

Urban Green Islands and Cardiovascular Health: A Narrative Review with a Case Illustration from Tianjin

Jingyi Jiang

*College of Management, Tianjin University of Traditional Chinese Medicine, Tianjin, China
jiangjingyi2005@163.com*

Abstract. High-density urbanization intensifies heat and air pollution, which increases cardiovascular disease (CVD) risk, particularly in aging urban populations. Urban Green Islands (UGIs), including pocket parks, microforests, and small vegetation corridors, have emerged as nature-based solutions with potential cardiovascular benefits. This paper uses a narrative literature review to synthesize peer-reviewed epidemiological, experimental, and satellite-based studies published between 2017 and 2026, and adds a descriptive case illustration from Tianjin, China. The reviewed evidence suggests that UGIs may reduce cardiovascular risk through microclimate cooling, pollutant deposition, stress buffering, and promotion of physical activity. Their benefits appear strongest when they are located within 300-500 m of residences and when they are accessible to socioeconomically disadvantaged communities. The Tianjin case applies a vegetation-to-temperature-to-regression framework to illustrate how greening and thermal exposure jointly relate to district-level CVD incidence. Overall, UGIs appear to be important environmental protective factors that support cardiovascular health, health equity, and urban resilience.

Keywords: Urban Green Islands, Cardiovascular Health, Environmental Protective Factors, Health Equity

1. Introduction

Rapid urbanization intensifies environmental stressors like extreme heat and air pollution, which accelerate cardiovascular diseases (CVD) [1]. In response, small-scale nature-based solutions, termed urban green islands (UGIs), have emerged as protective factors in municipal planning. Vegetated configurations mitigate these threats via canopy-mediated cooling and interception of vehicular emissions [2].

Extensive epidemiological evidence supports the multi-pathway protective mechanisms of urban green spaces, linking residential proximity to lower cardiovascular risks. However, traditional research often relies on coarse macroscopic vegetation indices, leaving a critical gap in understanding how micro-scale UGIs and community-led co-creation function within densely populated areas. How narrow service radii and socioeconomic factors interact to modify these mechanisms remains fragmented, particularly regarding green gentrification and equity challenges [3].

To bridge these gaps, this paper employs a narrative literature review to explore epidemiological evidence, physical-behavioral pathways, and socio-ecological modifiers of UGI-based cardiovascular protection [3-5]. It develops an integrated public health framework and includes a descriptive case illustration from Tianjin, China, to demonstrate real-world spatial-temporal dynamics. The review provides a framework linking localized vegetation structures to human health equity, offering strategic recommendations for urban planners and policymakers to optimize green infrastructure investments and promote cardiovascular resilience in climate-vulnerable communities.

2. Literature review

A growing body of epidemiological evidence confirms that urban green spaces are inversely associated with chronic cardiovascular risks [1, 6]. As small, localized vegetated patches, urban green islands (UGIs) mitigate these risks through distinct environmental and biological pathways [2, 7].

2.1. Physical and environmental mechanisms

UGIs buffer environmental hazards by regulating microclimates and trapping pollutants. Vegetation attenuates the urban heat island effect through shading and evapotranspiration. Remote sensing shows that small-scale green islands possess significant localized cooling capacities, lowering land surface temperatures (LST) in urban settings [8]. This thermal mitigation is essential, as extreme heat triggers acute cardiac strain and increases mortality [6, 8]. Simultaneously, tree canopies remove airborne particulate matter and traffic emissions via dry deposition [2, 9]. Long-term sensor arrays confirm measurable reductions in ambient pollution [9], shielding residents from triggers of ischemic heart disease and stroke [2, 7].

2.2. Physiological and behavioral mechanisms

Exposure to UGIs induces direct biological and behavioral benefits. Time in leafier communities stimulates the parasympathetic nervous system, reducing stress, lowering blood pressure, and improving heart rate variability [4, 5, 10]. Green spaces also promote physical activity and social cohesion [3, 11]. Community-led greening projects encourage outdoor exercise, combat sedentary lifestyles, lower obesity and hypertension [12], and mitigate metabolic syndromes that precede major cardiovascular events [10, 13].

2.3. Modifiers of protective effects

The efficacy of UGIs as environmental protective factors is not uniform but is strongly modified by spatial configurations and socio-ecological contexts.

2.3.1. Spatial factors

Proximity is decisive: green space density operates within a 300–500 m service radius, within which residential access is most strongly associated with lower diabetes and hypertension rates [12]. Fragmented and isolated patches offer weaker protection against cerebrovascular mortality than continuous, well-connected urban forest networks [14, 15].

2.3.2. Socioeconomic factors

Socioeconomic status (SES) shapes UGI exposure and health outcomes. Lower-income neighborhoods often face a scarcity of high-quality green infrastructure [16, 17]. However, when UGIs are implemented in these areas, marginal health benefits are often strongest among disadvantaged populations [2]. Lower-SES residents spend more time within their immediate residential boundaries, resulting in higher effective exposure dose [2, 16]. Nonetheless, planning must avoid green gentrification, which risks displacing vulnerable populations [17].

3. Case analysis: Tianjin

3.1. Spatial–temporal evolution of vegetation and thermal environment

To examine how urban greening may influence cardiovascular health in Tianjin, we treat fractional vegetation cover (FVC) as the primary ecological driver; ground temperature as its thermal consequence; and use a district-level panel regression to quantify associations with composite CVD incidence, controlling for demographics and year effects. The analysis proceeds in five steps.

3.1.1. Fractional vegetation cover mapping and summary statistics

Classified FVC maps for 2005, 2015, and 2025 (Figures 1-3) reveal a substantial greening transformation: low-cover classes (0–10% and 10–30%) dominated the urban core in 2005; medium- (30–45%) and high-cover (45–60%) expanded markedly in suburban areas by 2015; and by 2025, extensive northern and eastern districts exhibited dense vegetation exceeding 60% FVC. District-level mean FVC increased from 8.5% (2005) to 45.0% (2015) and 46.2% (2025), with the share of high-density vegetation (>60%) rising from 1.7% to 35.8%, establishing the exposure gradient used in subsequent analyses.

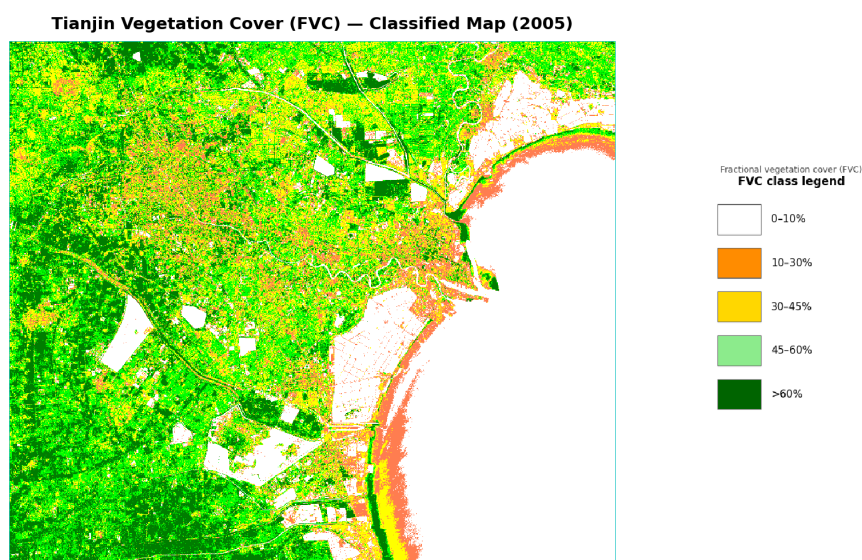


Figure 1. Tianjin fractional vegetation cover classified map (2005) with five-class legend (0–10% white through >60% dark green)

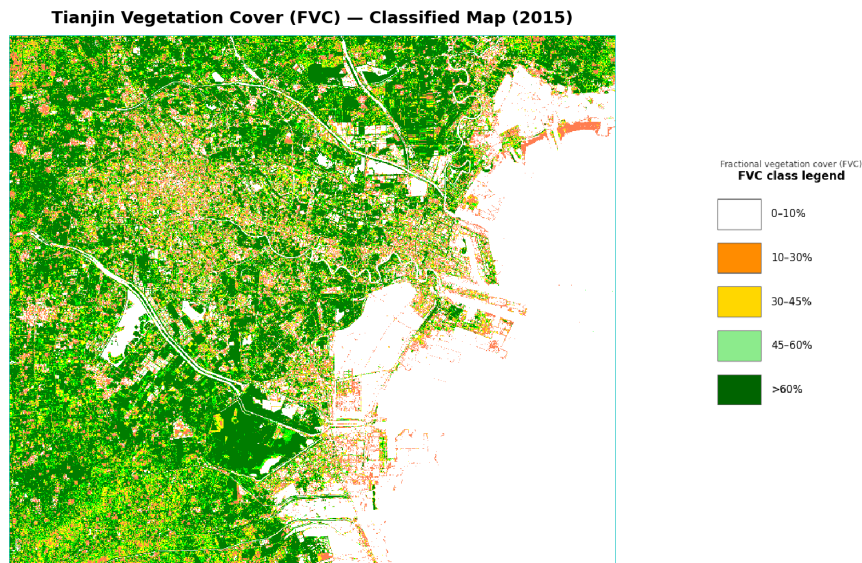


Figure 2. Tianjin fractional vegetation cover classified map (2015) with five-class legend (0-10% white through >60% dark green)

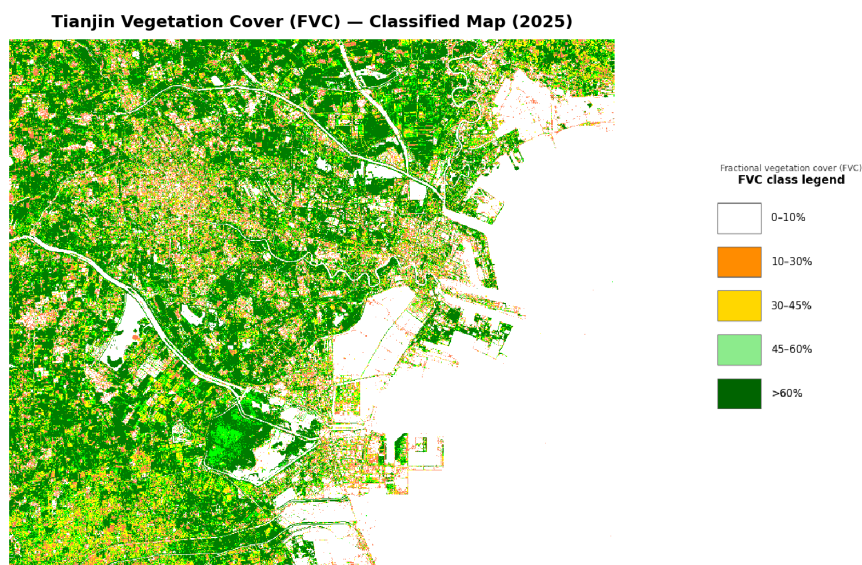


Figure 3. Tianjin fractional vegetation cover classified map (2025) with five-class legend (0-10% white through >60% dark green)

3.1.2. Ground-temperature response and thermal summary statistics

Classified LST maps for the same years (Figures 4-6) show persistent thermal hotspots in the built core and industrial corridors, while peripheral districts with higher FVC exhibit notably cooler conditions. District-averaged impervious-surface LST changed from 26.9°C (2005) to 27.3°C (2015) and declined to 23.5°C (2025). Spatial comparison of Figures 1-3 and 4-6 confirms an inverse correspondence between vegetation expansion and localized thermal stress, providing empirical support for treating vegetation coverage as a key explanatory variable.

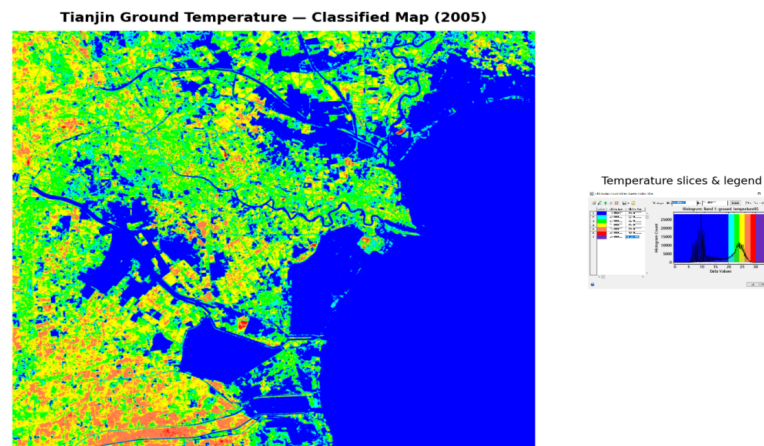


Figure 4. Tianjin ground-temperature classified map (2005) with ENVI raster color slices ($^{\circ}\text{C}$)

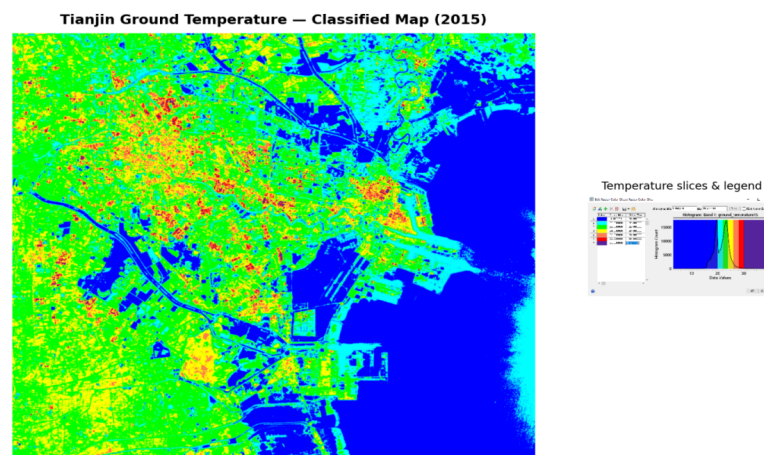


Figure 5. Tianjin ground-temperature classified map (2015) with ENVI raster color slices ($^{\circ}\text{C}$)

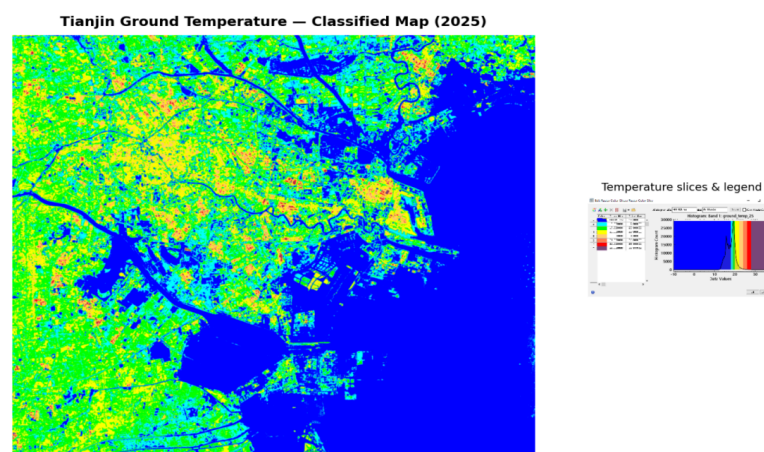


Figure 6. Tianjin ground-temperature classified map (2025) with ENVI raster color slices ($^{\circ}\text{C}$)

3.1.3. Panel regression model specification

To quantify relationships among vegetation, thermal stress, and CVD outcomes, we constructed a panel using 16 districts observed in 2005, 2015, and 2025. A multivariable regression framework

was developed with the following preferred specification:

$$CVD_{it} = \beta_0 + \beta_1 Heat_{it} + \beta_2 GreenIsland_{it} + \beta_3 Forest_{it} + \beta_4 Age_{it} + \beta_5 Elderly_{it} + \gamma_t + \varepsilon_{it} \quad (1)$$

where:

CVD_{it} denotes the composite cardiovascular disease incidence rate (cases per 100,000) in district i , year t (outcome variable).

$Heat_{it}$ denotes the relative heat-island intensity measured by district-level LST deviation from the annual mean (thermal effect downstream of vegetation).

$GreenIsland_{it}$ represents medium-to-high vegetation coverage (30-60% FVC).

$Forest_{it}$ represents dense woodland coverage (>60% FVC).

Age_{it} is the mean population age (demographic control).

$Elderly_{it}$ is the proportion of residents aged 65 years or above (demographic control).

γ_t denotes year fixed effects for 2005, 2015, and 2025.

Model M1 separates upstream vegetation exposure ($GreenIsland_{it}$ $Forest_{it}$), downstream thermal response ($Heat_{it}$), and health outcome (CVD_{it}), while year and demographic controls absorb confounding from population ageing and citywide temporal trends.

3.1.4. Temporal evolution of health and ecological indicators

Before interpreting regression coefficients, Figure 7 summarizes joint evolution. Mean FVC increased substantially from 8.5% in 2005 to 46.2% in 2025, and dense woodland expanded markedly. Despite these improvements, composite CVD incidence rose from ~163.6 to 278.0 per 100,000 over the same period, suggesting that vegetation alone cannot fully explain temporal variations; demographic aging, urban development, and thermal exposure also influence disease risk.

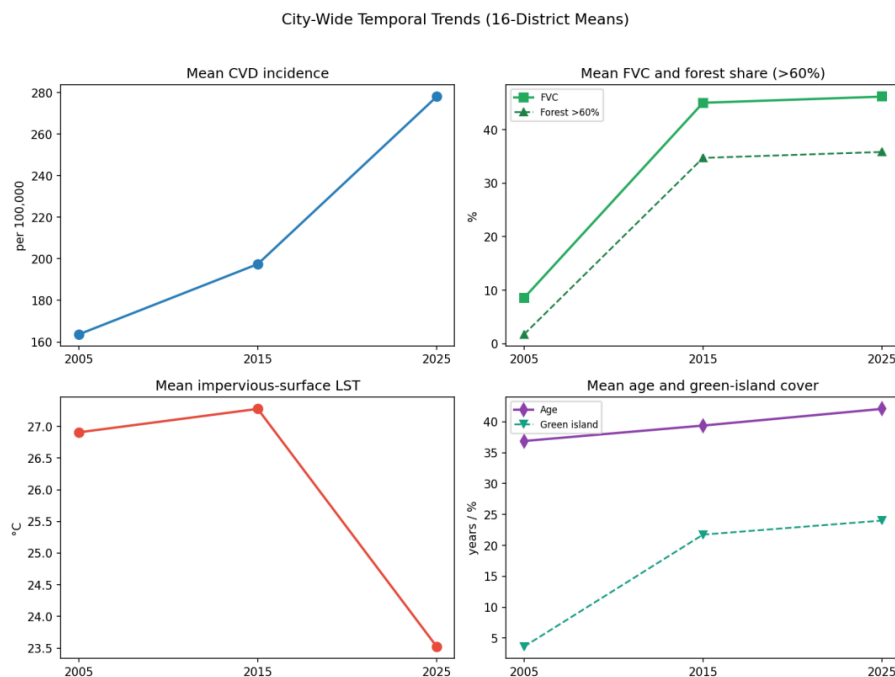


Figure 7. Temporal evolution of health and ecological indicators (2005-2025)

3.1.5. Regression estimates and relative variable contributions

Table 1 reports Model M1 estimates. The model achieved an adjusted R^2 of 0.9895, indicating that thermal conditions, vegetation structure, and demographic composition jointly explain 98.95% of district-level variation in CVD incidence.

Table 1. Two-way fixed effects regression results for composite CVD incidence rate

Variable	Coefficient (β)	Standard Error	p-value
Heat-island index (Relative LST)	2.8068	0.8062	0.0009
Urban green island cover (30–60% FVC)	-1.0313	0.2291	<.0001
Small forest proxy (>60% FVC)	0.0294	0.0936	0.7476
Mean population age	5.5279	3.2545	0.0875
Population share aged 65+	-6.4444	1.9640	0.0016
District Fixed Effects	Included	/	/
Year Fixed Effects	Included	/	/
Observations(n)	48	/	/
Adjusted R^2	0.9895	/	/

The relative heat-island index exhibits the strongest positive association with CVD incidence ($\beta = 2.8068$, $p < 0.001$), while urban green-island coverage (30–60% FVC) shows a significant protective effect ($\beta = -1.0313$, $p < 0.001$). In contrast, dense woodland (>60% FVC) is positive but non-significant ($\beta = 0.0294$, $p = 0.7476$). Figure 8 visualizes these contrasting coefficients, confirming that thermal exposure—not total forest area—is the dominant environmental driver of district-level CVD variation, while neighborhood-scale green infrastructure provides measurable protective benefits.

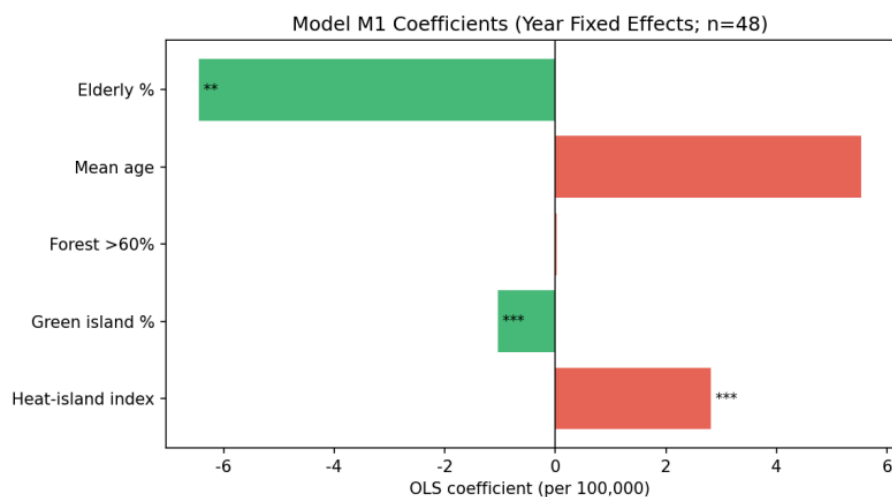


Figure 8. Linear regression coefficients (Model M1 with year and demographic controls)

3.2. Interpretation of major findings

The regression results identified significant associations between environmental conditions and cardiovascular disease incidence. However, statistical relationships alone do not explain the mechanisms through which these factors may influence population health. This section interprets the observed associations in light of existing environmental health research and explores potential pathways linking thermal exposure, vegetation patterns, and cardiovascular outcomes.

3.2.1. Relative heat-island intensity as the primary environmental risk factor

The regression results identified relative heat-island intensity as the strongest environmental risk factor associated with cardiovascular disease incidence. After controlling for demographic characteristics and year fixed effects, a one-unit increase in relative thermal intensity was associated with an increase of approximately 2.81 cases per 100,000 population.

Importantly, this finding differs from the simple bivariate relationship observed in the raw panel data. Pearson correlation analysis indicated a negative association between impervious-surface LST and CVD incidence ($r = -0.7522$). However, this apparent contradiction is largely attributable to temporal confounding. Specifically, 2025 exhibited both the lowest citywide mean LST and the highest cardiovascular disease incidence, producing a misleading negative correlation in the pooled dataset. Once the year fixed effects were introduced, the underlying positive association between localized heat exposure and disease incidence became evident. This result highlights the importance of controlling for temporal trends when evaluating environmental health relationships.

From a public health perspective, elevated temperatures increase cardiovascular strain by raising cardiac output, promoting dehydration, and increasing blood viscosity. Prolonged heat exposure may therefore contribute to higher risks of ischemic heart disease and stroke, particularly among older adults and vulnerable populations.

3.2.2. Protective effects of urban green islands

Urban green-island coverage (30-60% FVC) demonstrated a significant protective association with cardiovascular disease incidence after controlling for thermal and demographic factors. The negative coefficient observed in Model M1 suggests that districts containing greater proportions of medium-to-high vegetation coverage generally experienced lower cardiovascular disease burdens.

Unlike large forest reserves, green islands are embedded within residential neighborhoods, allowing their ecological benefits to translate more directly into population health outcomes. These areas contribute to local cooling through shading and evapotranspiration, improve air quality through pollutant interception, and provide opportunities for physical activity and social interaction.

The statistical significance and precision of the green-island coefficient indicate that neighborhood-scale vegetation is more effective for health than total vegetation area alone. Therefore, the health benefits of urban greening appear to depend not only on vegetation quantity but also on its spatial accessibility and integration within the built environment.

3.2.3. Limited independent contribution of dense forest patches

In contrast to urban green islands, dense forest coverage (>60% FVC) did not exhibit a statistically significant independent association with cardiovascular disease incidence in Model M1.

Although forested areas provide important ecological functions, their health benefits may not be fully captured at the district level. Many of Tianjin's largest forest patches are located in peripheral districts where population density is relatively low and direct human exposure is limited.

This finding suggests that the health impacts of vegetation are influenced not only by ecological characteristics but also by spatial distribution and accessibility. Large forest reserves may contribute substantially to regional environmental quality, yet their direct effects on population-level cardiovascular outcomes appear weaker than those associated with neighborhood-scale green infrastructure.

Consequently, increasing vegetation coverage alone may not guarantee measurable public health benefits. The location, accessibility, and integration of green spaces within urban environments are likely to be equally important determinants of health outcomes.

4. Discussion

4.1. Thermal environment as a key environmental health pathway

Our empirical findings confirm localized thermal conditions as a primary environmental determinant of CVD burden. Sustained heat exposure accelerates blood viscosity, dehydration, and cardiac workload [4, 5]. Urban heat-island expansion must be addressed as a structural driver of cardiovascular vulnerability. Mitigation via green infrastructure, community parks, corridors, street trees, and pocket parks, can simultaneously enhance sustainability, climate resilience, and cardiovascular health.

4.2. Health significance of urban green islands

A key contribution is the empirical divergence between neighborhood-scale UGIs and regional forests. While conventional literature often treats greenness as homogeneous, our results show that UGIs exert a strong protective influence, whereas dense forest patches do not. This is explained by spatial configuration: large forests are peripheral with low human interaction; UGIs are embedded in residential fabrics, optimizing cooling, pollution deposition, and stress reduction [8-10,18]. Public health efficacy depends on accessibility and integration, not total biomass.

4.3. Accessibility, environmental justice, and planning equity

The interaction between microclimate protection, aging, and spatial variation supports an environmental justice perspective. Socioeconomically vulnerable and elderly residents have restricted mobility and thus higher effective exposure to local green spaces. Equitable deployment of UGIs in disadvantaged areas can serve as a socio-ecological equalizer. However, planning must avoid green gentrification, which can displace the very populations most in need [17].

4.4. Current challenges in the field of environmental health planning

Systemic challenges persist: disconnect between research and implementation; temporal lags between greening and health outcomes discouraging sustained commitment; and lack of standardized equity metrics. Interdisciplinary collaboration is needed to codify evidence-based thresholds and hold planning agencies accountable for reducing disparities.

5. Conclusion

This study elucidates relationships between vegetation, thermal dynamics, and CVD incidence in Tianjin (2005-2025) using a two-way fixed effects panel. Results confirm that heat-island intensity is a dominant risk factor, while neighborhood-scale UGIs provide independent protective effects. The health efficacy of nature-based solutions is governed by spatial accessibility and residential integration, not raw vegetation quantity. For rapidly aging, high-density megacities, strategic deployment of pocket parks, microforests, and green corridors constitutes a socio-ecological equalizer that advances health equity and climate resilience.

Limitations include aggregate-level ecological inference and lack of individual-level data. Future research should use high-resolution mobility sensors and cohort designs, develop standardized equity metrics, and bridge evidence to planning codes.

References

- [1] Kaczyńska, M. (2024). Urban green spaces' influence on civilization diseases—Meta-analysis and critical review. *Sustainability*, 16, 5900–5921.
- [2] Bianconi, A., Longo, G., Coa, A. A., Fiore, M., & Gori, D. (2023). Impacts of urban green on cardiovascular and cerebrovascular diseases—A systematic review and meta-analysis. *International Journal of Environmental Research and Public Health*, 20, 5966–5985.
- [3] Rahimi-Ardabili, H., Astell-Burt, T., Nguyen, P. Y., Zhang, J., Jiang, Y., Dong, G. H., & Feng, X. (2021). Green space and health in mainland China: A systematic review. *International Journal of Environmental Research and Public Health*, 18, 9937–9958.
- [4] Yitshak-Sade, M., James, P., Kloog, I., Hart, J. E., Schwartz, J. D., Laden, F., Lane, K. J., Fabian, M. P., Fong, K. C., & Zanobetti, A. (2019). Neighborhood greenness attenuates the adverse effect of PM_{2.5} on cardiovascular mortality in neighborhoods of lower socioeconomic status. *International Journal of Environmental Research and Public Health*, 16, 4785–4801.
- [5] Ma, X., et al. (2024). Quantifying the air pollutant attenuation effects of localized urban parks. *Environmental Pollution*, 340, 122810.
- [6] Wang, J., et al. (2023). Localized cooling effects of small-scale urban green islands based on high-resolution land surface temperature. *Remote Sensing*, 15(12), 3045.
- [7] Plans-Beriso, E., Gullón, P., Cebrecos, A., Fontán, M., Díez, J., Nieuwenhuijsen, M., & Franco, M. (2019). Density of green spaces and cardiovascular risk factors in the city of Madrid: The Heart Healthy Hoods Study. *International Journal of Environmental Research and Public Health*, 16, 4918–4929.
- [8] Lin, W. Y., Lin, P. Y., Wu, C. D., Liang, W. M., & Kuo, H. W. (2024). Urban–rural disparity in socioeconomic status, green space and cerebrovascular disease mortality. *Atmosphere*, 15, 642–659.
- [9] Xu, L., Ren, C., Yuan, C., Nichol, J. E., & Goggins, W. B. (2017). An ecological study of the association between area-level green space and adult mortality in Hong Kong. *Climate*, 5, 55–68.
- [10] Ihle, T., Jahr, E., Martens, D., Muehlan, H., & Schmidt, S. (2024). Health effects of participation in creating urban green spaces—A systematic review. *Sustainability*, 16, 5000–5023.
- [11] Twohig-Bennett, C., & Jones, A. (2018). The health benefits of the great outdoors: A systematic review and meta-analysis of greenspace exposure and health outcomes. *Environmental Research*, 166, 628–637.
- [12] Yeager, R. A., Smith, T. R., & Bhatnagar, A. (2020). Green environments and cardiovascular health. *Trends in Cardiovascular Medicine*, 30, 241–246.
- [13] Keith, R. J., Hart, J. L., & Bhatnagar, A. (2024). Greenspaces and cardiovascular health. *Circulation Research*, 134, 1179–1196.
- [14] Astell-Burt, T., & Feng, X. (2020). Urban green space, tree canopy and prevention of cardiometabolic diseases: A multilevel longitudinal study of 46,786 Australians. *International Journal of Epidemiology*, 49, 926–933.
- [15] Feng, X., Navakatikyan, M. A., Toms, R., & Astell-Burt, T. (2023). Leafier communities, healthier hearts: An Australian cohort study of 104,725 adults tracking cardiovascular events and mortality across 10 years of linked health data. *Heart, Lung and Circulation*, 32, 105–113.
- [16] Sun, S., Cao, W., Ge, Y., Ran, J., & Tian, L. (2023). Residential greenness and cardiovascular disease risk in Chinese adults: A prospective cohort study with mediation analysis. *Environmental Pollution*, 335, 122301.

- [17] Yang, Y., Jiang, Y., Xu, Z., Zhao, Q., & Liu, Q. (2024). Greenness and cardiovascular mortality in South China: A large-scale cohort study. *The Lancet Regional Health – Western Pacific*, 44, 101015.
- [18] Anguelovski, I., Cole, H. V. S., Connolly, J. J. T., Triguero-Mas, M., Baró, F., Martin, N., Conesa, D., Shokry, G., Del Pulgar, C. P., Matheney, A., Goh, C., Hrelja, I., Kotsila, P., Segura-Barrero, R., Oscilowicz, E., Honey-Rosés, J., Argüelles Ramos, L., Máñez Costa, M. (2025). Conditions for equitable urban greening. *Nature Cities*, 2, 210–219.