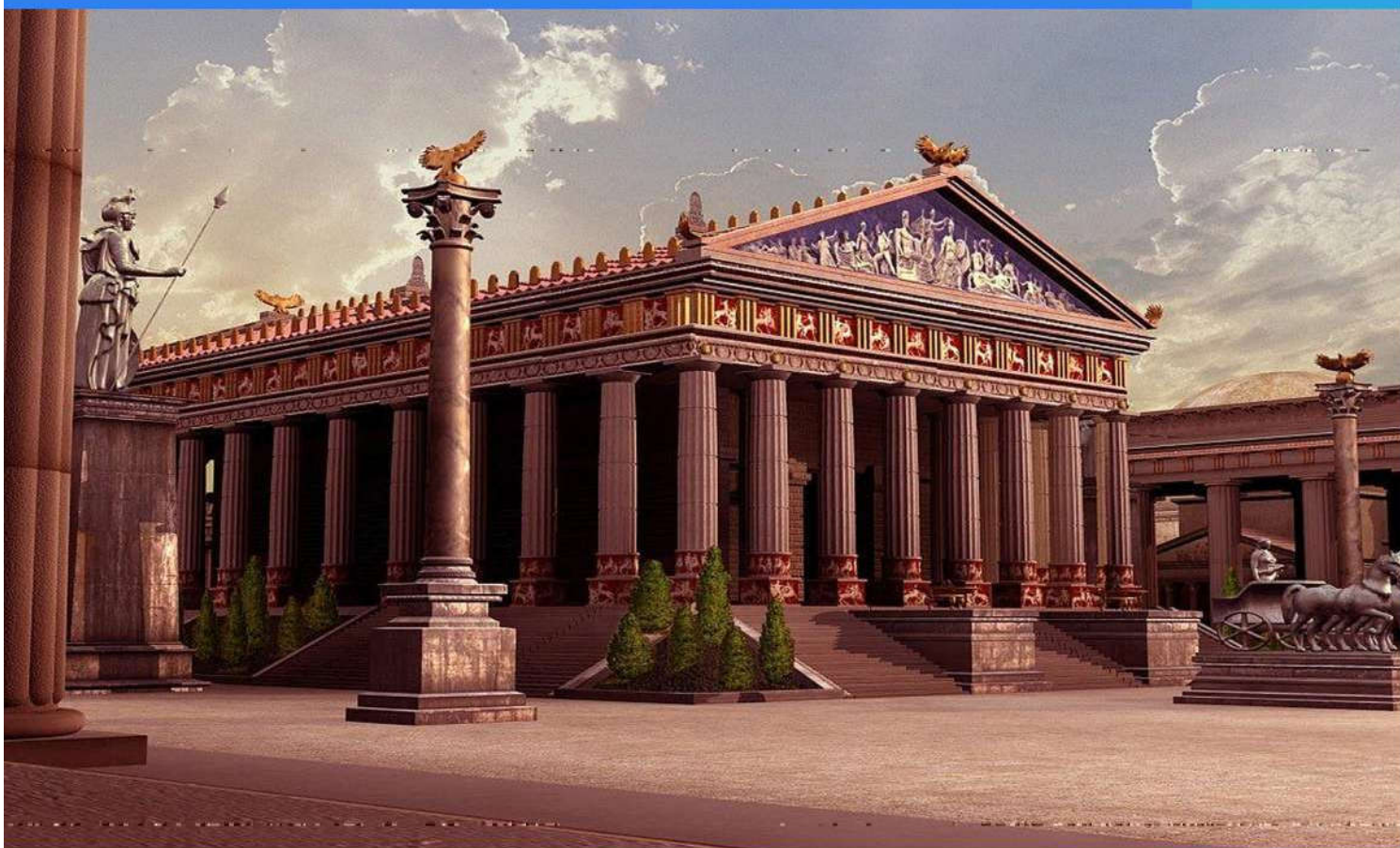


ВЕСТНИК НАУКИ



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**APPLICATION OF THE DPSIR FRAMEWORK
FOR DEVELOPING CRITERIA FOR URBAN GREEN SPACE
SITE SELECTION: A CASE STUDY OF HANOI, VIETNAM**

***Abstract:** urban green spaces (UGSs) play a vital role in improving environmental quality, regulating the urban microclimate, and enhancing residents' quality of life. In the context of rapid urbanization in Hanoi, where per capita green space remains limited and unevenly distributed, identifying priority locations for urban green space development has become an urgent requirement for promoting sustainable urban development. This study proposes a set of criteria for identifying priority areas for urban green space development by integrating the Driving Forces-Pressures-State-Impacts-Responses (DPSIR) framework with expert evaluation based on a five-point Likert scale.*

The proposed framework comprises 13 criteria classified into five DPSIR components, including two Driving Forces criteria, two Pressures criteria, six State criteria, two Impacts criteria, and one Responses criterion. The expert survey results demonstrated a high level of consensus among respondents ($CnS = 0.874-0.923$) and low response dispersion ($wStD = 0.501-0.618$), confirming the reliability of the proposed criteria. Among the evaluated criteria, population density was identified as the most important ($wM = 4.025$), followed by urbanization rate and distance from residential areas to urban green spaces (both $wM = 3.675$), as well as building density ($wM = 3.575$). The proposed criteria provide a robust scientific basis for integration with Geographic Information Systems (GIS) and Multi-Criteria Decision Analysis (MCDA), particularly the Analytic Hierarchy Process (AHP), to develop priority maps for urban green space development. The resulting framework can support urban planning and improve the effectiveness of urban green space management in Hanoi.

Keywords: *urban green space, DPSIR framework, Hanoi, green space development.*

1. Introduction.

With the rapid pace of urbanization, Hanoi is facing significant challenges in maintaining and expanding its urban green space (UGS) system. According to recent assessments, the city's average green space provision is approximately 2 m² per capita, which is substantially lower than both the Vietnamese urban planning standard of 7 m² per capita [6] and the World Health Organization (WHO) recommendation of 9 m² per capita [5]. Furthermore, the existing distribution of urban green spaces is highly uneven, resulting in only approximately 15% of the population having convenient access to green spaces within a reasonable walking distance [4]. In densely populated districts, the limited size of existing green spaces often leads to overcrowding and excessive recreational demand. Consequently, Hanoi exhibits a common characteristic of rapidly developing cities, namely, inequitable access to urban green spaces. To address these challenges, the Hanoi municipal government has implemented various initiatives to enhance the quantity and quality of urban green spaces. Under the Vietnamese Government's One Billion Trees Program (2021–2025), Hanoi aims to increase green space provision to 6–8 m² per capita by 2025 and 8–10 m² per capita by 2030.

The city has also launched programs to renovate and upgrade 45 parks and public gardens, develop five new parks and gardens, and implement numerous public open-space projects. In addition, the long-term strategy for urban green space development has been incorporated into the Hanoi Capital Master Plan to 2030, with a Vision to 2050 (Decision No. 1259/QĐ-TTg). This master plan proposes a green corridor occupying approximately 60% of the city's total area, comprising 40% conservation areas and 20% conservation-oriented development areas. Achieving these ambitious targets requires effective planning approaches capable of optimizing the spatial allocation of urban green spaces, thereby maximizing their ecological functions and improving public accessibility.

In recent years, numerous studies have investigated urban green spaces in Hanoi. For example, Nguyen Thi Tuyet et al. (2024) developed a spatial distribution map of urban green spaces and estimated the city's carbon credit potential [4]. Nguyen Van Huy et al. (2017) employed remote sensing techniques to evaluate the cooling effects of urban green spaces [1]. Duong Thi Loi et al. (2022) proposed an integrated framework for assessing urban green space quality in Hanoi [2], while Duong Thi Loi (2023) examined the role of urban green spaces in mitigating the urban heat island effect [3]. Although these studies have substantially improved the understanding of the distribution, quality, and ecological functions of urban green spaces, they have primarily focused on evaluating existing conditions. Limited attention has been paid to assessing the effectiveness of the current green space system or developing a systematic framework for identifying priority locations for future urban green space development based on residents' needs and urban development characteristics. To address this research gap, this study adopts the Driving Forces–Pressures–State–Impacts–Responses (DPSIR) framework to examine the cause-and-effect relationships influencing urban green space development. Based on this framework, a comprehensive set of criteria is proposed to support the identification and prioritization of suitable locations for future urban green space development in Hanoi.

This framework provides a scientific foundation for integrating Geographic Information Systems (GIS) and Multi-Criteria Decision Analysis (MCDA) in support of sustainable urban planning and green infrastructure development.

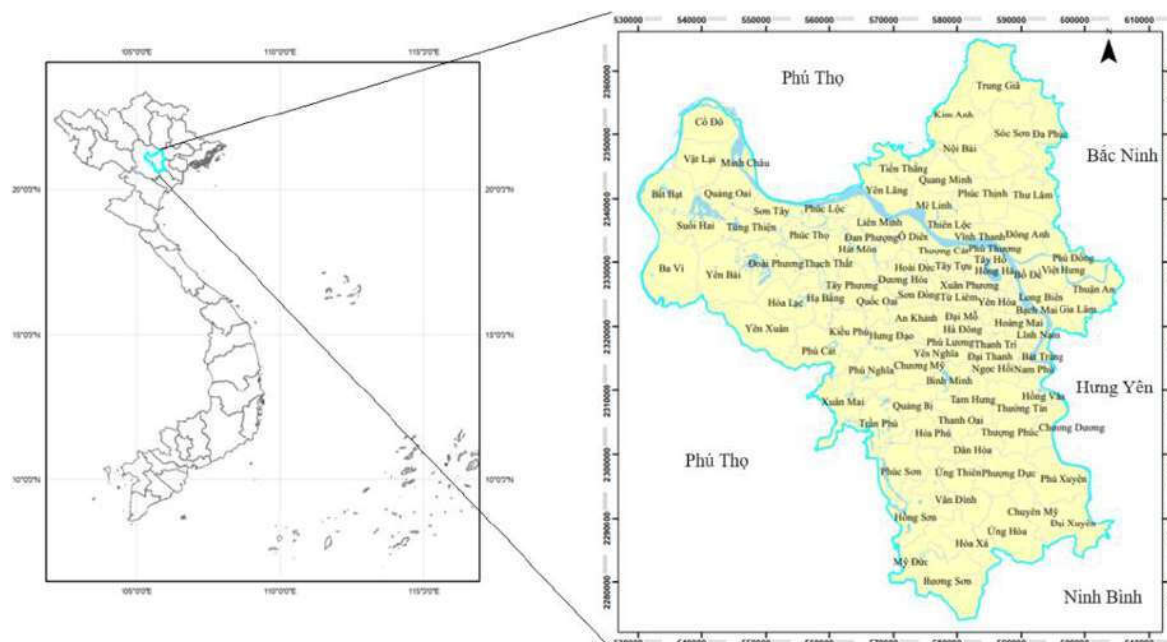


Fig. 1. Study area.

2. Materials and Methods.

2.1. Literature Review and Synthesis method.

To achieve the objectives of this study, a comprehensive literature review and synthesis approach was employed. Relevant scientific publications, peer-reviewed journal articles, technical reports, and policy documents from both domestic and international sources concerning urban green space planning and development were systematically reviewed. Based on this review, previous research approaches were critically analyzed to identify existing knowledge, methodological strengths, and research gaps. This process also provided the scientific and practical foundation for developing and selecting the criteria used to identify priority locations for urban green space development.

In addition, the characteristics of the study area were comprehensively examined, including its geographical setting, socio-economic conditions, population distribution and density, as well as the spatial distribution and quality of existing urban green spaces. These factors were analyzed in an integrated manner to better understand the pressures imposed by rapid urbanization and the increasing demand for urban green space development. Furthermore, relevant legal documents, urban planning strategies, national standards, and regulatory frameworks governing urban green space development were systematically reviewed and compared. This step ensured that the proposed criteria were not only scientifically sound but also consistent with the current legal framework and the sustainable urban development objectives established for the study area.

2.2. DPSIR Framework.

The Driving Forces–Pressures–State–Impacts–Responses (DPSIR) framework was developed by the European Environment Agency (EEA) in 1999 as a conceptual framework for identifying, analyzing, and evaluating the cause-and-effect relationships between human activities and environmental changes. The framework systematically describes how socio-economic driving forces generate environmental pressures, alter environmental conditions, produce ecological and socio-economic impacts, and ultimately trigger management responses aimed at mitigating adverse effects and promoting sustainable development. In this study, the DPSIR framework was adapted to develop a comprehensive set of indicators for identifying priority locations for urban green space development. Each component of the framework represents a distinct aspect influencing the planning and spatial allocation of urban green spaces, as described below.

Driving Forces (D): This component includes indicators representing the socio-economic factors that drive the demand for urban green space development, such as rapid urbanization, population growth, and increasing development intensity. These factors increase the need for green infrastructure to support environmental quality and residents' well-being.

Pressures (P): This component comprises indicators reflecting the direct pressures imposed on the urban green space system, including the decline in green space density and the expansion of building density associated with urban development. These pressures contribute to the fragmentation and reduction of existing green spaces.

State (S): This component evaluates the current condition of the urban green space system through indicators describing its spatial distribution, accessibility, and environmental suitability for long-term development. These indicators characterize the existing capacity of urban green spaces to provide ecological and social functions.

Impacts (I): This component includes indicators representing the environmental consequences resulting from changes in urban green space, such as increased land surface temperature and deteriorating environmental quality. These impacts directly affect urban ecological conditions and human well-being.

Responses (R): This component represents planning and management measures implemented to address the identified driving forces, pressures, environmental conditions, and impacts. In this study, the response is represented by the development of an urban green space planning framework that supports the identification of priority locations for future green space expansion and sustainable urban development.

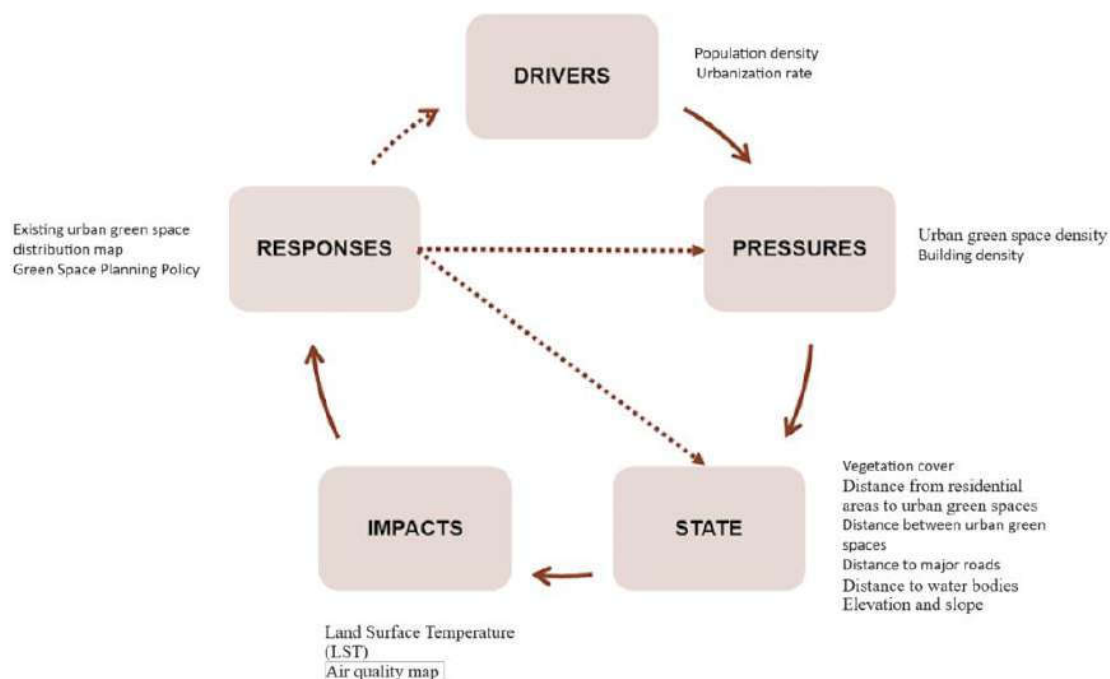


Fig. 2. DPSIR framework.

As the DPSIR framework is primarily a conceptual model, an expert-based evaluation was conducted to quantify the relative importance of the proposed indicators for identifying priority locations for urban green space development. A five-point Likert scale was employed to assess the perceived influence of each indicator. The evaluation framework comprised the five DPSIR components, with each indicator rated on a scale from 1 to 5, where 1 represented very low importance and 5 represented very high importance.

The expert evaluation was designed to measure the degree of influence of each indicator on urban green space planning and site selection. The resulting scores were subsequently used to calculate the weighted mean (wM), weighted standard deviation (wStD), and consensus coefficient (CnS), thereby assessing the relative importance, variability, and level of agreement among experts regarding each proposed criterion.

Table 1. Five-point Likert scale.

No.	Level of influence on urban green space site selection	Likert score
1	Very low	1
2	Low	2
3	Moderate	3
4	High	4
5	Very high	5

Based on the five-point Likert scale, a structured questionnaire was developed and the collected responses were analyzed using descriptive statistical measures. The following statistical indicators were employed to evaluate the importance of each criterion:

Weighted Mean (wM).

$$wMean = \sum_{i=1}^5 X_i P_i (X_i) \quad (1).$$

The calculated Weighted Mean (wM) values were interpreted according to the evaluation scale proposed by McKee (2012). The mean scores were classified into five levels of importance: 1.000–1.499 (very low), 1.500–2.499 (low), 2.500–3.499 (moderate), 3.500–4.499 (high), and 4.500–5.000 (very high). This classification was used to determine the relative importance of each indicator in identifying priority locations for urban green space development.

Weighted standard deviation (wStD).

$$wStD = \sqrt{\sum_{i=1}^5 \frac{(X_i - wMean)^2}{N}} \quad (2).$$

Consensus coefficient (CnS).

$$CnS(X) = 1 + \sum_{i=1}^5 P_i(X_i) \log_2 \left(1 - \frac{|X_i - wMean|}{d_x} \right) \quad (3).$$

Where: X_i represents the Likert scale scores, $P_i(X_i)$ denotes the relative frequency (proportion of responses) corresponding to each score, $N = 5$, d_x is the scale range, calculated as $d_x = d_{max} - d_{min}$.

3. Results and discussion.

3.1. Scientific and practical basis for the selection of urban green space development criteria.

The selection of priority locations for urban green space (UGS) development should be consistent with urban planning objectives, meet the recreational and environmental needs of local communities, and ensure the long-term sustainability of ecological and landscape functions. Accordingly, the development of the proposed criteria was based on the following scientific foundations.

Review of previous studies. A comprehensive review of national and international studies on urban green space development was conducted to identify the key criteria and factors influencing the selection of suitable locations for UGS development. This review provided the scientific basis for adopting existing methodological approaches and developing a criterion framework tailored to the characteristics of the study area through the integration of Geographic Information Systems (GIS) and remote sensing techniques. Bakolo et al. (2024) employed GIS integrated with the Analytic Hierarchy Process (AHP) to identify suitable locations for urban green space development in Lilongwe, Malawi, one of the rapidly urbanizing cities in southeastern Africa. Their study incorporated eight evaluation criteria, including distance to roads, the Soil-Adjusted Vegetation Index (SAVI), population density, slope, NO₂ concentration, existing urban green space area, distance to water bodies, and land use. The resulting suitability map classified potential development areas into five categories: unsuitable, low suitability, moderately suitable, suitable, and highly suitable [7].

Similarly, Kiberet et al. applied an integrated GIS–AHP approach to identify priority locations for urban green space development in Gondar, Ethiopia. Seven evaluation criteria were considered, including land use, distance to roads, soil quality, distance to water bodies, population density, historical heritage sites, and slope. Their findings successfully identified the most suitable areas for future urban green space development in Gondar [10]. Comparable GIS-based multi-criteria approaches have also been adopted in previous studies by Gelan (2021) and Zhang (2021), further demonstrating the effectiveness of integrating GIS with multi-criteria decision-making techniques for urban green space planning and site suitability assessment [8,9].

DPSIR-based analysis: The Driving Forces–Pressures–State–Impacts–Responses (DPSIR) framework was applied to analyze the causal relationships among urban development drivers, the pressures exerted on the urban green space system, the current distribution and quality of urban green spaces, the resulting environmental and socio-economic impacts, and the corresponding planning and management responses. The outcomes of this analysis provided the scientific basis for identifying priority criteria and guiding the selection of suitable locations for urban green space development, thereby enhancing the ecological performance and long-term sustainability of the urban green space system. Furthermore, all selected criteria were required to be spatially explicit and capable of being represented as thematic map layers. This requirement ensures that each criterion can be integrated into a Geographic Information System (GIS) environment to facilitate spatial analysis, overlay operations, and multi-criteria suitability assessment for identifying priority areas for urban green space development.

3.2. Results of developing urban green space development criteria for Ha Noi.

To identify priority areas for urban green space (UGS) development, this study employed the Driving Forces–Pressures–State–Impacts–Responses (DPSIR) framework to analyze the relationships among urban development drivers, pressures on the urban green space system, the current distribution of green spaces, environmental impacts, and planning responses.

Based on this framework, the proposed criteria for urban green space development in Hanoi were organized into five components, as described below.

(1) Driving Forces:

Driving Forces represent the socio-economic factors that stimulate the demand for urban green space development by reflecting the level of urban growth and residents' need for green spaces. In this study, the Driving Forces component was evaluated using two indicators:

Population density: High population density increases the demand for urban green spaces that provide opportunities for recreation, leisure, physical activity, and improvements in public health and quality of life. Areas characterized by high population density but limited green space provision should therefore be prioritized for the development of parks, public gardens, and green corridors.

Urbanization rate: Rapid urbanization accelerates land sealing and the expansion of built-up areas, leading to a reduction in urban green spaces and a decline in environmental quality and living conditions. Consequently, areas experiencing rapid urbanization generally exhibit a greater demand for additional urban green spaces.

(2) Pressures:

The Pressures component describes the extent to which the urban green space system is degraded or transformed as a consequence of urbanization. Two indicators were selected to represent these pressures:

Urban green space density: This indicator reflects the conversion of vegetated land into built-up areas during urban expansion. Areas experiencing substantial reductions in green space density should be prioritized for ecological restoration or the establishment of new green spaces.

Building density: High building density indicates an increased degree of land sealing and a shortage of open spaces within the urban environment. This indicator is essential for identifying areas under intense development pressure where additional green spaces are required to restore ecological balance and improve environmental quality.

(3) State:

The State component characterizes the current condition of the urban green space system by evaluating its ability to meet residents' needs while considering the natural and infrastructural conditions that support future green space development. The indicators are grouped into two categories.

(a) Green space accessibility.

Vegetation cover: Areas with a high proportion of existing vegetation provide favorable conditions for urban green space development because they require fewer restoration measures and possess higher ecological potential.

Distance from residential areas to urban green spaces: Urban green spaces can only effectively deliver ecological and social benefits when they are conveniently accessible to residents. The distance between residential areas and parks or public gardens directly influences visitation frequency and utilization rates. Consequently, areas located far from existing green spaces or currently underserved should be prioritized for future green space development.

Distance between urban green spaces: This indicator was included to ensure an equitable spatial distribution of parks and green spaces throughout the city. Appropriate spacing between green spaces improves accessibility and promotes a more balanced provision of ecosystem services across different urban districts.

Distance to major roads: Proximity to major transportation corridors reflects the accessibility and usability of urban green spaces. Ideally, green spaces should be easily accessible while remaining sufficiently separated from high-traffic roads to minimize the adverse effects of noise, air pollution, and traffic disturbances.

(b) Natural suitability.

Distance to water bodies: Water bodies constitute an essential component of urban ecological systems. Integrating green spaces with rivers, lakes, and other water features forms green, which contributes to urban cooling, increases atmospheric humidity, enhances landscape quality, and supports biodiversity conservation. Furthermore, riparian green spaces function as ecological buffers that reduce riverbank erosion, improve stormwater drainage, and mitigate urban flooding.

Elevation and slope: Topographic conditions are critical natural factors affecting the construction, operation, and management of urban green spaces. Relatively flat terrain or areas with gentle slopes are generally more suitable for establishing parks, public gardens, green squares, and supporting infrastructure because they require less land grading, reduce construction costs, and improve accessibility for all users, particularly older adults, children, and people with disabilities. Conversely, steep terrain often requires additional engineering measures, such as slope stabilization, retaining structures, and erosion-control drainage systems, resulting in substantially higher construction and maintenance costs.

(4) Impacts:

The Impacts component evaluates the environmental consequences associated with changes in the urban green space system using two indicators.

Land Surface Temperature (LST): LST reflects the effects of urbanization and the deficiency of urban green spaces. Areas with elevated LST are generally characterized by high building density, extensive impervious surfaces, and limited vegetation cover, all of which intensify the urban heat island effect. Therefore, prioritizing green space development in areas with high LST can effectively reduce ambient temperatures, improve the urban microclimate, and enhance residents' quality of life.

Environmental quality degradation: Reductions in urban green space adversely affect environmental quality and public health, particularly through deteriorating air quality. Accordingly, areas experiencing high concentrations of airborne particulate matter should be prioritized for green space development to improve environmental conditions and protect public health.

(5) Responses:

The Responses component represents planning and management actions implemented to address the identified driving forces, pressures, current environmental conditions, and associated impacts. In this study, the response is expressed through the planning and development of priority urban green space locations to improve the spatial distribution of green infrastructure, enhance ecosystem services, and support sustainable urban development in Hanoi.

Table 2. DPSIR-based criteria for urban green space site selection in Hanoi.

DPSIR Component	Criterion	Code
Driving Forces	Population density	TC1
	Urbanization rate	TC2
Pressures	Urban green space density	TC3
	Building density	TC4
State	Vegetation cover	TC5
	Distance from residential areas to urban green spaces	TC6
	Distance between urban green spaces	TC7
	Distance to major roads	TC8
	Distance to water bodies	TC9
	Elevation and slope	TC10
Impacts	Land Surface Temperature (LST)	TC11
	Air quality map	TC12
Responses	Existing urban green space distribution map	TC13

The results of the expert evaluation of the importance of each criterion in urban green space site selection, based on responses from experts in the field of natural resources and environmental management using a five-point Likert scale, are summarized in Table 3.

Table 3. Results of the importance assessment of urban green space site selection criteria.

DPSIR component	Criterion	Response probability for the five-point Likert scale					wM	wStD	CnS
		1	2	3	4	5			
Driving Forces	Population density	0,100	0,050	0,000	0,425	0,425	4,025	0,618	0,901
	Urbanization rate	0,075	0,025	0,200	0,550	0,150	3,675	0,554	0,911
Pressures	Urban green space density	0,150	0,125	0,325	0,300	0,100	3,075	0,501	0,889
	Building density	0,050	0,025	0,325	0,500	0,100	3,575	0,540	0,917
State	Vegetation cover	0,200	0,400	0,375	0,025	0,000	2,225	0,570	0,923
	Distance from residential areas to urban green spaces	0,075	0,075	0,150	0,500	0,200	3,675	0,554	0,899

DPSIR component	Criterion	Response probability for the five-point Likert scale					wM	wStD	CnS
		1	2	3	4	5			
	Distance between urban green spaces	0,100	0,200	0,150	0,400	0,150	3,300	0,511	0,874
	Distance to major roads	0,175	0,425	0,375	0,045	0,025	2,275	0,562	0,921
	Distance to water bodies	0,200	0,375	0,350	0,075	0,000	2,300	0,558	0,914
	Elevation and slope	0,100	0,325	0,325	0,125	0,125	2,850	0,503	0,891
Impacts	Land Surface Temperature (LST)	0,150	0,275	0,275	0,150	0,150	2,875	0,502	0,877
	Air quality map	0,075	0,525	0,325	0,025	0,05	2,450	0,536	0,920
Responses	Existing urban green space distribution map	0,075	0,175	0,275	0,225	0,250	3,400	0,520	0,874

The results of the expert assessment using the five-point Likert scale indicate that the weighted mean (wM) values ranged from 2.225 to 4.025, reflecting differences in the perceived importance of the proposed criteria for urban green space (UGS) site selection. The weighted standard deviation (wStD) values ranged from 0.501 to 0.618, indicating a relatively low dispersion of expert opinions. Furthermore, the Consensus Coefficient (CnS) values exceeded 0.87 for all criteria, demonstrating a high level of agreement among the experts and confirming the reliability of the survey results for selecting the criteria used to develop the urban green space planning model. As shown in Table 3, the Driving Forces and Pressures components were identified as the most influential factors in determining priority locations for urban green space development in Hanoi. Among all evaluated criteria, population density received the highest importance rating (wM = 4.025), indicating that densely populated areas should be prioritized for future green space provision to satisfy increasing recreational and environmental demands. The urbanization rate and distance from residential areas to urban green spaces ranked second, both with a wM of 3.675, highlighting the significant influence of rapid urban expansion and green space accessibility on site selection. Building density was the fourth highest-ranked criterion (wM = 3.575), suggesting that highly built-up areas with limited open space should receive priority for green space development to improve ecological conditions and urban livability. In contrast, urban green space density received a moderate importance rating (wM = 3.075), indicating that although the decline in existing green space reflects increasing development pressure, experts considered it less influential than building density in determining suitable locations for future green space expansion. The existing urban green space distribution map achieved a relatively high score (wM = 3.400), emphasizing its importance as the principal output of the proposed framework. This spatial product provides a scientific basis for identifying priority areas for urban green space development while supporting urban planning, environmental management, and decision-making processes. Moreover, the CnS values ranging from 0.874 to 0.923, together with wStD values below 0.62, indicate a high degree of consistency among expert judgments.

These findings confirm the robustness and reliability of the proposed criteria set and demonstrate its suitability for developing a GIS-based spatial evaluation model and priority map for sustainable urban green space development in Hanoi.

CONCLUSIONS.

This study developed a DPSIR-based framework for identifying priority locations for urban green space (UGS) development, providing a systematic approach to understanding the relationships among urban development drivers, environmental pressures on the UGS system, the current state of green space distribution, environmental impacts, and planning responses. By integrating findings from previous national and international studies with the specific characteristics of Hanoi, a set of 13 evaluation criteria grouped into the five DPSIR components was established, providing a scientific basis for assessing and prioritizing suitable locations for future urban green space development.

The expert evaluation using a five-point Likert scale demonstrated that the proposed criteria are highly reliable, with Consensus Coefficient (CnS) values ranging from 0.874 to 0.923 and weighted standard deviation (wStD) values below 0.62, indicating strong agreement and high consistency among experts. Among the proposed criteria, population density was identified as the most influential factor affecting urban green space site selection ($wM = 4.025$), followed by urbanization rate, distance from residential areas to urban green spaces, and building density. These findings suggest that residents' demand for green spaces and the intensity of urban development are the primary determinants of green space planning, whereas natural conditions and existing environmental characteristics serve as supporting factors in identifying suitable development locations. An important contribution of this study is that the proposed criteria are not only scientifically grounded but also spatially explicit, enabling their direct integration into a Geographic Information System (GIS) as thematic spatial layers.

This provides a practical foundation for combining the proposed framework with Multi-Criteria Decision Analysis (MCDA) techniques, such as the Analytic Hierarchy Process (AHP), to produce spatial suitability and priority maps for urban green space development. Such an integrated approach can effectively support urban planners and decision-makers in optimizing the allocation of green spaces, improving environmental equity, and promoting sustainable urban development in Hanoi.

Although the proposed framework was developed for Hanoi, the methodology can be adapted to other rapidly urbanizing cities with similar socio-economic and environmental characteristics by adjusting the evaluation criteria to local planning objectives and data availability. Future research should integrate the proposed DPSIR framework with GIS-based MCDA methods and validate the resulting suitability maps using field observations and stakeholder participation to further improve the robustness and applicability of urban green space planning.

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