite inherent uncertainties in step-by-step analyses, such as air quality modeling, health impact assessment, and value estimation, this calculation formula holds significance as it used in the development of the integrated air pollution health impact analysis toolkit within the Environmental Valuation System (EVIS) by the Korea Environment Institute.

Therefore, this study proposes evaluating the health value of a garden by considering the amount of air pollutants removed by vegetation and the associated VSL value.

IV. Results

1. Establishment of valuation indicators and evaluation methods

Table 5. Multifaceted value evaluation elements and evaluation methods for gardens(final)

Group	Class	Definition	index /monetary value	Assessment Methods
Social· Cultural value	community	Local community consciousness, utilization of places such as events and festivals, improving the quality of life of residents	index	Level of use according to local population and number of visitors
	Sustainability	Management. Continuous operability	monetary value	Willingness to pay amount
	Local Economy Revitalization	Vitalization of the local economy, such as job creation	monetary value	flexible input-output methodology
	landscape	Aesthetic elements and diversity to enjoy visual pleasure	index	Diversity of landscape using detailed land cover map
Environmental· Health value	Habitat provision	Stability of spatial structure according to land coating	index	InVEST Model
	Greenhouse gas control	Greenhouse gas absorption or storage provided by the ecosystem	monetary value	InVEST Model
	Flood control	Flood prevention by calculating the amount of penetration of land coating	monetary value	Infiltration storage volume by land cover
	Pollination	Pollination of vegetation by pollinators	monetary value	Artificial pollination cost for the garden area
	Health indicator	Improvement of users' physical and mental health	monetary value	Reduction in air pollutants, Mortality risk reduction value

The study focuses on the diverse value of gardens, categorizing them into social and cultural values, environmental and health values. The evaluation factors are chosen based on their representativeness of value, and the selection of the evaluation method considers the availability of existing data and the generalizability of valuation.

Methods like the InVEST model and industry-related models, which rely on securing relevant data, are suitable for evaluating large-scale gardens but may pose challenges for small-scale gardens. The study aims to address this by comprehensively organizing the definition of value for each evaluation element, facilitating the application of study goals to smaller gardens.

This research not only specifies valuation elements but also proposes an objective evaluation method, whether through indexing or monetary valuation. This approach clarifies the vague values associated with gardens and enables an objective comparison of different gardens. Additionally, the study provides standards for high-quality gardens, serving as a reference for the creation of new gardens.

2. Empirical analysis of established gardens

Among the selected indicators, a pilot evaluation focused on greenhouse gas control was conducted on two local gardens, Semiwon and Juknokwon. Semiwon, located at the confluence of two rivers, is characterized by aquatic plants, while Juknokwon is a bamboo garden encircling Seonginsan Mountain.

The InVEST carbon storage and sequestration model, used for carbon storage analysis, maps four carbon reservoirs (above-ground biomass, below-ground biomass, soil, and dead organic matter) to a land cover map, estimating carbon stored based on the input land cover map. The primary data for Land Cover/Land Use (LULC) used the detailed land cover map from the Ministry of Environment. The Biophysical Table and Carbon Pools (t/ha) were reconstructed using data from the Korea National Park Research Institute (2021) and the National Institute of Ecology (2022).

Table 6. Carbon storage analysis results using the InVEST carbon model

	Semiwon (118,408 ㎡)	Juknokwon (297,470 ㎡)
Above	219.60 tC	286.79 tC
Below	68.86 tC	144.38 tC
Soil	633.02 tC	579.68 tC
Dead	0.40 tC	89.24 tC
Total carbon storage	921.88 tC	1100.09 tC
Carbon storage per ha	77.85623 tC	36.98154 tC

Analyzing the carbon storage of each garden revealed that Juknokwon had a higher total carbon storage of 1100.09 (tC) compared to Semiwon's 921.88 (tC). However, on a per-hectare basis, Juknokwon's storage amounted to 36.98 (tC), while Semiwon's was 77.86 (tC), approximately twice that of Juknokwon. This disparity is explained by the composition of Semiwon, where 52% of the area is inland wetlands with a high Carbon Pool coefficient (Wetlands Carbon Pool coefficient: 132.42 tC). In contrast, 70% of Juknokwon comprises grasslands with a low Carbon Pool coefficient (Grasslands Carbon Pool coefficient: 17.23 tC). Notably, the bamboo garden in Juknokwon is categorized as grassland based on the “Land Cover Map Preparation Guidelines,” Article 1, Paragraph 5, Item 6.

The Carbon model used in this study assumes that no LULC type in the landscape gains or loses carbon over time, and that all LULC types are at some storage level equal to the average of the measured storage levels within that LULC type. This assumption represents a limitation of the Carbon model and should be considered when interpreting the results.

V. Conclusion

While gardens are commonly considered green spaces near residential areas within urban landscapes, their significance and impact extend beyond mere aesthetics. Particularly, in the context of societal shifts driven by climate change and the COVID-19 pandemic, gardens have assumed roles of heightened importance. However, previous examinations of domestic garden value primarily focused on large-scale counterparts, like Suncheonman National Garden and Taehwagang National Garden, or relied on cross-sectional valuations.

In this study, we suggest establishing a comprehensive framework for the valuation of gardens, considering social, cultural, environmental, and health values, aiming for a more holistic understanding and a basis for quantitative evaluation. The criteria for the multifaceted valuation of gardens were chosen based on indicators capturing garden uniqueness, means for objective evaluation (including potential monetary valuation), and the availability or collectability of data. Based on the results of this study, we expect that systematical quantifying garden value facilitates meaningful comparisons, establishes quality standards, and guides new garden creation. To check the appropriateness of the garden evaluation indicator, we conducted a pilot evaluation process for the greenhouse gas control indicator.

In our pilot evaluation, we assessed carbon storage in two local gardens, Semiwon and Juknokwon. The results revealed that Semiwon outperformed Juknokwon in carbon storage, with a notable difference of 77.86 (tC) per hectare compared to Juknokwon’s 36.98 (tC) per hectare. This variance can be attributed to the fact that Semiwon comprises 52% inland wetlands, which inherently possess a higher carbon storage coefficient per unit area. Considering this difference in carbon storage ability due to the land cover composition, it is necessary to refer to this difference in garden planning.

Acknowledging the diversity in garden size, function, and purpose—from national to community gardens—we recognize potential differences in required facilities and values. While our study did not weigh indicators based on garden types, we advocate for such considerations in future research. During our evaluation case study, we analyzed previous studies of facilities similar to gardens, gaining insights into environmental and functional characteristics. However, it is crucial to note that gardens, in general, tend to be smaller than other green spaces, and this factor should be considered when assessing their value. Future research could delve into nuanced considerations based on the specific type and function of gardens, refining the evaluation process and improving its applicability across a spectrum of green spaces.

In conclusion, our study not only advances the understanding of garden values but also lays the groundwork for a standardized and quantitative evaluation framework. These insights are pivotal for urban planning, particularly in the face of challenges like climate change and public health concerns, emphasizing the crucial role of gardens in resilient urban landscapes promoting well-being and sustainability.

For future research topics, it is necessary to upgrade the evaluation methodology and framework for the valuation of the garden. The detailed data appropriate to evaluate the diverse value of the garden is collected and analyzed.

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