Available online at www.agrifarming.org

DOI: http://dx.doi.org/10.18782/2582-7146.321

ISSN: 2582 – 7146

Current Research in Agriculture and Farming

Curr. Rese. Agri. Far. (2022) *3*(1), 16-24

Review Article

Peer-Reviewed, Refereed, Open Access Journal

Sustainable Landscaping Practices for Urban Green Spaces: Trends, Challenges, and Future Prospects

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Received: 14.12.2021 | Revised: 19.01.2022 | Accepted: 4.02.2022

ABSTRACT

Rapid urbanisation has intensified ecological degradation, heat-island formation, and biodiversity loss across cities worldwide, making sustainable landscaping of urban green spaces (UGS) a critical research and policy priority. Six core practices are examined: use of native and climate-adapted plants, water-efficient xeriscaping, organic soil management, green roofs and vertical gardens, permeable pavements and rain gardens, and integrated pest management. Evidence indicates substantial ecosystem-service benefits, including thermal regulation, stormwater attenuation, carbon sequestration, and improved psychological well-being. Persistent challenges relate to funding, governance, water scarcity, and invasive species. Future prospects centre on nature-based solutions, smart-irrigation technologies, biodiversity-sensitive design, and citizen participation to deliver climate-resilient, equitable, and biologically diverse cities.

Keywords: *Urban green spaces; sustainable landscaping; green infrastructure; biodiversity conservation; climate-resilient cities.*

INTRODUCTION

More than half of the global population now resides in urban areas, and this share is projected to exceed two-thirds by 2050 (United Nations, 2019). Such accelerated urbanisation has compressed natural habitats, increased impervious cover, and amplified environmental stressors including the urban heat-island effect, air pollution, stormwater flooding, and biodiversity decline (Haaland & van den Bosch, 2015). Urban green spaces (UGS)—parks, gardens, street trees, green roofs, and vegetated buffers—have therefore emerged as indispensable components of resilient and liveable cities. Their planning and maintenance, however, must transition from conventional, resource-intensive approaches to sustainable landscaping that minimises ecological footprints while maximising ecosystem services.

Cite this article: Pathak S. K. (2022). Sustainable Landscaping Practices for Urban Green Spaces: Trends, Challenges, and Future Prospects, *Curr. Rese. Agri. Far. 3*(1), 16-24. doi: http://dx.doi.org/10.18782/2582-7146.321

Sustainable landscaping is broadly defined as the design, installation, and management of vegetated landscapes in ways that conserve resources, protect biodiversity, and enhance ecological function (Calkins, 2012). It integrates principles of ecological design, water-wise horticulture, organic soil management, and biodiversity-friendly plant selection. The World Health Organization (WHO) recommends a minimum of 9 m² of accessible green space per capita, with an ideal target of 50 m² (Russo & Cirella, 2018), highlighting the public-health relevance of this domain.

Mitchell (2017) emphasises that sustainability in landscape architecture is not a static endpoint but a continuously evolving framework that must respond to climate change, demographic pressure, and shifting social values. The present review synthesises evidence published up to 2022 on (i) the principal sustainable landscaping practices applied in urban green spaces, (ii) emerging trends, (iii) major challenges constraining adoption, and (iv) future prospects for research and policy.

Figure1. Six core components of sustainable urban landscaping practices

3. Core Sustainable Landscaping Practices

3.1 Native and Climate-Adapted Plant Selection

The use of indigenous and climate-adapted species is the cornerstone of sustainable landscaping. Native plants are evolutionarily attuned to local soils, rainfall, and pollinator communities, requiring less irrigation, fertiliser, and pesticide than ornamental exotics (Tallamy, 2007). Burghardt et al. (2009) demonstrated that suburban yards dominated by native vegetation supported four times the abundance and diversity of breeding birds compared with conventionally landscaped properties. Selection must also avoid invasive species and high biogenic-volatile-organic-compound emitters along busy roads (Russo & Cirella, 2018). In tropical and subtropical contexts, regionally adapted species such as Azadirachta indica, Pongamia pinnata, and Ficus religiosa provide simultaneous benefits of shade, carbon sequestration, and cultural value, while in temperate cities oaks, maples, and lindens support hundreds of associated invertebrate taxa (Tallamy, 2007). Effective plant palettes are increasingly assembled using ecological-niche modelling and reference-ecosystem analogues, which forecast species performance under projected climate envelopes rather than relying on historical hardiness zones alone.

3.2 Water-Efficient Design and Xeriscaping

Xeriscaping—landscaping that drastically reduces or eliminates supplemental irrigation—originated in semi-arid Denver in the early 1980s and has since spread globally. Sovocool et al. (2006) reported average annual water savings of 30 % when conventional turf-grass yards were converted to xeric designs in Las Vegas. Complementary tools include drip and sub-surface irrigation, soil-moisture sensors, mulching, and rainwater harvesting. Mitchell (2017) notes that climate-smart irrigation scheduling can reduce landscape water consumption by an additional 20–50 % without compromising plant health. The seven established xeriscape principles—planning and design, soil improvement, appropriate plant selection, practical turf areas, efficient irrigation, mulching, and appropriate maintenance—provide a structured decision-making sequence that can be transferred across climatic zones (Sovocool et al., 2006). Greywater recycling and stormwater harvesting into cisterns further decouple landscapes from potable-water supplies, an issue of growing importance in cities such as Cape Town, Chennai, and Phoenix that experienced acute water emergencies between 2015 and 2022.

3.3 Soil Health and Organic Amendments

Healthy soils underpin every other landscape function. Composting of urban organic waste, application of biochar, and mycorrhizal inoculation enhance soil structure, water-holding capacity, and nutrient cycling while sequestering carbon (Lal, 2018). Avoidance of synthetic fertilisers reduces nitrate leaching to urban water bodies, and maintenance of mulched soil surfaces decreases evaporation and weed pressure. Urban soils are frequently compacted, contaminated, and depleted of organic matter; remediation strategies that combine deep tilling, phytoremediation with hyperaccumulator species, and progressive incorporation of mature compost can restore biological activity within three to five growing seasons (Calkins, 2012). Closed-loop nutrient cycling—wherein landscape pruning, leaf litter, and food waste are composted on-site and returned to planting beds—reduces dependence on imported inputs and lowers the overall carbon footprint of landscape maintenance.

3.4 Green Roofs and Vertical Gardens

Green roofs and living walls retrofit vegetation onto built surfaces, recapturing ecological function in densely built environments. Berardi et al. (2014) reviewed energy and hydrological performance of green roofs and reported summer indoor-temperature reductions of 0.4–4 °C and stormwater retention of 40–80 % depending on substrate depth. Vertical greenery systems further attenuate façade temperatures and improve outdoor air quality (Manso & Castro-Gomes, 2015). Figure 4 illustrates the multilayered structure of an extensive green roof.

3.5 Permeable Pavements and Rain Gardens

Conventional impervious surfaces drive flash flooding and waterway pollution. Permeable interlocking concrete pavers, porous asphalt, and bioretention basins—commonly designed as rain gardens—mimic natural hydrology by allowing infiltration and pollutant filtration (Dietz, 2007). Rain gardens planted with deep-rooted native perennials can capture 30–99 % of suspended sediments, metals, and hydrocarbons before runoff reaches sewers.

3.6 Integrated Pest Management

Integrated pest management (IPM) combines biological, cultural, mechanical, and chemical controls into a tiered strategy that minimises reliance on synthetic pesticides. In urban landscapes, IPM protects pollinators, reduces chemical drift, and lowers long-term maintenance costs (Flint, 2012). Diverse plantings, conservation of natural enemies, and threshold-based intervention are central tenets. Monitoring through pheromone traps, scouting transects, and degree-day models enables interventions timed to pest biology rather than calendar schedules. Where chemical controls are required, IPM prioritises reduced-risk products such as horticultural oils, insecticidal soaps, and biological agents like Bacillus thuringiensis, applied with minimal off-target exposure.

4. Ecosystem Services Delivered by Sustainable Urban Landscapes

Sustainable landscapes generate a portfolio of provisioning, regulating, supporting, and cultural ecosystem services. Bolund and Hunhammar (1999) catalogued seven categories of urban ecosystem services, including microclimate regulation, noise dampening, and aesthetic value. Nowak et al. (2014) estimated that urban trees in the conterminous United States remove approximately 17.4 million tonnes of air pollutants annually, valued at US$6.8 billion in avoided health costs.

Bowler et al. (2010), in a meta-analysis of 22 studies, found that parks were on average 0.94 °C cooler than surrounding built-up areas during the day, with effects extending several hundred metres beyond park boundaries. Property-value premiums for residences adjacent to well-maintained green space range between 7 % and 20 % (Crompton, 2001). Figure 2 summarises representative magnitudes of these benefits.

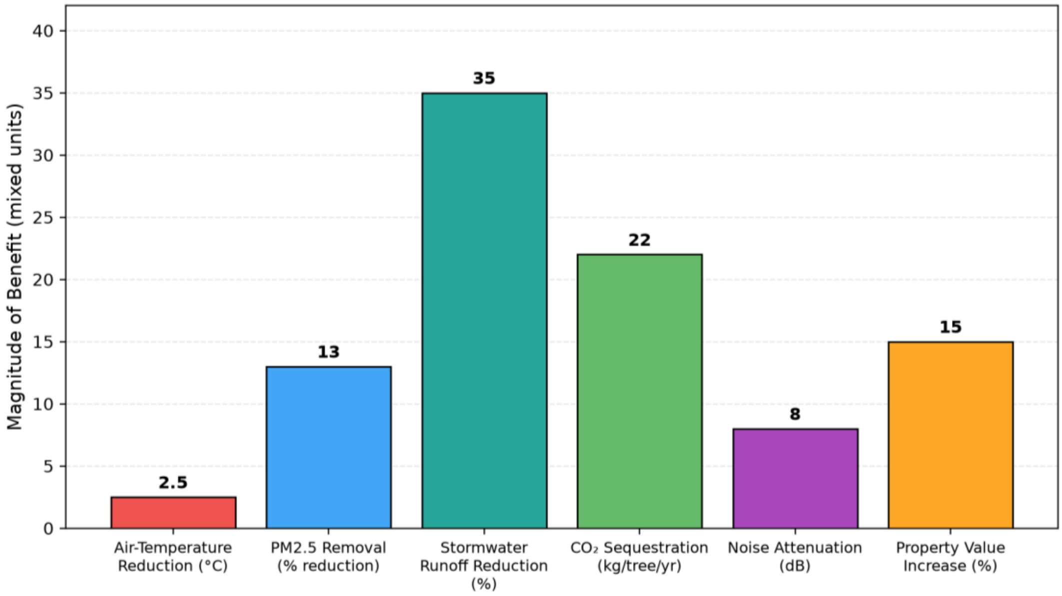

Figure2. Representative ecosystem services delivered by urban green spaces (synthesised from Bolund & Hunhammar, 1999; Nowak et al., 2014; Bowler et al., 2010)

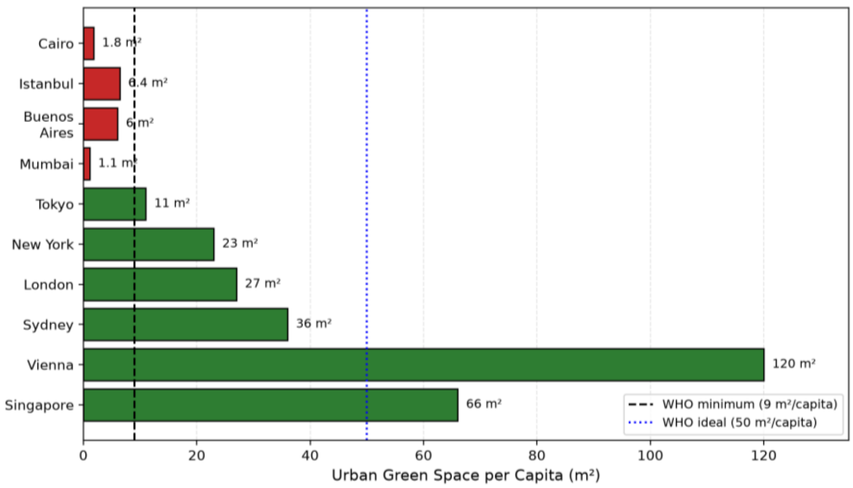

Figure3. Urban green space per capita in selected global cities, benchmarked against WHO minimum (9 m²) and ideal (50 m²) thresholds; data compiled from published sources up to 2022

4.1 Human Health and Well-being

Beyond purely ecological metrics, sustainable urban landscapes confer substantial public-health benefits. Systematic reviews have linked exposure to neighbourhood greenness with reduced all-cause and cardiovascular mortality, lower incidence of type 2 diabetes, healthier birth outcomes, and improved mental health (Hartig et al., 2014). Even brief visits to vegetated parks measurably reduce salivary cortisol, blood pressure, and self-reported stress, while supporting physical activity and social cohesion. During the COVID-19 pandemic of 2020–2022, accessible green space emerged as a critical refuge, underscoring its role in community resilience.

Children with proximity to vegetated environments display better cognitive development and attention restoration, while older adults benefit from improved mobility and reduced loneliness (Wolch et al., 2014). These findings reinforce the argument that sustainable landscaping is not a discretionary amenity but a fundamental component of urban public-health infrastructure.

4.2 Illustrative Global Case Studies

Singapore's 'City in a Garden' programme has integrated extensive skyrise greenery, biodiversity corridors, and Active-Beautiful-Clean Waters initiatives, achieving more than 47 % canopy cover by 2020 and demonstrating that high-density urbanisation and ecological abundance can coexist. Berlin's biotope-area-factor regulation requires every new development to deliver a minimum proportion of biologically effective surface, institutionalising green roofs and permeable paving as standard practice. Curitiba, Brazil, expanded per-capita green space from less than 1 m² in 1970 to over 50 m² by the early 2000s through integrated park-and-floodplain planning, providing a widely cited model for resource-constrained cities (Russo & Cirella, 2018). In India, Bengaluru's Lalbagh and Cubbon Park, together with the urban-forestry programme of Chandigarh, illustrate how heritage green spaces can be coupled with contemporary biodiversity management to deliver sustained ecological and cultural value.

5. Emerging Trends (up to 2022)

Five interrelated trends have shaped sustainable urban landscaping in the past two decades. First, nature-based solutions (NbS) have been formally adopted in policy frameworks of the European Union, the World Bank, and the IUCN, positioning landscaping as a tool for climate adaptation and disaster risk reduction (Cohen-Shacham et al., 2016). Second, biophilic urban design—rooted in the work of Beatley (2011)—has popularised the integration of greenery into building façades, transit corridors, and public realms. Third, smart-irrigation and sensor-driven horticulture have reduced water demand while improving plant health, leveraging Internet-of-Things technologies.

Fourth, urban agriculture and edible landscaping have re-emerged through community gardens, rooftop farms, and orchard parks, reconnecting citizens with food systems (Lin et al., 2015). Finally, pollinator-friendly landscaping has gained traction in response to global insect declines, with cities such as Oslo, London, and Toronto adopting pollinator pathways and bee-corridor strategies up to 2022 (Hall et al., 2017).

6. Challenges

6.1 Funding and Maintenance Gaps

Even when capital funds are secured, long-term maintenance budgets are frequently inadequate, leading to degraded landscapes and erosion of public trust (Haaland & van den Bosch, 2015). Performance-based maintenance contracts and dedicated green-space levies have been proposed as remedies.

6.2 Land-Use Conflicts and Urban Densification

Compact-city policies, while reducing transport emissions, compete with land allocation for parks and gardens. Russo and Cirella (2018) caution that densification without parallel greenery provisioning can reduce per-capita UGS below WHO minimum thresholds, with documented health consequences.

6.3 Climate Change and Water Stress

Increasing temperatures, erratic rainfall, and prolonged droughts stress urban vegetation, especially in Mediterranean, semi-arid, and tropical-monsoon climates. Mitchell (2017) advocates climate-adaptive species palettes and assisted species migration to maintain canopy resilience.

6.4 Invasive Species and Pest Outbreaks

Globalisation of horticultural trade has accelerated invasive-species establishment. Emerald ash borer, Asian longhorned beetle, and box-tree moth have devastated urban canopies in North America and Europe since the 2000s (Tobin, 2015).

6.5 Equity and Environmental Justice

Access to high-quality green space is unevenly distributed across socio-economic and ethnic groups. Wolch et al. (2014) documented the 'green-space paradox', whereby well-intentioned greening can trigger ecological gentrification, displacing the very residents intended to benefit. Equity-centred planning frameworks are essential.

6.6 Policy and Governance Fragmentation

Sustainable landscaping cuts across municipal departments—planning, water, transport, and public works—making cross-sector coordination difficult. Lack of standardised performance metrics further complicates evaluation (Hansen & Pauleit, 2014).

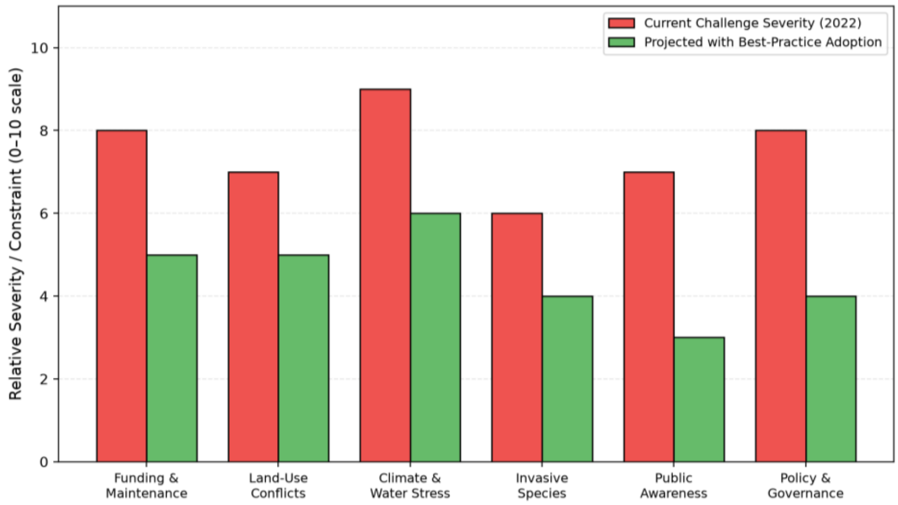

Figure4. Key challenges (2022 baseline) and projected improvement following adoption of best-practice sustainable landscaping interventions

7. Future Prospects

Looking beyond 2022, several research and practice frontiers will define the next era of sustainable urban landscaping. Climate-adaptive species palettes informed by ecological-niche modelling will replace static plant lists, ensuring resilience under projected warming. The convergence of remote sensing, geographic information systems, and machine learning will allow city-scale monitoring of canopy cover, urban heat exposure, and biodiversity in near real time (Wu, 2014). High-resolution LiDAR and multispectral satellite imagery, paired with deep-learning classifiers, now permit automated detection of individual trees, species attribution, and quantification of carbon stocks at street-block resolution, transforming the evidence base available to urban foresters and planners.

Performance-based green-space standards—measuring services such as cooling, infiltration, and habitat value rather than mere area—are anticipated to gain regulatory traction. Citizen science and community stewardship will deepen, leveraging mobile applications for tree-inventory, pollinator monitoring, and invasive-species reporting. Finally, the integration of blue and green infrastructure—linking rivers, wetlands, and parks into multifunctional corridors—holds promise for simultaneously addressing climate, biodiversity, and well-being objectives (Cohen-Shacham et al., 2016).

At a policy level, the alignment of sustainable landscaping with the United Nations Sustainable Development Goals—particularly Goal 11 on sustainable cities and Goal 15 on life on land—offers a powerful mandate for mainstreaming green-space investment. Financing mechanisms such as green bonds, biodiversity offsets, and payment-for-ecosystem-services schemes can mobilise resources at scale, while public–private partnerships are well suited to long-horizon maintenance commitments. Educational integration is equally critical: training programmes for landscape architects, municipal horticulturists, and community volunteers must keep pace with the rapidly evolving science of urban ecology, ensuring that practice on the ground reflects the most current evidence.

Equity must be embedded as a non-negotiable design criterion. Indices that measure park access and greenness distribution allow planners to identify under-served neighbourhoods and direct investment to where it is most needed (Wolch et al., 2014). Genuinely participatory co-design processes that include residents, schools, and indigenous knowledge holders strengthen ecological outcomes and foster long-term stewardship, helping to avoid the displacement effects associated with green gentrification.

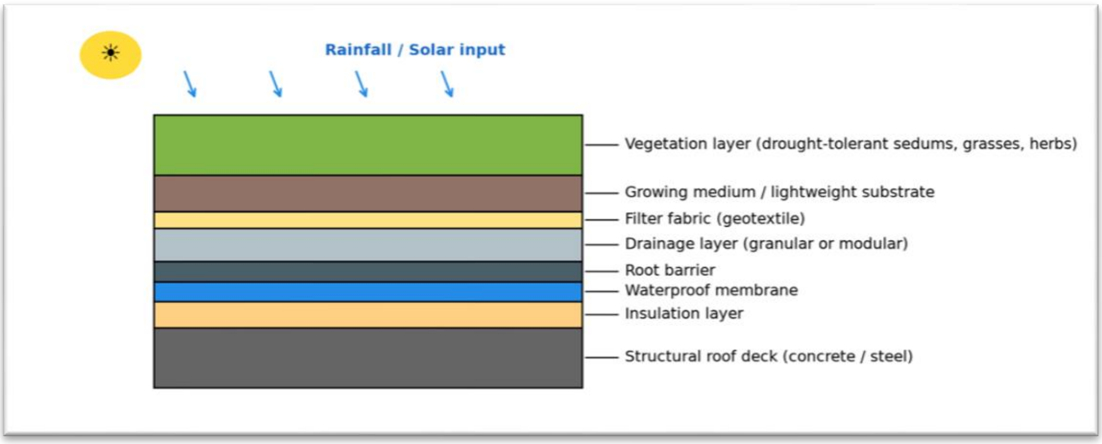

Figure5. Cross-sectional schematic of an extensive green roof system showing key functional layers

CONCLUSION

Sustainable landscaping of urban green spaces is no longer an aesthetic luxury but an ecological and public-health imperative. Evidence accumulated up to 2022 demonstrates that integrating native plant communities, water-wise design, healthy soils, green roofs, permeable surfaces, and integrated pest management can deliver substantial co-benefits across climate adaptation, biodiversity, and human well-being. Yet adoption is constrained by funding gaps, governance fragmentation, climate stressors, invasive species, and inequitable access. Realising the full potential of sustainable urban landscaping will require performance-based standards, cross-sector governance, climate-adaptive species selection, and meaningful community participation. As cities navigate the converging crises of climate change, biodiversity loss, and rapid urbanisation, sustainable landscaping offers one of the most tangible and cost-effective tools for cultivating ecologically vibrant, socially just, and climate-resilient urban futures.

Acknowledgements:
The author would like to acknowledge to all of the staff of the Department of Agriculture Govt. of Bihar.

Funding:
No financial support was received.

Conflict of Interest:
The author declare no conflicts of interest.

Author Contributions:
Not Applicable.

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