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An ecology of suboptimals? Lessons learned from balancing green and gray in cities

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> *"Suboptimal (adj.): of less than the highest standard or quality, not very good"*

Introduction

Biodiversity conservation in the Anthropocene is often afflicted with suboptimal situations in which humans' needs and nature's needs are imbalanced or even in conflict (Martin et al., 2016; Kortetmäki et al., 2021). In human-dominated landscapes, increasing land use intensification often results in the loss of large habitat patches, which are critical for metapopulation stability, being replaced by a landscape composed of smaller and sometimes isolated habitat patches (Tilman et al., 2017; Díaz et al., 2019). Island Biogeography Theory would thereby predict that, in such situations, we would find low biodiversity (Tilman et al., 2017; Díaz et al., 2019) and thus conservation might be considered suboptimal (Riva and Fahrig, 2022). In cities–especially those experiencing rapid human population growth and the densification of built infrastructure–this situation may be at its most extreme: urban nature is at risk of loss due to the horizontal and vertical expansion of built infrastructure, habitat fragmentation is exacerbated, and adding large habitat areas is often unfeasible. Urban biodiversity conservation may face a situation in which small urban green spaces, including balconies, home and allotment gardens, small forest patches, and green walls, are the primary available compensatory interventions to retain habitats and support biodiversity. However, under certain conservation frameworks (e.g., land-sparing vs. land-sharing; Single Large or Several Small ('SLOSS')) (Fahrig, 2020; Riva and Fahrig, 2022), such small urban green spaces spread out across the landscape may be predicted to have suboptimal or even detrimental outcomes for biodiversity, for example, if their size and isolation prevent them to maintain viable population sizes (Haddou et al., 2022; Ancillotto et al., 2025). Thus, this ecology of suboptimals, which we present as a metaphorical framing, can result in a futile perspective on the possibilities for nature and its conservation in densifying cities. This perspective may lead to undesirable outcomes for effective biodiversity conservation measures and a Herculean effort, or a perceived impossibility, of supporting green space in the built environment.

And yet, we may also find optimism in rethinking, imagining, and building urban environments that harness this "ecology of suboptimals". In this perspective, we critically analyze the challenge to balance both green and gray, to balance both the needs of people and nature in dense and densifying cities via the implementation of small urban green spaces, which might be seen as unconventional from a traditional conservation perspective (Mace, 2014). We argue that implementing such green spaces, regardless of the degree of optimality, is better than not implementing anything at all. But even within the field of conservation, such actions in small and diverse forms can

accumulate to provide habitat within the cityscape, sustaining biodiversity and ecosystem functioning as well as providing positive contributions to city residents, rather than merely being suboptimal actions from a pure conservation perspective. A more positive perspective, we argue, is one in which an ecology of "suboptimal" urban greening actions can be amplified across city landscapes in diverse forms by diverse people to have a meaningful impact (Casanelles-Abella and Egerer, 2025), while also not forgetting more "optimal" conservation activities that can be carried out alongside (Klaus, 2013; Klaus and Kiehl, 2021; Croeser et al., 2022; Segar et al., 2022). We provide three dimensions–preserving, transforming, and creating urban green space within (dense) urban landscapes (Figure 1)–each offering valuable insights into how the balance between green and gray can be effectively achieved.

Preserve existing small and valuable urban green spaces

Several cities already have many important habitat patches of small green spaces that are crucial for balancing green and gray areas. These include allotment gardens, pocket prairies and remnant forest patches. These patches may often be contested due to building development (e.g., community gardens as temporary use (Egerer et al., 2024b); vacant lots being lost (Mogk et al., 2010; Turo et al., 2021), and hence, their preservation should nevertheless be maximized as much as possible. For example, despite their substantially smaller extent, vacant lots, brownfields, and pocket prairies can support a similar arthropod abundance and taxonomic richness as larger urban grasslands–including rare native species (Gardiner et al., 2013; Pham et al., 2025). In the urban forest of Brazilian cities, 20% of tree species used in city squares are endemic to the Atlantic forest and are of conservation value (Freitas et al., 2020). Urban gardens, such as community gardens, home gardens and allotments, present in many cities worldwide, contain a mix of cultivated and wild plants (Frey and Moretti, 2019; Sexton et al., 2023), and this "land sharing" among plants for people via food and aesthetics and nature conservation via habitat provision can in turn support diverse animal communities (Tew et al., 2022; Casanelles-Abella et al., 2023; Felderhoff et al., 2023; Rotondi et al., 2023; Neumann et al., 2024). In sum, these diverse forms of green spaces should be preserved as habitat in the landscape for their valuable contribution to biodiversity.

Transform existing urban green spaces

The transformation of existing urban space is a cost-effective way to enhance habitats without introducing significant changes to the city landscape, especially where space is limited or unfeasible. This involves, for example, working on existing green spaces where features could be modified with minimal interventions, such as relaxing or reducing management intensity or redesigning, rehabilitating and restoring areas with natural features (Klaus, 2013; Klaus and Kiehl, 2021). Reduced mowing in urban green spaces like parks, tree pits or sidewalk verges can reduce disturbance, create habitat niches as low-management "oases" and thereby support a higher diversity of plants and associated animal communities (Vega and Küffer, 2021; Lundquist et al., 2022; Berger et al., 2024). Adding flower strips, meadows, or patches within existing green spaces can provide food and shelter resources, benefiting biodiversity (Ulrich and Sargent, 2025). For example, in post-industrial cities, transforming so-called "vacant land" using native flowering plants into valuable wild bee habitat can lead to higher wild bee foraging and thereby add conservation value within these spaces (Anderson and Minor, 2017; Pham et al., 2025; Dennison et al., 2026). Restoration activities, such as of the once highly polluted Detroit River through decontamination and the reintroduction of diverse native wetland species, have been a major success story in ecological transformation of green and blue space (Hartig and Wallace, 2015). Here, renaturalized urban shorelines lined with recreational and educational boardwalks serve as a nexus between contemporary Detroit, a history of economic/industrial plight, and social and ecological resilience. At a much smaller scale yet also valuable, are native plant gardening within tree pits through citizen-led "grassroots" initiatives as a co-creative practice to transform common and prevalent–but usually degraded–spaces into social-ecological valuable small green spaces that traverse city landscapes (Egerer et al., 2024c,a), and which can have a cumulative effect in providing habitat. In sum, from large to small, such actions are ways to harness potentially suboptimal situations of polluted or degraded habitats, small areas, etc., to support larger goals around the ecological transformation of existing green spaces to optimize their biodiversity benefits.

Create new small urban green spaces

The creation of new green spaces can take the form of green roofs, balcony gardens, raised beds on city squares, green walls on buildings, among others. These novel urban ecosystems–or "nature of the third kind" (Kowarik, 2011)–are often seen as suboptimal due to their inherent biophysical restrictions; these systems are often disconnected from (parent) soil material and/or soil substrate is at a minimum, involve high social investment (e.g., via irrigation), and rely on technical or built infrastructure in their design or function (Lin et al., 2018). Such created systems can be considered *social-ecological-technological* systems that are, in essence, confined within the built infrastructure in which they are created (Keeler et al., 2019; McPhearson et al., 2022). Nevertheless, such novel ecosystems created potentially on top of built infrastructure can still have conservation value through their support of biodiversity and ecosystem function. For example, pop-up grasslands created on wooden slabs in Melbourne, Australia, increased arthropod species richness over 6 weeks (Mata et al., 2019). Studies on the value of green roofs for biodiversity–roofs with a vegetated surface and substrate supporting any kind of vegetation (Oberndorfer et al., 2007; Braaker et al., 2014)–have found that they can significantly increase biodiversity (plants, arthropods, birds) in relation to their conventional counterpart (Filazzola et al., 2019). For example, in Sydney, Australia, in comparison to bare roofs, green roofs supported 4x the avian diversity, 7x the arthropod diversity, and 2x the gastropod diversity, and locally rare species (Wooster et al., 2022). Even small balconies have been found to support ecologically important wind-dispersed plant species: using a citizen science approach in Zurich, Switzerland, Vega et al. (2021) found 37 plant

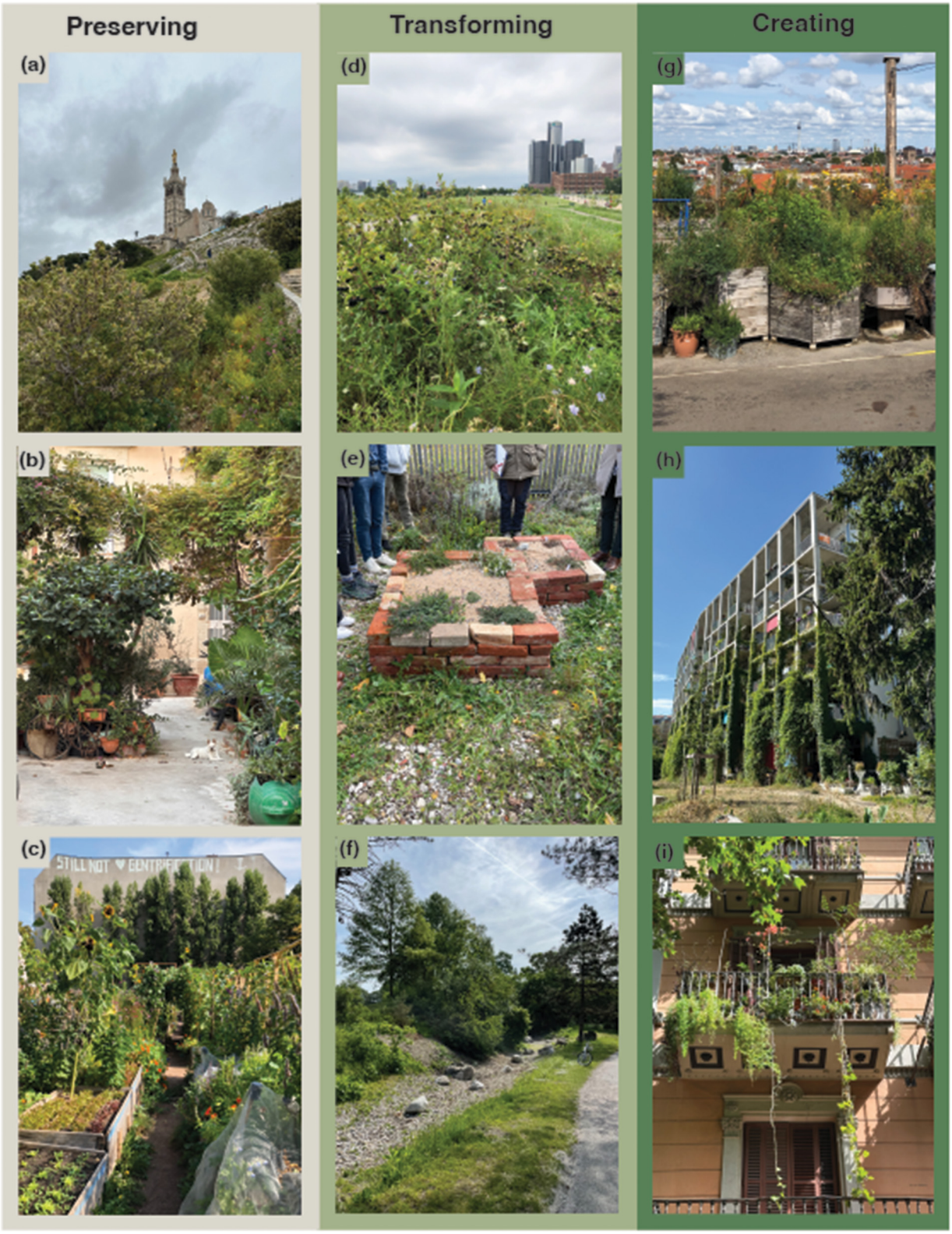

FIGURE 1
Examples of creating, transforming and preserving small urban green spaces. Preserving: **(a)** Jardin du bois sacré, Marseille, France; **(b)** street garden in Siracusa, Italy; **(c)** community garden in Berlin, Germany. Transforming: **(d)** rehabilitated wetland in Detroit, USA; **(e)** small habitat in a ruderal site, Munich, Germany; **(f)** restored margin in a park in Munich, Germany. Creating: **(g)** rooftop garden in Berlin, Germany; **(h)** green spaces in a cooperative housing unit in Geneva, Switzerland; **(i)** a balcony in Barcelona, Spain.

species from 15 families, most native to Switzerland, colonized bare soil trays across the participating 80 balconies.

In sum, creating novel habitats that are low-bar or easy to integrate into gray space could, if high in numbers and connected across a landscape, have a positive aggregate effect on biodiversity while also improving the aesthetic quality of the dense landscape (Hernandez-Santin et al., 2022; Kabisch and Egerer, 2025). Yet, it is important to note that such novel ecosystems like green roofs and green walls can support and benefit biodiversity to some extent–often of generalist species or native plants (Lee et al., 2014), but cannot replace natural habitats or more complex urban green spaces (Wang et al., 2022). Now, we turn to summarizing lessons learned on potential promises and challenges of such green spaces in dense cities.

Balancing opportunities and challenges

While opportunities exist in the preservation, transformation, and creation of green spaces, several challenges and limitations also arise. From an ecological perspective, such small urban green spaces are not a panacea that will support overall biodiversity; rather, their importance will depend on the taxa, with certain groups being more benefited than others, as seen in general terms for cities (Theodorou et al., 2020). Yet, any habitat will satisfy the niche of a subset of the available species. Furthermore, the degree of isolation represents a main challenge, and in the context of densifying cities, this degree could worsen, leading to negative consequences such as the creation of ecological traps (Zuñiga-Palacios et al., 2021). Accordingly, small urban green spaces should not be conceived as discrete, independent units, but rather as components of a broader, interconnected urban landscape (LaPoint et al., 2015). This includes considering where important habitat patches are within a landscape where ecological connectivity can be optimized, and strategically integrating additional green spaces both in these areas and in parts of the landscape where connectivity among patches is currently weak (Huang et al., 2021).

In addition, particularly in highly engineered urban green spaces where human decisions, behaviors and actions play a major role in community assembly, special care must be taken to provide adequate habitat quality, structural diversity and resource availability, while avoiding exacerbating existing problems such as the erosion of genetic diversity and facilitation of biological invasions (Shochat et al., 2010; Cadotte et al., 2017, 2021; González-Lagos et al., 2021). For example, plant selection, habitat design and maintenance regimes are essential to maximize ecological value, and strategies to promote good practices are critical.

The long-term viability of small urban green spaces is another main challenge. First, they might be exposed to urban stressors, including heat, pollution, soil compaction, water scarcity, and frequent (Kayhanian et al., 2012; Filazzola et al., 2019). Moreover, the surrounding landscape might also be very dynamic, particularly in the context of densification. For example, ground-level urban green spaces, such as small ruderal sites or community gardens, might lose connectivity, sunlight or access to water due to new or expanding built infrastructure (Volf et al., 2024). Management and human investment (Avolio et al., 2021; Swan et al., 2021), especially when establishing adequate stewardship (Egerer et al., 2024c), can counteract this problem. However, the involvement of people is not necessarily temporally guaranteed. For example, managers of small urban green spaces might have dynamic levels of interest, time and capacity (Mohr-Stockinger et al., 2023). For example, gardeners in a community garden or an allotment community might vary and with them, their preferences, experience and behaviors. In addition, ownership of small urban green spaces may also be dynamic or even contested, as seen in the cases of community gardens (Egerer et al., 2024b) or vacant lots (Anderson and Minor, 2017). In this regard, certain small urban green spaces may be particularly vulnerable, such as balconies and terraces used for greening, which can be lost when residents move out—a trend that can be intensified in cities where housing units increasingly shift from long-term residences to tourist or short-term rentals (Wrede, 2022).

Additionally, equitable distribution is crucial, as the benefits of small green spaces–such as improved mental health, opportunities for food growing, or enhanced microclimates (Astell-Burt and Feng, 2019; Egerer et al., 2024a; Qiu et al., 2024)–tend to accrue unevenly across neighborhoods (Schell et al., 2020; Burghardt et al., 2023; Casanelles-Abella et al., 2025). At the same time, small urban green space greening might be a cost-effective alternative to improve uneven distribution and access to urban nature, as small urban green spaces might be less prone to triggering green gentrification, unlike other forms of urban greening (Anguelovski et al., 2019; Triguero-Mas et al., 2022). Notably, the relationships between different forms of urban greening and social and economic processes, such as segregation and gentrification, in a densification context remain unclear. Uncovering such relationships is critical to successfully implement small urban green spaces that are inclusively planned, ecologically informed, and supported by community engagement and policy frameworks.

Overall small urban green spaces should be viewed as complementary efforts to enhance a complex and dynamic cityscape, rather than low-hanging fruit solutions that can replace existing large spaces or compensate for continued densification without limit.

Assessing and quantifying these thresholds is a critical need in densifying cities, as well as preserving large-sized urban green spaces and enhancing connectivity (Donati et al., 2022, Perrelet et al., 2025).

A final challenge lies in governance and socio-economic dimensions, particularly as many of these spaces rely heavily on private initiatives and unpaid or voluntary labor. While such arrangements can foster local ownership and engagement, they also raise questions regarding governance capacity, institutional responsibility, and accountability. To ensure positive and lasting effects, greater attention needs to be paid to how public institutions can support, complement, or formalize these initiatives without undermining their grassroots character. The development of long-term funding and maintenance models remains a critical consideration, as the absence of stable support can limit continuity and impact. Addressing these dimensions does not imply a single or clear pathway forward but rather underscores the importance of context-sensitive

governance arrangements that balance flexibility with institutional support to enhance the broader contribution of small urban green spaces.

Conclusion

The trade-offs of accommodating a large urban population and maintaining existing urban living standards while preserving non-urban ecosystems are prompting many cities to densify, often at the expense of existing urban green spaces, whether formal or informal. In such a complex context, we discussed the value of small urban green spaces as, at least partially, offsetting actions for urban nature and people. Compelling evidence shows that, across contexts, once urban density surpasses certain thresholds, it can have profound negative impacts on urban biodiversity (Groffman et al., 2014; La Sorte et al., 2018; Villalta et al., 2022), ecological and evolutionary processes (Ellis et al., 2023; Casanelles-Abella et al., 2024), ecosystem services (Grêt-Regamey et al., 2020), and human wellbeing (Engemann et al., 2019), which might be in some cases irreversible. Although we cannot fully predict what increasingly dense cities will look like, current trends already offer a glimpse of what awaits ahead. As William Gibson allegedly remarked, "*the future is already here—it's just not very evenly distributed.*" In this context, finding ways to counteract and balance ongoing densification is urgently needed. Small urban green spaces have several features that portray them as rather suboptimal, as we have presented. Yet, densifying cities might become increasingly gray while waiting for the development of optimal compensatory greening actions. Hence, an alternative scenario to graying cities does not have to be perfect–if perfect is even possible–but preferable. Small urban green spaces have the potential to be this preferable alternative, and rather than asking whether they are suboptimal, it might be more productive to ask how their social and ecological value can be maximized for the benefit of people and nature (Kowarik et al., 2025). Given the challenges of the Anthropocene, the consequences of not exploring solutions should be too troubling to not pragmatically use all tools–in small and large formats, suboptimal and optimal–in the urban greening toolbox.

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