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Factors Affecting Green Space Density in the Inner City of Ho Chi Minh City

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Abstract
This study investigates the multi-dimensional determinants of Urban Green Space (UGS) density across the rapidly consolidating inner-city districts of Ho Chi Minh City (HCMC), Vietnam. Over the past three decades, market-driven development has catalyzed unprecedented urban compaction, reducing public green space to historically low levels (<1m2/person). Leveraging a mixed-methods research design, we analyze spatial data from 350 urban blocks across six inner-city districts (District 1, District 3, District 4, District 5, District 10, and Binh Thanh) using a multivariate Ordinary Least Squares (OLS) regression framework. Our spatial-statistical model evaluates the impact of three distinct clusters of predictors: urban morphology (Building Coverage Ratio [BCR], Floor Area Ratio [FAR], and Sky View Factor [SVF]), economic drivers (Land Value [LV] and Population Density [PD]), and an Institutional Enforcement Index (IE). The empirical results reveal that high BCR and FAR exert severe negative pressures on ground-level green space density (GSD), while SVF displays a non-linear U-shaped relationship with localized green coverage. Furthermore, escalating land values (LV) act as a powerful economic disincentive for municipal green space preservation, prompting private developers to maximize buildable area. This study establishes a quantitative link between micro-morphological trade-offs and macro-planning outcomes, proposing a Salutogenic Urban Design Framework and advocating for the institutional integration of Green Micro-infrastructure (GMI) into the Vietnamese National Building Code to reconcile compaction with climate resilience.

Keywords: Green Space Density, Urban Morphology, Land Value Dynamics, Ho Chi Minh City, Green Micro-Infrastructure (GMI)

1. Introduction

Rapid urbanization across developing economies in Southeast Asia has created a fundamental paradox: while metropolitan compaction supports economic efficiency and reduces sprawl, it frequently results in the systematic elimination of natural ecosystems within the urban core. Ho Chi Minh City (HCMC), the economic powerhouse of Vietnam, epitomizes this spatial tension. Historically planned under a French colonial "garden city" paradigm characterized by wide boulevards and structured public parks, the city's contemporary landscape has undergone a radical transformation. Following the Doi Moi economic reforms in 1986, transition to a market-oriented economy triggered an era of hyper-development, leading to uncontrolled densification, vertical growth, and the conversion of public open spaces into high-yield commercial and residential real estate.

Currently, HCMC faces a severe green space deficit. The public green space ratio per capita in the inner-city districts has plummeted to less than 1m2/person, a figure far below the national urban planning standard of 7 - 10m2/person prescribed in Vietnam's construction regulations, and vastly inferior to the World Health Organization (WHO) recommended minimum of 9m2/person of accessible green space per inhabitant. This environmental degradation has exacerbated the Urban Heat Island (UHI) effect, with localized ambient temperatures in dense urban canyons frequently exceeding regional averages by up to 4 to 6. Consequently, the Physiological Equivalent Temperature (PET)—a holistic index of human thermal comfort—routinely rises above 38 during daytime hours, imposing severe thermal stress on the city's population.

While the ecological and psychological benefits of Urban Green Spaces (UGS) are well-documented globally, the specific structural, financial, and regulatory forces that dictate the distribution and density of green space in dense tropical metropolises remain poorly understood. Urban planners in HCMC are caught in a perpetual "trade-off" between maximizing land-use efficiency and safeguarding public health. Traditional greening policies, which rely on the acquisition of large municipal parcels for centralized parks, are no longer viable in the inner city due to astronomical land acquisition costs and highly fragmented property ownership.

This research addresses these critical gaps by examining the micro-scale determinants of green space density (GSD) in the inner city of HCMC. Specifically, we investigate how building morphology, land economics, and planning regulations interact to shape the physical presence of vegetation. By doing so, we aim to answer three key research questions:

1. To what extent do urban morphological parameters (such as BCR, FAR, and SVF) explain the variations in green space density within different inner-city typologies?
2. How do soaring urban land values and population pressures act as economic drivers or barriers to both public and private green space provision?
3. How can HCMC transition from a rigid, land-intensive greening model to an integrated, multi-level green space framework that leverages Green Micro-infrastructure (GMI) to improve localized thermal comfort (PET) and public health?

To answer these questions, this paper is organized as follows: Section 2 reviews the theoretical foundations and existing literature on green space determinants and urban morphology. Section 3 details our empirical methodology, spatial data collection, and statistical model specification. Section 4 presents the regression results and discusses the planning trade-offs, structural barriers, and design interventions. Section 5 concludes with strategic policy recommendations for the future sustainable development of Ho Chi Minh City.

2. Literature Review

2.1 Theoretical Foundations of Urban Green Spaces

The literature on urban ecosystems identifies UGS as a core component of "natural capital" within cities, delivering critical ecosystem services that regulate microclimates, manage stormwater runoff, and reduce atmospheric carbon dioxide. Beyond these ecological services, UGS is deeply linked to human health through two prominent psychological theories:

1. **Attention Restoration Theory (ART):** Developed by Kaplan (1995) [7], ART posits that highly built, chaotic urban environments demand prolonged directed attention, leading to cognitive fatigue. Natural environments, by contrast, offer effortless, involuntary attention ("soft fascination"), allowing the human cognitive system to recover and restore processing capacity.
2. **Stress Recovery Theory (SRT):** Formulated by Ulrich (1983) [12], SRT suggests that immediate visual exposure to natural features triggers an evolutionary, sympathetic-parasympathetic nervous system response. This biochemical shift rapidly lowers cortisol levels, blood pressure, and heart rate, accelerating recovery from psychological stress.

In tropical, high-density metropolises like HCMC, the physical presence of vegetation acts as a vital buffer against environmental stressors. However, achieving adequate green space density is not merely a design challenge; it is a spatial-allocation problem dictated by underlying physical, economic, and institutional forces.

2.2 Urban Morphology and the Spatial Limits of Greening

Urban morphology—the physical form and spatial structure of city elements—is a primary physical constraint on green space density. Key metrics used to quantify morphology include:

- **Building Coverage Ratio (BCR):** The percentage of a plot covered by building footprints, defined as:

$$BCR = A_{build}/A_{land} \times 100\%$$

- **Floor Area Ratio (FAR):** The ratio of total gross floor area to the land area:

$$FAR = A_{floor}/A_{land}$$

- **Sky View Factor (SVF):** The ratio of the visible sky hemisphere to the total hemispherical view from a specific ground point.

High BCR environments leave virtually no unpaved ground-level space for traditional planting. When BCR exceeds 80%, a threshold common in HCMC's historic alleyways, the soil is completely sealed by concrete. This prevents water infiltration and root growth, restricting vegetation to small, containerized plants.

The relationship between vertical density (FAR) and green space is more complex. Under the "compact city" theory (Haaland & van den Bosch, 2015) [5], high FAR combined with low BCR (vertical high-rises with generous ground-level setbacks) can theoretically liberate land for public plazas and parks. However, in many developing Asian metropolises, high FAR is coupled with relatively high BCR, resulting in hyper-dense urban blocks that completely crowd out green spaces.

Furthermore, SVF plays a critical dual role in microclimate and vegetation viability. Low SVF in deep urban canyons provides shading from direct solar radiation during the day, which can reduce localized air temperatures. Yet, extremely low SVF ($SVF < 0.2$) limits the photosynthetically active radiation (PAR) reaching ground-level plants, stunting growth and reducing the overall health and density of the canopy.

2.3 Spatial Economics and the Land Value Squeeze

In a market-driven real estate environment, urban green space must constantly compete with other high-value land uses. Spatial economic theory, particularly the bid-rent model, dictates that land values (LV) peak at the urban core or Central Business District (CBD) due to accessibility and agglomeration economies.

As land values escalate, the opportunity cost of dedicating land to non-revenue-generating uses like public parks becomes exceptionally high. For private developers, every square meter of land left unbuilt represents a direct loss of potential floor area and financial return. In developing nations where planning enforcement may be weak or subject to negotiation, developers often seek variances to exceed maximum BCR and minimize mandatory green setbacks. Consequently, a strong negative correlation is typically observed between localized land values and the percentage of ground-level green space, creating a "land value squeeze" that systematically depopulates nature from high-value urban cores.

2.4 Institutional and Policy Frameworks in Vietnam

The regulatory environment in Vietnam is governed by a hierarchical system of planning laws, building codes, and master plans. The Prime Minister's Decision No. 2631/QD-TTg, which approved the master plan for HCMC's socio-economic development, explicitly set ambitious targets for expanding green cover. Additionally, National Construction Standard QCVN 01:2021/BXD stipulates strict guidelines for the minimum ratio of green space in urban residential areas.

However, a persistent implementation gap exists between macro-level planning visions and micro-level enforcement. Municipal authorities face severe financial constraints, making it impossible to compensate private landowners at market rates for land expropriation to build public parks. Furthermore, historical zoning loop-holes have allowed developers to convert designated public green zones within new master-planned communities into low-density luxury villas or commercial centers.

To bypass these ground-level land constraints, contemporary research has turned toward **Green Micro-infrastructure (GMI)**—such as extensive green roofs, living vertical walls, pocket parks, and bioswales. These localized, integrated systems do not require dedicated municipal land parcels. Instead, they leverage existing building envelopes and micro-spaces to provide cooling, runoff management, and psychological restoration. However, the formal integration of GMI into the Vietnamese legal planning framework remains in its infancy.

3. Research Methodology

3.1 Research Design and Study Area

This study employs a quantitative spatial-statistical research design to model the factors affecting green space density (GSD) across the inner city of Ho Chi Minh City. The study area comprises six core districts representing diverse historical, structural, and socio-economic typologies (Figure 4):

1. **District 1 & District 3:** The French colonial core, characterized by structured grid layouts, relatively low BCR, historic villa structures, high land values, and mature, large-canopy street trees.
2. **District 5 & District 10:** High-density commercial and residential zones, including Cholon (Chinatown), featuring extremely high BCR, narrow shophouses, highly fragmented land ownership, and minimal public green space.
3. **District 4 & Binh Thanh District:** Rapidly transitioning districts characterized by a mix of informal, high-density settlements (along canals) and new, high-rise, high-intensity commercial developments.

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+--------------------------------------------------------+
|          STUDY AREA: INNER-CITY HCMC                   |
+--------------------------------------------------------+
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|                                   |
+------v-----------------+        +------v-----------------+
| HISTORIC CORE       |            | TRANSITION ZONE    |
| - District 1 & 3    |          | - District 4 & Binh  |
| - Planned Grid      |          |   Thanh              |
| - High Land Values  |          | - High-Rise & Slums  |
+-----------------------+        +-----------------------+
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Fig 1: Spatial classification of the study area in the inner city of Ho Chi Minh City

To capture high-resolution spatial variations, the unit of analysis is defined as the urban block. A total of 350 distinct urban blocks were delineated across the six districts using GIS road network files and high-resolution satellite imagery.

3.2 Data Collection and Variable Construction

Data was gathered from multiple spatial, governmental, and field-measurement sources to construct a highly reliable, multi-source dataset. All variables are calculated at the individual block level.

Dependent Variable

- **Green Space Density (GSD_{index}):** Calculated using high-resolution (0.5m) satellite imagery from the Pleiades Neo constellation captured during the dry season (to minimize cloud cover). The Normalized Difference Vegetation Index (NDVI) was computed for each pixel:

$$NDVI = (NIR - Red)/(NIR + Red)$$

Pixels with an NDVI ≥ 0.3 were classified as vegetation. GSD_{index} is defined as the percentage of the block's total area covered by classified vegetation:

$$GSD_{index} = \sum A_{veg\_pixels}/A_{block} \times 100\%$$

Independent Variables

1. **Building Coverage Ratio (BCR):** Extracted from municipal GIS building footprint layers, validated against satellite imagery. Calculated as the sum of building footprint areas divided by the total block area.
2. **Floor Area Ratio (FAR):** Obtained from the Urban Planning Information System of HCMC, representing the average vertical intensity of the buildings within each block.
3. **Sky View Factor (SVF):** Captured via field measurements at 10 randomized street-level locations within each block using a digital SLR camera equipped with a 180^{O} fisheye lens. Images were processed using the RayMan software to calculate mean localized SVF.
4. **Land Value (LV):** Estimated using a combination of the official municipal land price frame (issued by the HCMC People's Committee) and market transactional data extracted from real estate valuation platforms during the 2024–2025 period. To control for extreme

skewness, land values are normalized using a natural logarithmic transformation: ln(LV).

5. **Population Density** (PD)**:** Calculated using block-level census data from the 2019-2024 local population registers, defined as the number of permanent and temporary residents per hectare (ha).
6. **Institutional Enforcement Index** (IE)**:** A qualitative index scored from 1 (lowest) to 5 (highest), representing the strictness of local planning control and enforcement of green setbacks, evaluated based on interviews with municipal planning officials and historical zoning variance records.

3.3 Statistical Model Specification

To model the complex, multi-variable interactions, we specify a multivariate Ordinary Least Squares (OLS) regression model. To control for extreme values and instrument errors, all continuous spatial variables are winsorized at the 1% and 99% levels prior to running the regression.

The baseline empirical equation is formulated as follows:

$$GSD_i = beta_0 + beta_1 * BCR_i + beta_2 * FAR_i + beta_3 *SVF_i + beta_4 * SVF_i^2 + beta_5 * \ln(LV_i) + beta_6 * PD_i + beta_7 * IE_i + epsilon_i$$

Where:

- i represents the individual urban block.
- $beta_0$ is the intercept term.
- SVF^2 is included to capture the hypothesized non-linear, U-shaped relationship between sky visibility and green density.
- $epsilon_i$ is the stochastic error term.

To ensure the validity of our OLS estimators, a series of post-estimation diagnostics are performed:

- **Multicollinearity:** Verified using the Variance Inflation Factor (VIF). Any variable with a VIF > 10 is flagged for removal.
- **Heteroscedasticity:** Checked using the Breusch-Pagan test. If heteroscedasticity is detected, robust standard errors (Huber-White Sandwich Estimator) are applied to adjust the t-statistics.
- **Normality of Residuals:** Evaluated using the Shapiro-Wilk test and visual inspection of Q-Q plots.

4. Research Results and Discussion

4.1 Descriptive Statistics and Spatial Typologies

The descriptive statistics for the 350 analyzed urban blocks reveal extreme variations in both urban morphology and green space distribution across the inner city of HCMC (Table 3).

Table 1: Descriptive statistics of the variables across 350 urban blocks

Variable	Mean	Std. Dev.	Min	Max	Unit
GSD_{index}	8.42	6.12	0.45	28.50	%
BCR	72.15	14.80	32.10	94.20	%
FAR	4.85	3.10	1.20	14.50	-
SVF	0.38	0.18	0.08	0.82	-
LV	120.5	85.2	22.0	450.0	Million VND/m2
PD	385.2	192.4	45.0	1200.0	People/ha
IE	2.80	1.15	1.00	5.00	Index (1-5)

We identify three distinct spatial typologies within our dataset:

1. **Typology A (The Historic Planned Grid):** High green density (GSD > 15), moderate BCR (50% - 65%), low-to-moderate FAR (2.0 - 4.0), and relatively high SVF (0.45 - 0.60). This is typical of Districts 1 and 3, where wide, tree-lined boulevards and deep building setbacks preserve ground-level green corridors.
2. **Typology B (The High-Density Organic Core):** Extremely low green density (GSD < 3%), extremely high BCR (BCR > 80%), moderate FAR, and low SVF (SVF < 0.20). Typical of District 5 (Cholon) and deep communities in Binh Thanh, where building footprints cover almost the entirety of the parcels, leaving zero ground space for vegetation.
3. **Typology C (The High-Rise Compact Enclave):** Low-to-moderate ground-level green density (GSD approx 5% - 10%), low-to-moderate BCR (35% - 50%), but extremely high vertical intensity (FAR > 8.0), accompanied by variable SVF. Typical of new luxury mixed-use developments along the Saigon River in District 4 and Binh Thanh.

4.2 Regression Results

The multivariate OLS regression results are presented in Table 4. The model displays a high goodness-of-fit, with an adjusted R2 of 0.684, indicating that approximately 68.4% of the variance in inner-city green space density is explained by our independent variables. The overall model is highly significant (F-statistic = 108.5, p < 0.001).

Table 2: OLS Regression Results (Dependent Variable: GSD_{index}

Predictor	Coefficient (beta)	Standard Error	t-statistic	p-value	VIF
Intercept	42.150	4.820	8.74	< 0.001	-
BCR	-0.325	0.045	-7.22	< 0.001	2.45
FAR	-0.680	0.120	-5.67	< 0.001	3.12
SVF	-18.420	5.120	-3.60	< 0.001	5.80
SVF^2	22.150	6.040	3.67	< 0.001	5.42
ln(LV)	-2.150	0.450	-4.78	< 0.001	1.88
PD	-0.005	0.002	-2.50	0.013	1.65
IE	1.450	0.380	3.82	< 0.001	1.35

Note: Standard errors are robust (Huber-White Sandwich Estimator) to account for heteroscedasticity.

4.3 Interpretation and Discussion of Key Findings

4.3.1 Physical Constraints: The Dominance of BCR and FAR

The regression coefficients confirm that BCR (beta = -0.325, p < 0.001) and FAR (beta = -0.680, p < 0.001) are the strongest physical predictors of green space loss. A 10% increase in building coverage ratio is associated with a 3.25% decrease in overall green space density within a block. When building footprints expand, they physically seal the urban soil, leaving no room for ground-level plantings. This explains the near-total absence of vegetation in Typology B (Cholon).

The highly negative coefficient of FAR illustrates a critical planning failure in HCMC. In theory, high-rise development (high FAR) should allow for lower building footprints (BCR) and larger open plazas. However, in HCMC, the pressure for high investment yields has driven developers to seek variances that allow for both high FAR and high BCR.

This double-compaction leaves no ground-level setback area, causing vertical development to act as a significant driver of green space depletion.

4.3.2 The Non-Linear Effect of Sky Visibility (SVF)

The relationship between SVF and GSD_{index} is non-linear and U-shaped, as evidenced by the negative coefficient of the linear term SVF (beta = -18.420, $p < 0.001$) and the positive coefficient of the quadratic term SVF2 (beta = 22.150, $p < 0.001$).

GSD Density (%)

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|                          /
|                         /
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|                       /
|    _________________/
|
+---------------------------> SVF (0.0 to 1.0)
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Fig 2: The non-linear U-shaped relationship between Sky View Factor (SVF) and Green Space Density (GSD)

This U-shaped relationship (Figure 5) reveals a fascinating spatial trade-off:

- **At extremely low** SVF **(**SVF < 0.2**):** Microclimatic conditions (heavy shading, lack of sunlight) combined with extremely narrow street widths in dense alley networks make natural canopy survival difficult. Vegetation is minimal, consisting of sparse, containerized plants.
- **At moderate** SVF (0.2 < SVF < 0.5)**:** Moderate shading can support certain shade-tolerant plant species, but the built density still limits large canopy development.
- **At high** SVF (SVF > 0.5)**:** The sky is highly open, and solar radiation is abundant. In these zones, large-canopy street trees (such as *Dau rai* or *Sao den* in District 1 and 3) can flourish, resulting in high localized green space density.

This highlights the need to coordinate street geometry with species selection: deep, narrow streets require highly adaptive, shade-tolerant vertical green installations, whereas wide streets must be preserved for large-canopy structural trees.

4.3.3 Economic Pressures: The Land Value Squeeze

The natural log of land value ln(LV) exhibits a statistically significant negative coefficient (beta = -2.150, $p < 0.001$). This confirms that the rising price of real estate in HCMC's inner city acts as a major economic barrier to greening. In premium zones like District 1, where land prices can reach hundreds of millions of VND per square meter, municipal authorities find it financially prohibitive to purchase land for public parks.

For private developments, high land costs create an intense financial incentive to convert every available square meter of mandated green open space into commercial floor area. This highlights a structural issue: market forces left unregulated will naturally deplete urban green spaces. Therefore, strong public-policy interventions and economic disincentives (such as green taxes or strict building-code enforcement) are necessary to counteract the land value squeeze.

4.3.4 Institutional Controls and Regulatory Enforcement

The positive coefficient of the Institutional Enforcement Index IE (beta = 1.450, $p < 0.001$) shows that proactive planning enforcement can successfully preserve green cover. Blocks within districts with higher IE scores (such as planned sectors in District 1 and parts of District 3) maintain significantly higher green density.

Conversely, in districts where historical planning enforcement has been lax or compromised by informal development (such as the canal-side areas of Binh Thanh or District 4), illegal encroachment and unchecked variances have systematically eroded designated green buffers.

4.4 Strategic Interventions: Designing for HCMC's Inner City

To reconcile HCMC's high-density urban morphology with the urgent need for climate resilience, the city must move away from the traditional, land-intensive "large park" model. We propose a **Salutogenic Urban Design Framework** that integrates green space directly into the built environment through a hierarchy of scales (Figure 3).

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+-------------------------------------------------------+
|        SALUTOGENIC URBAN DESIGN FRAMEWORK              |
+-------------------------------------------------------+
                     |
      +--------------------+--------------------+
      |                                         |
+--------v---------------+          +--------v---------------+
| MACRO SCALE            |          | MICRO SCALE            |
| - Green Fingers        |          | - Vertical Walls       |
| - Canal Restoration    |          | - Green Roofs          |
| - Urban Setbacks       |          | - Pocket Parks (GMI)   |
+------------------------+          +------------------------+
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Fig 3: Multi-level spatial intervention framework for high-density HCMC

a. Integrating Green Micro-infrastructure (GMI)

- **Vertical Green Walls:** In blocks with a BCR > 80%, where ground-level soil is unavailable, vertical surfaces must be used. Installing modular living walls on blank building facades and concrete canal retaining walls can block direct solar radiation, lower surface temperatures, and absorb noise, without requiring additional land footprints.
- **Extensive Green Roofs:** On medium-rise and high-rise structures (moderate-to-high FAR), rooftops represent an underutilized asset. Implementing lightweight, drought-resistant sedum green roofs can reduce building cooling loads by up to 30%, mitigate stormwater runoff, and contribute to the overall green index.
- **Pocket Parks:** Utilizing highly fragmented, micro-spaces (underutilized street corners, vacant lots under 500m2, and building setbacks) to create small, high-density green areas. These pocket parks should combine shaded seating with high-canopy vegetation to optimize localized PET and foster social interaction.

b. Institutionalizing the "Green Area Ratio" (GAR)

To address the "land value squeeze," the HCMC Department of Planning and Architecture should institutionalize a Green Area Ratio (GAR) system, similar to successful frameworks used in Singapore and Berlin.

- The GAR assigns weighted points to different greening surfaces based on their ecological value (e.g., 1.0 for natural deep soil, 0.7 for intensive green roofs, 0.5 for vertical green walls, and 0.3 for permeable pavement).

- To obtain building permits, developers must achieve a minimum GAR score tailored to their zone. This mechanism leverages private investment to build public-interest GMI, bypassing municipal land acquisition constraints.

c. Canal-Side Green Corridor Restoration

The canal networks running through District 4, District 5, and Binh Thanh present a unique opportunity to create continuous, linear green corridors. By enforcing strict environmental setbacks along canals and relocating informal settlements to modern, master-planned housing, the city can establish continuous pedestrian greenways. These linear parks can facilitate passive cooling via water-vegetation microclimate interactions, lowering localized PET and offering residents a dedicated space for active recreation.

5. Conclusion

This study has empirically analyzed the physical, economic, and institutional factors that govern green space density (GSD) across the inner-city districts of Ho Chi Minh City. By applying a multivariate OLS regression model to a spatial dataset of 350 urban blocks, we have demonstrated that:

1. High BCR and FAR act as significant physical drivers of green space depletion.
2. The relationship between SVF and green density is non-linear and U-shaped, highlighting the need to match street-level geometry with plant species selection.
3. Escalating real estate values (ln(LV)) create a powerful economic disincentive for ground-level greening, necessitating regulatory interventions.
4. Robust institutional planning control (IE) is a highly effective tool for preserving urban ecosystems.

Policy Recommendations

Based on these findings, we recommend the following policy actions for the sustainable planning of Ho Chi Minh City:

- Revise the National Building Code (QCVN 01:2021/BXD): Incorporate mandatory Green Area Ratios (GAR) that allow developers to substitute ground-level green requirements with high-performance vertical walls and green roofs (GMI).
- Adopt a Decoupled Greening Model: Transition from a focus on centralized public parks to a decentralized network of pocket parks, linear canal-side greenways, and street-level bio-swales.
- Strengthen Zoning Enforcement: Establish independent, GIS-based auditing systems to monitor and prevent the illegal conversion of designated green zones in new urban developments.
- Implement Green Incentives: Offer density bonuses (allowing additional FAR) to developers who voluntarily integrate high-performance GMI or dedicate ground-level setbacks to public pocket parks.

Limitations and Future Research

While this study provides robust empirical insights, certain limitations remain. First, our cross-sectional design does not capture the seasonal dynamics of vegetation health, particularly the differences between the dry and rainy seasons in HCMC. Second, the Institutional Enforcement Index (IE) relies on qualitative evaluations and could be refined in future research with more granular administrative data.

Future studies should employ longitudinal research designs to track the evolution of green space density over decades. Additionally, integrating physiological and psychological sensors (such as EEG or heart-rate monitors) could help quantify the immediate health benefits of GMI installations on residents navigating HCMC's dense urban core.

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