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Research Article

Assessment of urban planning, green coverage, and biodiversity under the climate-smart city model

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ABSTRACT

Smart cities, or intelligent cities, are the current trend in urban infrastructure development, in which urban planning, green cover, and biodiversity are among the five key pillars under India's Framework 3.0. This study focuses on assessing the current status of urban planning, green cover, and biodiversity in Ho Chi Minh City according to the Climate-Smart City model under India's Framework 3.0, based on seven indicators: (1) Rejuvenation & conservation of water bodies & open areas; (2) Green cover per capita in the city (m^2/person); (3) Proportion of urban green land to total urban construction land area; (4) Urban biodiversity; (5) Application of GIS and digital data in urban planning; (6) Smart disaster warning and management system; and (7) The city's climate action plan. The results show that Ho Chi Minh City achieved level 5 for the indicator ``*Rejuvenation & conservation of water bodies & open areas*'' reflecting the effective maintenance of canals, rivers, and riverbank protection corridors. In contrast, the indicator ``*Green cover per capita in the city (m^2/person)*'' reached only level 1, indicating a severe shortage of public green spaces. The indicator ``*Proportion of urban green land to total urban construction land area*'' reached level 3, and the indicator ``*Application of GIS and digital data in urban planning*'' also stood at level 3, reflecting a medium level of adoption of digital planning tools. The indicator ``*Urban biodiversity*'' cannot be fully evaluated due to lack of data, although the presence of the Can Gio Biosphere Reserve and vast suburban green areas indicates a relatively high proportion of natural land. Meanwhile, the indicator ``*Smart disaster warning and management system*'' reached level 3, and the indicator ``*City's climate action plan*'' stood at level 2. The study proposes solutions to enhance green space development, apply smart technologies, and improve climate policies, aiming toward sustainable urban development and adaptation to climate change.

Key words: Smart city, urban planning, green cover, biodiversity, climate change, Ho Chi Minh City

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INTRODUCTION

Urban planning plays an important role in creating sustainable living spaces and increasing resilience in the context of climate change (CC)[1]. Integrated planning that includes green cover, expanded open spaces, and biodiversity conservation not only improves the urban microclimate but also contributes to reducing urban flooding, mitigating the heat island effect, enhancing public health, and maintaining ecological balance[2,3]. In the Net Zero roadmap, in addition to high-tech solutions (renewable energy, electric vehicles, smart materials), nature-based solutions such as expanding green cover and regenerating open spaces bring significant benefits for carbon absorption[4]. Accordingly, in the climate-smart city model, urban planning, green cover, and biodiversity are core components among the five pillars of India's Framework 3.0[5]. Urban planning, green cover, and biodiversity conservation in major cities are also being promoted under the Asian Smart Cities Framework[6] and the OECD framework[6]. International studies focus on building assessment criteria to measure and enhance the quality of living space while increasing the adaptive capacity of cities to CC.

Criteria for green urban planning often include the ratio of public green space per capita, the density and distribution of green areas, the connectivity of green corridors, as well as the diversity and quality of urban ecosystems[7,8]. In addition, research emphasizes the role of urban water bodies such as lakes, rivers, and canals in regulating the microclimate, mitigating floods, and conserving biodiversity[9]. Indicators such as the City Biodiversity Index (CBI), developed by the Convention on Biological Diversity (CBD), are widely used to assess biodiversity in cities, including criteria related to the area and quality of natural habitats, the presence of native species, as well as conservation and ecological restoration activities[10]. Besides, criteria for applying technology in urban planning are receiving increasing attention, particularly the use of

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Geographic Information Systems (GIS), Big Data, Artificial Intelligence (AI), and the Internet of Things (IoT) to manage green spaces, monitor biodiversity, and issue disaster warnings [11–13]. Integrating these technologies helps improve management efficiency, forecasting, and decision-making in sustainable urban planning and development. In Vietnam, research on urban planning and green cover has also made significant progress, focusing on identifying criteria suitable for the specific conditions of tropical cities with high population density and rapid economic development pressure [14]. Commonly used criteria include the ratio of public green space per capita, the proportion of green land in total built-up urban area, the connectivity of green spaces, and the role of natural ecosystems such as mangrove forests and wetlands in environmental protection and CC adaptation [15–17]. Moreover, domestic studies also emphasize developing indicator systems for evaluating smart cities, incorporating green planning and biodiversity criteria to promote sustainable urban development and climate adaptation [18,19]. However, the application of these criteria still faces many challenges due to limitations in data, technology, and cross-sectoral coordination in urban management.

Ho Chi Minh City (HCMC) is one of the urban areas most severely affected by CC in Vietnam. According to the 2023 report by the Department of Natural Resources and Environment, many low-lying areas such as Districts 7, 8, Binh Thanh, Thu Duc, Nha Be, and the former Binh Tan are at risk of permanent inundation. In addition, the frequency and intensity of extreme heavy rainfall events are increasing, overloading the aging drainage system and leading to recurrent flooding in many wards. The city's average annual temperature is projected to rise by 1.5–2°C by 2050 compared to the 1980–2010 period, resulting in more frequent occurrences of extreme heatwaves, which affect public health and labor productivity [20]. According to the project "Building HCMC into a Smart City by 2025" and the HCMC Master Plan for the 2021–2030 period with a vision to 2050, urban planning plays a crucial role, particularly in fulfilling the commitment to achieve net-zero emissions by 2050 made at the COP26 Conference.

Aiming toward the goal of net zero emissions, the India's Framework 3.0 model (CSCAF 3.0) [5] was developed with 5 sectors and 28 criteria, including the sector of urban planning, green cover, and biodiversity. CSCAF 3.0 was developed by the Ministry of Housing and Urban Affairs of India [5] with the dual objective of promoting digital transformation in urban management while enhancing CC adaptation capacity. India and Vietnam share many similarities in urban development conditions, such as high population density, rapid urbanization, and being under significant pressure from flooding and CC, while urban infrastructure and data remain inconsistent [21]. Therefore, the CSCAF 3.0 framework, originally designed for developing cities in Asia, shows both feasibility and high adaptability when applied to HCMC. Based on the above analysis, this study focuses on assessing the current state of urban planning, green cover, and biodiversity in HCMC under the climate-smart city model of India's Framework 3.0 [5], with the aim of evaluating the level of compliance and identifying gaps and opportunities for improvement in the context of implementing emission reduction and carbon neutrality goals.

RESEARCH METHODS AND DATA SOURCES

Data sources

Urban planning and land use data: Data were collected from the report on the revised HCMC Master Plan to 2040 with a vision to 2060, published by the HCMC Department of Planning and Architecture (2023).

Data on green spaces, water bodies, and open spaces: Compiled from planning reports and current condition surveys.

Population data: Annual average population figures were obtained from the HCMC Statistical Yearbook.

Biodiversity and natural area data: Information on the area of natural zones, the Can Gio Mangrove Biosphere Reserve, and ecological restoration sub-zones was compiled from sectoral reports and HCMC's environmental management documents.

Data on technology application and climate action plans: Information related to the application of GIS, disaster warning systems, and climate action plans was collected from policy documents, government proposals issued by the HCMC People's Committee, research reports, and relevant technical documents.

The map titled "Master Plan of Ho Chi Minh City for the period 2021–2030" at a scale of 1:50.000, along with related spatial data and figures, was collected from the Department of Agriculture and Rural Development and the Department of Natural Resources and Environment of HCMC.

Methodology

Expert consultation method (AHP – Analytic Hierarchy Process)

The expert consultation method was applied to support the selection of indicators. The survey was conducted using a questionnaire distributed to experts in the fields of urban planning, land management, environment, and CC, in order to gather opinions on the selection of indicators. This expert consultation approach helped align the assessment framework to the specific context of HCMC.

The expert consultation was carried out through questionnaires in the form of a two-round workshop as follows:

Round 1: Consultation with 23 experts with more than 5 years of experience in the fields of urban planning, environment, land management, meteorology, hydrology, and CC to establish a set of criteria suitable for the context of HCMC.

Round 2: Consultation with 16 experts with more than 10 years of experience in the fields of urban planning, environment, land management, meteorology, hydrology, and CC to determine the classification levels of the maturity scale for the set of criteria. These workshops were organized under the framework of the seminar: "Consultation on the development of a climate-smart city assessment indicator set for Ho Chi Minh City," which is part of the project: "Research on the development of a climate-smart city assessment indicator set for HCMC," code 28/2024/HD-QKHCN.

Climate-Smart Urban Assessment Framework

To suit the conditions of HCMC, the study adapted the Climate Smart Cities Assessment Framework 3.0 by referencing international standards such as ISO 37122: 2019, the City Biodiversity Index (CBI), and relevant scientific literature [5,22,23]. The adapted assessment framework includes five domains, within which this study focuses on analyzing the domain "Urban Planning, Green Cover, and Biodiversity" through seven specific indicators:

Indicator 1: Rejuvenation & conservation of water bodies & open areas

Indicator 1 evaluates the effectiveness of planning, conservation, and development of water surface areas integrated with open spaces in urban areas. The research team applies the composite index $R_{so-total}$according to formulasEquations (01), (02) and (03), inherited and adjusted from the Climate-Smart City Assessment Framework, TCVN ISO 37120:2018 on sustainable development for communities, and the recommendations of UN-Habitat on land allocation for open spaces [5,24,25]. The evaluation is presented in Table 1:

$$R_{S-water} = \frac{S_{water-present}}{S_{water-plan}} \times 100 \quad (01)$$

$$R_{S-op} = \frac{S_{op-present}}{S_{op-plan}} \times 100 \quad (02)$$

$$R_{so-total} = \left(R_{S-water} + R_{S-op}\right)/2 \quad (03)$$

Where:

$R_{S-water}$: Proportion of water surface (%)

$S_{water-present}$: Current area of water surface (ha)

$S_{water-plan}$: Planned area of water surface (ha)

R_{S-op}: Proportion of open space (%)

$S_{op-present}$: Current area of open space (ha)

$S_{op-plan}$: Planned area of open space (ha)

$R_{so-total}$: Composite index (%)

Indicator 2: Green cover per capita in the city (m^2/person)

Indicator 2 evaluates the average green space per capita in the urban area of HCMC. The research team applied a composite indicator using formula Equation (04), adapted from the Climate-Smart City Assessment Framework, QCVN 01:2021/BXD (4–7 m^2/person), and the WHO recommendation (9 m^2/person). The scoring scale for evaluating green coverage in the city is presented in Table 1.

$$R_{cover} = \frac{S_{pp}}{p} \quad (04)$$

Where:

R_{cover}: Green coverage ratio (m^2/person)

S_{pp}: Public green space area (m^2)

P: Total population (person)

Indicator 3: Proportion of urban green land to total urban construction land area

This indicator reflects the proportion of land area allocated for green spaces within the total urban construction land area in HCMC. The calculation and evaluation are based on formula Equation (05), with reference to the Climate-Smart City Assessment Framework, QCVN 01:2021/BXD on Construction Planning, and the recommendations of WHO and URDPFI 2014 (India) regarding the minimum green land ratio [26,27]. Table 1 presents the evaluation levels of green land ratio and corresponding scores.

$$R_{land-p} = \left(\frac{S_{land-p}}{S_{total-land}}\right) \times 100 \quad (05)$$

Where:

R_{land-p}: Proportion of green land (%)

S_{land-p}: Area of urban green land (ha)
$S_{total-land}$: Total urban construction land area (ha), based on this formula

Indicator 4: Urban biodiversity

The research team applies the Urban Biodiversity Index (UBI - PNRA), which reflects the proportion of natural and ecologically restored areas over the total area of the city. This index is calculated according to formula Equation (06), and classification thresholds are based on the report by the City Biodiversity Index (CBI)[28]. The scoring scale for this index is presented in Table 1.

$$UBI\ (PNRA) = \frac{A_{natural} + A_{restored}}{A_{city}} \times 100\,(\%) \quad (06)$$

Where:
: Urban biodiversity index (Proportion of natural and ecologically restored areas within the city) (%)
: Total area of natural regions (ha)
: Total area of ecologically restored zones (ha)
: Total area of HCMC (ha)

Indicator 5: Application of GIS and digital data in urban planning

Indicator 5 evaluates the level of GIS technology and digital data application in urban planning, management, and development in HCMC. The research team assessed this indicator based on three aspects: (1) the level of GIS integration in general and detailed planning projects; (2) the application of GIS in green space management; and (3) the ability to update data and support real-time decision-making. The indicator was developed using a five-level qualitative scoring scale, adapted from and adjusted based on standards ISO 37122:2019[22], ISO 37120:2018[29], Decision No. 950/QD-TTg[30], Decision No. 1004/QD-BXD[31], Official Dispatch No. 1247/BXD-PTDT[32], as well as the UN-Habitat Smart City Roadmap[33,34] and the CSCAF 3.0 indicator (5), with details presented in Table 1.

Indicator 6: Smart disaster warning and management system

This indicator evaluates the capacity to apply smart technologies (AI, IoT, Big Data) in early warning, management, and damage mitigation from natural disasters (flooding, tidal surges, urban heat islands) in HCMC. The criteria are developed based on international frameworks and standards such as the Sendai Framework for Disaster Risk Reduction 2015–2030, ISO 37123:2019 – Sustainable cities and communities – Indicators for resilient cities, ISO 22320:2018 – Emergency management guidelines, and the Law on Natural Disaster Prevention and Control of Vietnam[35–37] (Table 1).

Indicator 7: City's climate action plan

This indicator assesses the formulation, implementation, and effectiveness of HCMC's CC adaptation action plan. The evaluation table for the city's climate action level (Table 1) developed based on four main foundations: the C40 Cities Framework, the Paris Agreement, Decision 896/QD-TTg, and ISO 14080:2018[38,39].

Geographic Information System (GIS)

The study used QGIS software to process data and analyze changes in water surface and open space areas in HCMC across different periods. Input data included current land use and land use planning maps collected from relevant authorities, standardized to a common coordinate system and quality-checked. The processing procedure included: (1) **Data preparation** – importing vector map layers, standardizing coordinate systems, and verifying consistency; (2) **Overlay analysis** – integrating current and planned maps to identify land use changes; (3) **Classification** – separating water surfaces and open spaces based on attribute data; (4) **Area calculation and change comparison** – calculating areas and comparing changes, with results used for computing related indicators.

Table 1: Integrated evaluation framework on urban planning, green cover, and biodiversity

Indicator	Level 1 (0 points)	Level 2 (25 points)	Level 3 (50 points)	Level 4 (75 points)	Level 5 (100 points)	Reference
Indicator 1: Rejuvenation & conservation of water bodies & open areas	< 15%	15% – 25%	25% – 35%	35% – 45%	> 45%	National Standard TCVN 37120:2018 on Sustainable Development for Communities – Indicators for Urban Services and Quality of Life [29].
Indicator 2: Green cover per capita in the city (m^2/person)	< 4 m^2/ person	4-6 m^2/ person	6-7 m^2/ person	7 – 9 m^2/ person	> 9 m^2/ person	Vietnam National Technical Regulation on Construction Planning (QCVN 01:2021/BXD) [26]
Indicator 3: Proportion of urban green land to total urban construction land area	< 5%	5% – < 9%	9% – < 12%	12% – < 18%	≥ 18%	Vietnam National Technical Regulation QCVN 01:2021/BXD on Construction Planning [26]
Indicator 4: Urban biodiversity	< 1%	1% – 6%	7% – 13%	14% – 20%	> 20%	CBI (City Biodiversity Index) [28]
Indicator 5: Application of GIS and digital data in urban planning	Not yet applying GIS (manual planning, fragmented, no digitalization)	Basic GIS (static maps, digitalized < 50%, no in-depth analysis)	Integrated planning information (digitalized data 50–75%, regularly updated, publicly managed)	Advanced spatial analysis (digitalized data 75–90%, monthly updates)	Real-time GIS (Digital Twin) (digitalized data >90%, real-time simulation/decision making)	ISO 37122:2019 (Indicators for Smart Cities) [22]. Decision 950/QD-TTg, Decision No.1004/QD-BXD) [30,31]. Official Dispatch No.1247/BXD-PTDT) [32]. ISO 37120:2018 (City Services/Quality of Life) [29]. CSCAF 3.0 (India) [5]

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Table 1 continued

Indicator	Level 1 (0 points)	Level 2 (25 points)	Level 3 (50 points)	Level 4 (75 points)	Level 5 (100 points)	Reference
Indicator 6: Smart disaster warning and management system	Manual/traditional warning systems. Forecasting and response rely on experience, paper maps, scattered information; no automatic monitoring stations; early warning is almost nonexistent.	A few automatic monitoring stations in place but at low density (<1 station/100 km^2), disconnected data, mainly manual warnings; only SMS/traditional speakers used.	GIS integrated; monitoring data managed on digital maps, station density 1–2 stations/100 km^2; no AI/IoT yet; automated warning rate 30–50%.	AI and IoT applied (sensors, automated analysis), station density >2 stations/100 km^2; automated warning rate 50–80%; data updated continuously but not citywide.	Intelligent multi-hazard warning system, dense sensor network (>5 stations/100 km^2), citywide integration of GIS–IoT–AI–Big Data, real-time warnings, automation >80%, personalized information to residents.	Sendai Framework [36], ISO 37123:2019 [35], Law PCTT VN [40], UNDRR [41] , ISO 22320:2018 [37], ISO 37120 [29], ISO 37122:2019 [22], WMO MH-EWS [42], ASEAN Smart Cities Network [43]

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Table 1 continued

Indicator	Level 1 (0 points)	Level 2 (25 points)	Level 3 (50 points)	Level 4 (75 points)	Level 5 (100 points)	Reference
Indicator 7: City's climate action plan	No climate action plan developed or only general orientation without specific goals, solutions, or roadmap.	Preliminary plan developed or climate aspects integrated into the master plan, but lacks quantitative goals and implementation roadmap; remains at general solutions or vision level.	limate action plan issued by the People's Committee, with clear goals (e.g., 10–20% emissions reduction by 2030), integrated into urban development planning; assigned responsibilities; some measures implemented.	Plan sets mid-term emissions reduction goals (Net Zero 2045–2050), defines priority sectors (energy, transport, construction, etc.), has an implementation roadmap, control/monitoring mechanisms (MRV), regularly updated.	Comprehensive integrated climate action plan, Net Zero or carbon neutral target before 2050, large-scale mitigation projects implemented, transparent MRV monitoring system, annual public reporting, connected to international networks (C40, Race to Zero), engaging community and businesses.	C40 [38], Paris Agreement [44], QD 896/QD-TTg) [39], ISO 14080 [38]

RESULTS AND DISCUSSION

Current status of urban planning and biodiversity in HCMC

According to data in the HCMC planning report for the period 2021 – 2030, with vision to 2050, the urban construction land area in HCMC increased from 49,787 ha in 2007 to 63,725 ha in 2019, with a target of 96,316 ha by 2025, corresponding to about 30% of the planning roadmap (Figure 1). This increase mainly focuses on residential land and industrial infrastructure projects, reflecting pressure from population growth.

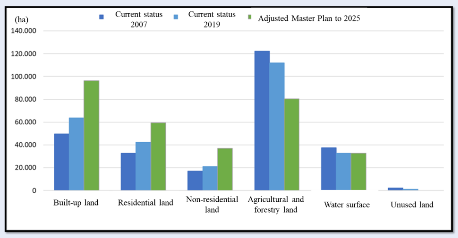

Figure 1: Comparison of current and planned land use in HCMC [45]

Urban expansion has led to a significant reduction in ecological buffer zones. Agricultural and forestry land decreased from 122,321 ha (2007) to 111,961 ha (2019), and is expected to drop to about 80,500 ha by 2025 if planning adjustments are fully implemented. At the same time, the area of water surfaces, which are important for hydrological regulation, has hardly increased. This shrinkage not only reduces landscape space but also weakens the city's resilience against flooding, saltwater intrusion, and extreme climate events.

HCMC still possesses considerable peripheral ecological resources, including more than 34,000 ha of Can Gio mangrove forest and most agricultural and forestry land in the five suburban districts. However, the conversion of agricultural land to residential and industrial land disrupts ecological corridors, threatening climate regulation functions and biodiversity.

The urban functional structure of HCMC shows an imbalance between grey infrastructure and green infrastructure. Traffic land area has doubled to meet increasing transportation demands, while public green land only increased from 969 ha to 1,658 ha from 2007 to 2019. Although the target is to reach 6,877 ha, this number remains much lower than international standards for per capita green area (Figure 2). This deficit not only affects quality of life but also limits microclimate regulation and mitigation of urban heat island effects.Urban expansion has led to a significant reduction in ecological buffer zones. Agricultural and forestry land decreased from 122,321 ha (2007) to 111,961 ha (2019), and is expected to drop to about 80,500 ha by 2025 if planning adjustments are fully implemented. At the same time, the area of water surfaces, which are important for hydrological regulation, has hardly increased. This shrinkage not only reduces landscape space but also weakens the city's resilience against flooding, saltwater intrusion, and extreme climate events.

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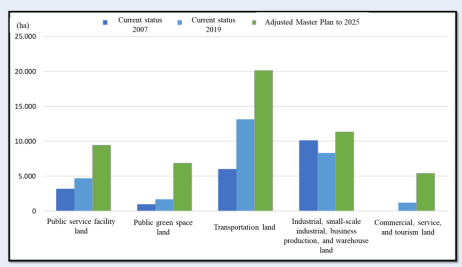

Figure 2: Changes in land area by type in HCMC [45]

During the period 2016–2023, HCMC recorded more than 30 high-tide events exceeding alarm level III, numerous extreme rainstorms, and a series of landslide incidents. The current dyke and drainage system, originally designed based on old climate scenarios, is no longer suitable for present conditions. Reassessment and upgrading of infrastructure based on new disaster data is necessary to enhance resilience against extreme climate phenomena. The combination of population pressure, land use change, and climate risk underscores the urgency of quantitative monitoring tools.

Thus, HCMC is facing major challenges in balancing rapid urbanization and environmental protection. The increase in construction land area, reduction of ecological buffer zones, imbalance of infrastructure, and climate risks require sustainable planning solutions. Quantitative monitoring tools will play a crucial role in ensuring that HCMC develops into a global, modern, and sustainable city, while maintaining quality of life and resilience against CC.

Analysis of urban planning level, green cover, and biodiversity according to the smart climate city model

Analysis of urban planning level, green cover, and biodiversity in HCMC

Applying the scoring scale from Table 1 to the current data of HCMC, the evaluation results are shown in Table 2. The overall results show significant differences among the evaluation indicators. For the first indicator, "*Rejuvenation & conservation of water bodies & open areas*" HCMC achieved level 5 with a score of 100. This indicates that the city has effectively maintained its system of rivers, canals, and water protection corridors, reflecting the efficiency of policies for natural aquatic ecosystem conservation and the planning of green corridors along rivers. This is a prominent strength of HCMC compared to many regional urban areas, where water surfaces are often reduced due to urbanization. For the second indicator, "*Green cover per capita in the city*" the city reached only level 1 with a value of 0.55 m^2/person. This result is far below the WHO recommendation (9 m^2/person), reflecting a severe shortage of public green spaces for residents, mainly due to high population density, rapid urbanization, and limited land availability in the inner-city area. This is the weakest indicator in HCMC's assessment system. The third indicator, "*Proportion of urban green land to total urban construction land area*" reached level 3 with a score of 50. The proportion of urban green land to total construction land area, at 9.6%, shows that the city still maintains some green space within urban development zones, but this is lower than the recommended standard of ISO 37122:2019 (12–18% of construction land). Expanding and connecting new green areas and parks in the inner districts is necessary to raise this indicator to a higher level in the future. For the fourth indicator, "*Urban biodiversity*" the evaluation could not be completed due to lack of comprehensive data. However, HCMC possesses an important ecological area, the Can Gio Mangrove Biosphere Reserve, which has great potential to contribute to urban biodiversity if integrated into an overall ecological planning framework. Therefore, building an urban biodiversity database should be prioritized in the next phase. The indicators "*Application of GIS and digital data in urban planning*" and "*Smart disaster warning and management system*" were both ranked at level 3 with scores of 50. Finally, the indicator "*City's climate action plan*" achieved level 2 with a score of 25. To reach a higher level, HCMC needs to complete its Climate Action Plan (CAP) with clear measurable targets, linked to emission reduction and adaptation goals according to the Paris Agreement. This result is visualized through the diagram in Figure 3.

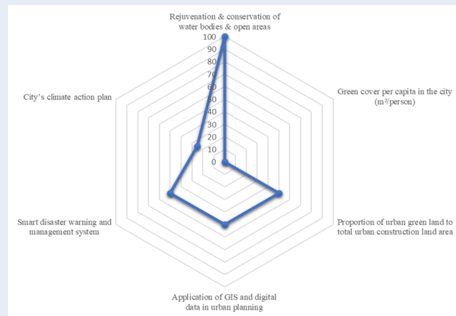

Figure 3: Assessment scores of HCMC in urban planning, green coverage, and biodiversity (Source: Authors' team)

Figure 3 shows the score structure through a radar chart: the outline peaks at the "water planning" axis but sharply narrows at the "climate plan" axis, forming an irregular pentagon. This disparity reflects investment priorities: HCMC has performed well in physical space planning but has not kept pace with requirements for climate governance and digital transformation of risk forecasting infrastructure. At the same time, the concavity remaining at the green land axis also indicates the need to increase small parks and green corridors in the inner city to improve microclimate and reduce urban heat island effects. This geometric analysis suggests a strategic approach: to balance the pentagon, the city needs to concretize emission reduction roadmaps, expand sensor and AI systems for disaster warning, and convert land funds into green space. When these measures are implemented, the radar chart will gradually become more rounded, reflecting harmonious development between spatial planning and climate adaptation capacity.

Table 2: Urban planning level, green cover, and biodiversity according to the smart climate city model

Indicator	Current status	Level	Score
1. Rejuvenation & conservation of water bodies & open areas	97.2%	5	100
2. Green cover per capita in the city (m^2/person)	0.55 m^2 per capita	1	0
3. Proportion of urban green land to total urban construction land area	9.60%	3	50
4. Urban biodiversity	Insufficient data for assessment		
5. Application of GIS and Digital Data in Urban Planning	Integration of Urban Planning Information (50–75% digitized data, regularly updated, publicly managed)	3	50
6. Smart Disaster Warning and Management System	Automation 30–50%	3	50
7. City's climate action plan	Preliminary plan	2	25

(Source: Authors' team)

Comparison of urban planning indicators, green cover, and biodiversity of HCMC with other countries worldwide

Rejuvenation & conservation of water bodies & open areas: According to UN-Habitat, to ensure urban health and effective operation, approximately 45–50% of urban land area should be allocated for roads and open public spaces. Among these, 30–35% of the land area needs to be designated for streets and sidewalks, while 15–20% should be allocated for open public spaces such as parks, squares, and riverside areas. The internal index RS-op of HCMC currently lacks a direct international threshold for comparison; however, for effective benchmarking, HCMC needs to convert its land allocation capacity from planning into actual land shares according to UN-Habitat's recommendations [24,25]. Compared to other Southeast Asian cities, Singapore is a special case: although its natural water surface ratio is not large, the country plans very deep catchment areas, with about two-thirds of the land area currently designated as catchment zones and a direction to expand to 90% of the land area. Rainwater is collected through more than 8,000 km of canals, drains, and rivers into 17 reservoirs for flood management and urban water security. This shows that Singapore does not rely on a high "water surface ratio" but on a hydrological network – reservoirs integrated into land use planning to achieve water management and flood control goals [46]. In Jakarta, Kuala Lumpur (KL), and Metro Manila, satellite image analyses indicate that water surface areas significantly decreased during the period 1988–2014, approximately 42% in Jakarta, 31% in KL, and 59% in Metro Manila, reflecting pressures from encroachment, land reclamation, and rapid urbanization on traditional hydrological spaces (canals, rivers, ponds) [47].

Green cover ratio in the city: HCMC currently achieves only 0.55 m^2/person, far below the WHO minimum recommended threshold of 9 m^2/person for healthy cities, revealing a large gap in residents' access to green spaces [48]. In regional comparison, Bangkok currently has about 7.3–7.6 m^2/person according to official statistics [49], Jakarta is recorded at approximately 7.1 m^2/person of green open space (GOS) according to Pacific Geographies, though there is uneven availability across districts [50]. This gap indicates that HCMC needs significant improvement to reach the regional average.

Proportion of urban green land to total urban construction land area: The URDPFI 2014 guideline recommends urban green land to account for 12–18% of total construction land area [27]. HCMC currently has a lower ratio than this threshold. Integrating green infrastructure and water bodies from the planning stage and project implementation will help the city increase this ratio, aiming toward sustainable urban development. Within the region, Singapore leads with a rate of 47–66.2% urban green space, including large parks and roadside greenery [51]. Kuala Lumpur reaches 30–45%, with significant contributions from urban forests and conservation areas [52], while Jakarta is at 5–6.3% [53].

Urban biodiversity: Due to limitations in data, quantitative assessment for HCMC remains incomplete, although the Can Gio Mangrove Biosphere Reserve offers significant ecological potential. Meanwhile, countries in the same region such as Bangkok, Jakarta, and Kuala Lumpur have begun implementing the restoration of urban ecological corridors and the rehabilitation of wetland ecosystems under the framework of the Singapore City Biodiversity Index (CBI).

Application of GIS and digital data in urban planning: The current status of HCMC has only reached level 3, whereas Singapore has opened planning data at the system level since 2019: publicly releasing layers of planning boundary data, land-use layers, regularly updated, while also providing an online planning map platform for use by experts, businesses, and the public [54,55]. This indicates that Singapore has achieved city-wide operation of GIS and open data with the capacity to integrate into planning decision-making processes. In Kuala Lumpur, the Urban Planning Department operates the City Planning System (CPS) – an online geospatial system that allows citizens, investors, and stakeholders to access information on development control by land parcel in accordance with the Kuala Lumpur Local Plan 2040 [56]. The Philippines has Geoportal Philippines (NAMRIA) and Open Data Philippines, which provide a national geospatial data repository to support planning and multi-sectoral decision-making (multi-scale base maps, WMS/WFS services), along with open geospatial data initiatives at the metropolitan level aimed at promoting evidence-based and equitable planning approaches [57,58]. Thus, compared to the above-mentioned Southeast Asian cities, HCMC has a GIS foundation operating at a medium level (digitization – regular updates), but still has a considerable gap.

Smart disaster warning and management system: HCMC currently reaches an intermediate level (Level 3/5) in smart disaster warning and management systems, with GIS integration and automation at about 30–50%, partially meeting national regulations such as the Disaster Prevention Law, Decision 2149, Circular 22, and international standards like the Sendai Framework (prioritizing early warning), ISO 22320 (command organization), and C40 recommendations on IoT/AI application in monitoring and forecasting [36–38]. However, the city still lacks real-time data, a sufficiently dense monitoring station network, unified command procedures, and fast, widespread warning channels to the public. To improve, HCMC needs to enhance rainfall, water level, and air quality monitoring stations per Circular 22, ensuring data transmission within 5 minutes and issuing warnings within 10 minutes; standardize command procedures according to ISO 22320 with regular drills; develop impact-based forecasting models for flooding, tidal surges, storms, and heatwaves, simultaneously integrating IoT/AI to reduce false alarms and prioritize emergency response. These steps will help HCMC upgrade its disaster management index in the 2025–2030 period, better meeting both international standards and domestic regulations.

City's climate action plan: HCMC is currently at Level 2 in climate action, having developed a preliminary plan and integrated climate factors into the general planning, but without defining quantitative targets for 2030, lacking detailed sectoral roadmaps (energy, transportation, waste, buildings, land use), and has not yet implemented a standardized measurement, reporting, and verification (MRV) mechanism. Meanwhile, international standards require: (i) targets aligned with the Paris Agreement (43% emission reduction by 2030, aiming for Net Zero by 2050, prioritizing the 1.5°C trajectory) with specific sectoral allocations per the C40 CAPF framework; (ii) transparent MRV systems per ISO 14080, including annual emission inventories following GPC (Scopes 1–2–3) and data disclosure through CDP/ICLEI for inter-city comparison; (iii) investment plans with clear climate budgets, defined implementation roles, and annual monitoring [38,44].

Roadmap for Urban Planning, Green Coverage, And Biodiversity Sector

The key indicators and tasks in the sector of Urban Planning, Green Cover, and Biodiversity for the period 2020–2030, with a vision toward 2050, are defined to guide the development of HCMC into a smart, climate-adaptive, and ecologically sustainable city (Table 3). Specifically, in terms of planning, protecting, and developing water surfaces and open spaces, the city is oriented toward the period 2040–2060 to carry out urban ecological restoration, enhance flood resilience, conserve and utilize the cultural and tourism values of the canal-river system, aiming to shape the image of an internationally recognized "waterfront – marine city".

In terms of urban green cover per capita, the target is to reach at least 0.65 m^2/person by 2025 and at least 1.0 m^2/person by 2030, in association with the coordinated development of parks, public greenery, and green corridors. The proportion of urban green land over the total urban construction land is targeted to reach 8,300–9,200 ha out of 100,000–105,000 ha of construction land by 2030, and 10,500–11,500 ha out of 125,000–130,000 ha by 2040, contributing to the improvement of environmental quality and living spaces. In the application of GIS and digital data in urban planning, according to ISO 37120/37122 standards, by 2030 the city needs to achieve a digitalization rate of 75–90% for planning data with monthly periodic updates (corresponding to level 4), and after 2030 should aim for level 5, which is the operation of a real-time GIS system (Digital Twin) with over 90% data digitalized and capable of simulation and real-time decision support.

For the smart disaster warning and management system, the objective is to build a synchronized, interconnected, real-time disaster prevention and control database; complete database coverage across 100% of directing agencies at all levels; install monitoring systems at all critical and vulnerable areas; and equip 100% of offshore and nearshore fishing vessels with tracking and communication systems, to enhance forecasting and response capabilities. Finally, in the City's climate action plan for the period 2026–2030, HCMC needs to strengthen CC adaptation capacity for sectors, communities, and ecosystems; improve the resilience of urban infrastructure and natural ecosystems; while reducing greenhouse gas emissions and developing a low-carbon economy in line with the green – sustainable urban development orientation.

Table 3: Roadmap for Urban Planning, Green Coverage, And Biodiversity Sector

Indicator	Current status of Ho Chi Minh City	Level	2024	Targets
Indicator 1: Rejuvenation & conservation of water bodies & open areas	Decision No. 1125/QĐ-TTg dated 11/06/2025 The master plan orients the creation of development corridors along the Saigon River; preservation of the city's water-based urban identity; development of riverside open spaces and ecological landscapes.	97.2%	5	Explanatory Report for the Adjustment of HCMC Master Plan to 2040, Vision 2060: shift toward "ensuring quality" with urban ecological restoration, flood mitigation, enhancement of cultural–tourism values, and building an internationally recognized waterfront–coastal city image.
Indicator 2: Green cover per capita in the city (m^2/person)	The total public park area within the inner city is about 508.56 ha, equivalent to 0.55 m^2 of public green space per person.	0.55 m^2/person	1	Decision No. 2198/QĐ-UBND dated 17/06/2021 and Decision No. 1125/QĐ-TTg dated 11/06/2025 2025: $\geq$ 0,65 2030: $\geq$ 1,00
Indicator 3: Proportion of urban green land to total urban construction land area	QCVN 01:2021/BXD (Urban Planning National Technical Regulation). - Level 1: <5% / - Level 2: 5-9%/ - Level 3: 5-9%/ - Level 4: 5-9%/ - Level 5: $\geq$ 18%	9.6%	3	Decision No. 1125/QĐ-TTg dated 11/06/2025: Land use planning to By 2030: urban green land 8,300–9,200 ha / 100,000–105,000 ha of urban construction land. By 2040: urban green land 10,500–11,500 ha / 125,000–130,000 ha of urban construction land.
Indicator 4: Urban biodiversity	No specific roadmap has been established.			

Continued on next page

Table 3 continued

Indicator	Current status of Ho Chi Minh City	Level	2024	Targets
Indicator 5: Application of GIS and digital data in urban planning	The GIS system has been used to integrate information for the city master plan, supporting management and public disclosure. Digitization rate: 50–75%, data updated annually.		3	Decision No. 950/QĐ-TTg (01/08/2018) and Decision No. 749/QĐ-TTg (03/06/2020)
				Official Letter No. 1247/BXD-PTĐT - Build an interoperable GIS-based data infrastructure; apply advanced technologies; enable open sharing across software platforms - Develop digital platforms and public information services on a GIS foundation.
Indicator 6: Smart disaster warning and management system	A smart disaster warning and management system has been implemented, integrating GIS and achieving approximately 30–50% automation. However, the system currently lacks the capacity for automated data analysis, trend forecasting, and decision-support functions.		3	Establish a synchronous, interoperable, real-time disaster-risk (PCTT) database.
	Lacks real-time data and a sufficiently dense monitoring station network			Complete database coverage in 100% of command agencies at all levels; install monitoring systems in 100% of critical/high-risk areas; equip 100% of offshore and coastal fishing vessels with tracking and communication systems.
Indicator 7: City's climate action plan	A preliminary climate plan has been prepared and integrated into the general master plan; however, it still lacks quantitative targets, sectoral timelines, and a standardized MRV (measurement - reporting verification) mechanism.		2	Decision No. 3273/QĐ-UBND dated 08/09/2021 for 2026-2030:

Continued on next page

Table 3 continued

Indicator	Current status of Ho Chi Minh City	Level	2024	Targets
				Enhance climate change adaptation capacity for sectors, communities, and ecosystems; strengthen the resilience of infrastructure and ecosystems, and promote biodiversity conservation Foster effective adaptation that generates economic, social, and environmental co-benefits. Reduce greenhouse gas emissions and promote the development of a low-carbon economy.

(Source: Authors' team)

CONCLUSION AND RECOMMENDATIONS

The study conducted an assessment of the current status of urban planning, green cover, and biodiversity in HCMC based on the Climate Smart Cities Assessment Framework 3.0 with 5 indicators. The results of applying the Climate Smart Cities Assessment Framework 3.0 show that the city leads in water surface planning and maintaining seimi-urban ecological reserves; however, it remains slow in the greenification process of urban space and the digitalization of climate risk management. The maximum score recorded in the indicator "Rejuvenation & conservation of water bodies & open areas" indicates that river corridors and canals have been protected and relatively well integrated into the subdivision planning. Thanks to the Can Gio Biosphere Reserve and the suburban agricultural and forestry areas, the biodiversity criterion achieved a fairly good level, ensuring that the natural area ratio is approximately 16% of the total city area.

Despite a favorable planning foundation, HCMC still faces three major issues. First, proportion of green cover accounts for only about 9.6% of built-up land, leading to a public green space area per capita of only 1.4 m^2/person, much lower than the minimum threshold recommended by national standards and WHO. Second, the disaster warning system is transitioning from a pilot phase to operation, but the sensor coverage, forecasting models, and early warning dissemination mechanisms remain sparse. Finally, the new city climate action plan only reaches a framework orientation, lacking quantitative emission reduction targets as well as standardized measurement, reporting, and verification systems, causing this indicator to score low. To improve the quality of a smart and sustainable city, HCMC needs to prioritize increasing green spaces through regulations reserving land for trees and parks and encouraging models such as rooftop gardens and green walls. At the same time, a large-scale tree planting program with community participation should be launched. Regarding technology, the city needs to accelerate the application of GIS and AI, build a multi-hazard early warning system, and develop Digital Twin models to support effective decision-making. Finally, a specific climate action plan with Net Zero targets should be issued soon, establishing a transparent monitoring system and developing green corridors to conserve biodiversity, contributing to building a livable and climate-resilient HCMC.

However, this study has not conducted an assessment of the biodiversity index due to the lack of complete and updated data, although some departments and agencies have had statistics, these data sources are outdated (from 1994) and no longer accurately reflect the current state of the ecosystem. The inclusion and assessment of the biodiversity index is highly necessary in future studies, as this is an important indicator that helps determine the natural CO_2 absorption capacity of the city, influences the carbon balance, and supports the evaluation of emission neutrality levels.

LIST OF ABBREVIATIONS USED

AHP: Analytic Hierarchy Process
AI: Artificial Intelligence
ASEAN: Association of Southeast Asian Nations
BXD: Ministry of Construction
C40: C40 Cities Climate Leadership Group
CAP: Climate Action Plan
CAPF: Climate Action Planning Framework
CBD: Convention on Biological Diversity
CBI: City Biodiversity Index
CC: Climate Change
CDP: Carbon Disclosure Project
COP26: 26th United Nations Climate Change Conference of the Parties
CPS: City Planning System
CSCAF: Climate Smart Cities Assessment Framework
GIS: Geographic Information System
GOS: Green Open Space
GPC: Global Protocol for Community-Scale Greenhouse Gas Emission Inventories
HCMC: Ho Chi Minh City
HD-QKHCN: Contract for Science and Technology Task Implementation
ICLEI: Local Governments for Sustainability
IoT: Internet of Things
ISO: International Organization for Standardization
KL: Kuala Lumpur
MH-EWS: Multi-Hazard Early Warning Systems
MRV: Measurement, Reporting and Verification
NAMRIA: National Mapping and Resource Information Authority
NIUA: National Institute of Urban Affairs
OECD: Organisation for Economic Co-operation and Development
ODPH: Open Data Philippines
PCTT: Natural Disaster Prevention and Control
PNRA: Proportion of Natural and Restored Areas
QCVN: National Technical Regulation
QD/QĐ: Decision
QGIS: Quantum Geographic Information System
SMS: Short Message Service
TCVN: National Standard of Vietnam

TTg: Prime Minister
UBI: Urban Biodiversity Index
UBND: People's Committee
UN: United Nations
UNDRR: United Nations Office for Disaster Risk Reduction
UN-Habitat: United Nations Human Settlements Programme
URA: Urban Redevelopment Authority
URDPFI: Urban and Regional Development Plans Formulation and Implementation
VN: Vietnam
WHO: World Health Organization
WMO: World Meteorological Organization
WMS/WFS: Web Map Service / Web Feature Service

CONFLICT OF INTEREST

The authors declare no conflict of interest in the publication of this paper.

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AUTHORS' CONTRIBUTIONS

Research idea development: P.T.M.D., N.K.P., T.T.K. Methodology: P.T.M.D., D.Q.L., N.K.P., T.T.K. Data processing: P.T.M.D., N.K.P., T.T.K. Result analysis: P.T.M.D., D.Q.L., L.T.H., N.K.P., N.T.B., D.T.T.T., T.T.K. Writting manuscript: P.T.M.D., D.Q.L., N.K.P., N.T.B., T.T.K.

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Bài nghiên cứu

Đánh giá hiện trạng quy hoạch đô thị, lớp phủ xanh và đa dạng sinh học theo mô hình thành phố thông minh thích ứng khí hậu

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TÓM TẮT

Thành phố thông minh là xu hướng phát triển đô thị hiện nay, trong đó quy hoạch đô thị, độ phủ xanh và đa dạng sinh học là một trong năm trụ cột quan trọng theo Khung đánh giá Thành phố thông minh thích ứng khí hậu (Climate Smart Cities Assessment Framework 3.0 - CSCAF 3.0) của Ấn Độ. Nghiên cứu này tập trung đánh giá hiện trạng quy hoạch đô thị, độ phủ xanh và đa dạng sinh học của Thành phố Hồ Chí Minh theo mô hình thành phố thông minh thích ứng khí hậu thông qua 7 chỉ số gồm: (1) Mức độ quy hoạch, bảo vệ và phát triển mặt nước và không gian mở; (2) Tỷ lệ phủ xanh trong thành phố (m^2/người); Tỷ lệ đất cây xanh đô thị trên tổng diện tích đất xây dựng đô thị; (4) Đa dạng sinh học đô thị; (5) Ứng dụng GIS và dữ liệu số trong quy hoạch đô thị; (6) Hệ thống cảnh báo và quản lý thiên tai thông minh; và (7) Kế hoạch hành động về khí hậu của thành phố. Kết quả cho thấy Thành phố Hồ Chí Minh đạt mức 5 đối với chỉ số mức độ quy hoạch, bảo vệ và phát triển mặt nước và không gian mở; đạt mức 1 đối với chỉ số tỷ lệ phủ xanh trong thành phố với giá trị 0,55 m^2/người; đạt mức 3 đối với chỉ số Tỷ lệ đất cây xanh đô thị trên tổng diện tích đất xây dựng đô thị và chỉ số Ứng dụng GIS và dữ liệu số trong quy hoạch đô thị. Chỉ số đa dạng sinh học chưa thể đánh giá đầy đủ do thiếu dữ liệu cập nhật. Hệ thống cảnh báo và quản lý thiên tai thông minh đạt mức 3, trong khi kế hoạch hành động về khí hậu của thành phố đạt mức 2. Trên cơ sở đó, nghiên cứu đề xuất các giải pháp nhằm tăng cường phát triển không gian xanh, đẩy mạnh ứng dụng công nghệ số và hoàn thiện các chính sách khí hậu, góp phần hướng tới phát triển đô thị bền vững và thích ứng với biến đổi khí hậu tại Thành phố Hồ Chí Minh.

Từ khoá: Thành phố thông minh, quy hoạch đô thị, độ phủ xanh, đa dạng sinh học, biến đổi khí hậu, Thành phố Hồ Chí Minh

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