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EDITED BY
Zhibin Ren,
Chinese Academy of Sciences (CAS), China

REVIEWED BY
Rasha A Waheeb,
University of Baghdad, Iraq
Paula Andrea Zapperi,
Universidad Nacional del Sur, Argentina

*CORRESPONDENCE
Igor Zelnik
✉ igor.zelnik@bf.uni-lj.si

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Green-minded densification: designing resilient and sustainable cities

Barbara Goličnik Marušić[1], Manca Dremel[1], Damjan Marušić[2] and Igor Zelnik[3]*

[1]Urban Planning Institute of the Republic of Slovenia, Ljubljana, Slovenia, [2]Institute DIPSTOR Evolucija, Koper, Slovenia, [3]Department of Biology, Biotechnical Faculty, University of Ljubljana, Ljubljana, Slovenia

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Introduction

As cities grow denser, reconciling urban intensity with ecological and social quality becomes increasingly urgent. The question of whether a city can be both dense and green is often framed as a technical challenge. In reality, it is a conceptual one. Cities already know how to build densely and how to introduce greenery. What remains unresolved is how to meaningfully integrate the two without reducing one to a justification for the other.

In recent years, vegetation-covered buildings, green façades, planted balconies, and vertical forests have become powerful symbols of a sustainable urban future. They suggest that density and ecology are not only compatible but mutually reinforcing. Yet this image risks oversimplifying a far more complex relationship. If cities are to be both dense and green, urban greening must operate across multiple scales and be evaluated not only by how it looks, but by how it performs.

High-density development is often justified on environmental grounds: it reduces land consumption, limits urban sprawl, and supports public transport systems (e.g., Jenks et al., 1996; UN-Habitat, 2020). But at the scale of everyday life, density can come at a cost. Smaller apartments with limited private outdoor space and increased pressure on shared infrastructure can diminish the quality of living space per resident. This is where greenery becomes essential, not as an aesthetic supplement, but as a structural component of livability. Urban vegetation improves air quality (Diener and Mudua, 2021), reduces heat stress (Jia et al., 2026), absorbs noise (Łowicki et al., 2025), and contributes to psychological wellbeing (WHO, 2016; Elmqvist et al., 2015). In dense environments, these are not luxuries; they are compensatory mechanisms. However, a key tension emerges: as density increases, the availability of ground-level green space often decreases. This raises a critical question: can vertical greenery compensate for this loss? This paper explores whether a city can be both dense and green, arguing that success depends on a multi-scalar, evidence-based approach to urban greening.

The limits of vertical green

Vegetation integrated into high-rise buildings is frequently presented as a solution to land scarcity. Green façades, terraces, and rooftop gardens, as elements of vertical greenery, are expected to deliver environmental benefits while preserving buildable area. In principle, this is an attractive proposition. In practice, it is limited. Vertical greenery performs differently from ground-level green space. While it can contribute to shading, microclimate regulation, and localized air filtration, it does not easily replicate the social, ecological, and spatial functions of accessible urban green areas (Elmqvist et al., 2015). A planted balcony is not a public park. A green façade does not replace an urban forest. In our opinion, the biggest shortcoming of vertical green elements is that they do not contribute enough to the quality of living space per resident.

Moreover, the implementation of vertical greenery is far from neutral. It introduces significant economic and technical demands: structural reinforcement to support additional loads, irrigation systems, specialized planting techniques, and long-term maintenance regimes. These systems must comply with fire safety regulations and often require centralized management (Al-Kodmany, 2023; Perini and Ottelé, 2014), which can limit ecological spontaneity and adaptability. Vertical greening also has limited capacity to reduce air temperatures, which depend on the exposure of the wall, and to address urban stormwater management. Vertical greenings do not contribute to CO2 concentration reduction, and have, according to the life-cycle assessment of this product reverse effect (Dremel et al., 2023).

This raises an uncomfortable but necessary question: are we building ecosystems, or are we simulating them?

Greenwashing or green thinking?

The popularity of vegetation-covered buildings also reflects the persuasive power of greenery itself. Plants are widely associated with health, sustainability, and environmental responsibility. As a result, their presence in architecture can legitimize projects that may otherwise be environmentally questionable. This is where the risk of greenwashing becomes real. When greenery is applied as a visual layer rather than integrated as a functional system, it serves more as a narrative device than a meaningful intervention (Al-Kodmany, 2023). The building appears sustainable, but its overall environmental performance may tell a different story.

To move beyond this, we need clearer criteria. A genuinely green high-rise should:

- integrate planting systems from the earliest design stages,
- demonstrate long-term viability through maintenance and occupancy, and
- address the specific challenges of height and density, considering the physical characteristics of the area, its identity and keeping spatial coherence.

Without these conditions, vertical greenery risks remaining symbolic rather than transformative.

A multi-scalar approach: from buildings to urban systems

If the debate remains focused on individual buildings, it misses the larger picture. Urban greening must be understood as a multi-scalar system, operating simultaneously at the level of the building, the neighborhood, and the city. At the building scale, vertical greenery primarily contribute to environmental performance and visual identity. At the neighborhood scale, green courtyards, streets, and public spaces primarily support social interaction and local microclimates. On the city scale, green corridors, networks, and ecological infrastructures enable biodiversity and resilience.

The relationship between these scales is not additive, it is interdependent. Vertical greenery cannot compensate for the absence of accessible green space, but it can enhance a system in which such spaces already exist. This aligns with frameworks that emphasize linking nature-based solutions with spatial planning across scales (Goličnik Marušić et al., 2023). Here, we want to remind the decision-makers and planners of the need for greening with native plant species or assemblages to operate across multiple levels, emphasizing the interplay between vertical vegetation and ground-level green spaces. Native habitat types can further strengthen this approach by supporting biodiversity and resilience across all scales, from buildings to hinterlands. Dremel et al. (2023) presented native habitat types as a nature-based solution that represents the most resilient, particularly when the hydric deficit is concerned (Perillo et al., 2023), and sustainable form of greenery. Native habitat types, defined as plant communities with more complex canopy structures, also enable enhanced cooling effects (Jia et al., 2025). We also have to mention their role in preserving biodiversity, especially in horizontal elements, which can host a wider list of native plant species. Native habitat types would also host more native animal species, such as birds (Wang et al., 2025) and insects, increasing biodiversity.

Dynamic proportionality: a missing metric

One key challenge in this discussion is the lack of appropriate evaluation tools. Urban greening is often measured quantitatively (e.g., square meters of green space, number of trees, or percentage of coverage). While useful, these metrics fail to capture the quality and performance of green systems. To address this gap, this paper introduces the concept of dynamic proportionality, defined here as the adaptive and context-sensitive balance between urban density and the capacity, performance, and accessibility of green infrastructure over time. Rather than a fixed ratio, dynamic proportionality emphasizes that as cities densify, green infrastructure must not only increase in quantity but also evolve in intensity, diversity, and functionality—as a response or support to reintroduced built environment. This includes both horizontal expansion and vertical or hybrid integration, depending on spatial constraints; as well as a temporal component reflecting

TABLE 1 The following cases demonstrate that the relationship between density and green infrastructure is dynamic: the environmental and social performance of greenery evolves over time through ecological growth, adaptive management, and multifunctional integration into urban systems.

Project	What density enabled	Key green approaches	Greenery dynamics	Multifunctionality of greenery	Key lesson
Aspern Seestadt, Vienna, Austria, https://www.aspern-seestadt.at/en	High mixed-use density around public transport	Large open-space system, central lake and park, stormwater retention, tree-lined streets	Early phases were initially too paved, later intensive tree planting and shading strategies improved environmental performance over time	Cooling, water retention, wind reduction, recreation, biodiversity	Young trees do not immediately create high-quality environments; long-term canopy development is essential
Vauban, Freiburg im Breisgau, Germany https://www.freiburg.de/pb/208732.html	Medium-density compact housing with reduced car dependency	Shared green courtyards, bioswales, pedestrian-oriented design	Community greenery evolved slowly over decades through resident participation and vegetation growth	Shared gardens, social infrastructure, water infiltration, biodiversity	Social dynamics are part of green infrastructure performance
Hammarby Sjöstad, Stockholm, Sweden https://www.neighbourhoodguidelines.org/hammarby-sjstad-case-study	Dense waterfront redevelopment	Blue-green infrastructure, ecological water treatment, green promenades	Green systems planned together with the urban water cycle and environmental infrastructure	Water filtration, biodiversity, recreation, cooling	Natural systems can function as core urban infrastructure
Merwede, Utrecht, NL https://www.bura.city/en/projects/merwede/	Very dense low-carbon urban district	Shared gardens, green roofs, water-sensitive systems, car-light design	Planned long-term canopy growth and shading integrated into climate adaptation strategies	Mobility, ecology, energy, water management, social use	Represents a new generation of climate-responsive urbanism

growing characteristics of greenery and potential of the concept of managed vegetation succession, in which long-term stability, continuous canopy cover, and the functionality of green spaces are ensured through sequential planting, thinning, and replanting succession models.

In practice, dynamic proportionality can be observed in projects showing a wide range of established solutions for simultaneously increasing urban density and enhancing urban greening, which can be divided into "land sparing" and "land sharing" approaches (McDonald et al., 2023). The former focuses on preserving and protecting natural habitats (e.g., remnant ecosystems, riparian corridors, and designated conservation areas), planning parks, and developing green and blue-green infrastructure systems that support biodiversity while improving quality of life in dense urban settings. The latter approach involves sharing space between the built environment and nature, for example, through green roofs and facades, vegetation around buildings and streets, private gardens, and the reuse of degraded land for new green spaces. Together, these approaches demonstrate that density and green infrastructure are not necessarily in conflict—with appropriate urban planning and regulation, they can be effectively combined to create compact yet nature-rich urban environments (Samuelsson et al., 2021). Therefore, early integration of green infrastructure in planning is essential to achieve dynamic proportionality between densification and available green areas (Goličnik Marušić et al., 2023), a key measure of urban resilience and equitable quality of life.

Beyond the mentioned surface metrics, it advocates for qualitative indicators to assess socio-economic-ecological benefits, including increased shading, water retention, and biodiversity enhancement, providing a more holistic framework for evaluating urban greening strategies (Elmqvist et al., 2015; Haase et al., 2014). This requires moving beyond surface measurements toward more complex qualitative indicators, such as:

- shading capacity and reduction of heat stress,
- water retention and stormwater management,
- support for biodiversity,
- accessibility and usability for residents
- noise reduction and air quality improvement.

At the same time, strategies such as vertical greening, often promoted as a key solution in dense environments, should be approached critically. While they offer important benefits, including space efficiency and microclimatic regulation, they also present limitations related to maintenance requirements, cost, and uneven accessibility. In many cases, vertically integrated greenery may complement rather than substitute ground-level public green space, particularly in terms of social use and inclusivity. A balanced approach is therefore necessary, combining vertical, horizontal, and hybrid green systems.

Without such a proportional and multidimensional approach, densification risks producing spatial and social imbalances. Overburdened green spaces, reduced access to nature, and declining environmental quality can disproportionately affect urban populations, particularly in already dense areas (UN-Habitat, 2020; WHO, 2016). This is not only an environmental issue but a social one. Access to greenery is closely linked to health, wellbeing, and social cohesion (WHO, 2016). If green infrastructure does not keep pace with density, cities risk becoming more unequal as they become more compact (Table 1).

Conclusion: can a city be dense and green?

Yes, but not by default, and not by design shortcuts. A dense and green city is not achieved by adding plants to buildings after the fact. It requires:

- early integration of green infrastructure in planning,
- coordination across scales, from façades to regional systems,
- realistic acknowledgment of economic and technical constraints (Chau et al., 2025),
- and a shift from symbolic to performance-based evaluation (Goličnik Marušić et al., 2023).

It is important to consider economic and technical factors in the planning and maintenance of green areas, particularly vertical greenery. Vertical greenery has a role to play, but it is not a substitute for ground-level green space. It is one element within a broader system that must be carefully balanced and continuously maintained (Al-Kodmany, 2023). Densification without proportional expansion or enhancement of green spaces risks spatial and social imbalance. Ultimately, the question is not whether density and greenery can coexist, but whether cities are willing to treat greenery as infrastructure rather than ornament. Only then can the dense city also become genuinely green.

Author contributions

BGM: Conceptualization, Writing – original draft, Writing – review & editing. MD: Writing – original draft, Writing – review & editing. DM: Writing – original draft, Writing – review & editing. IZ: Writing – original draft, Writing – review & editing.

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