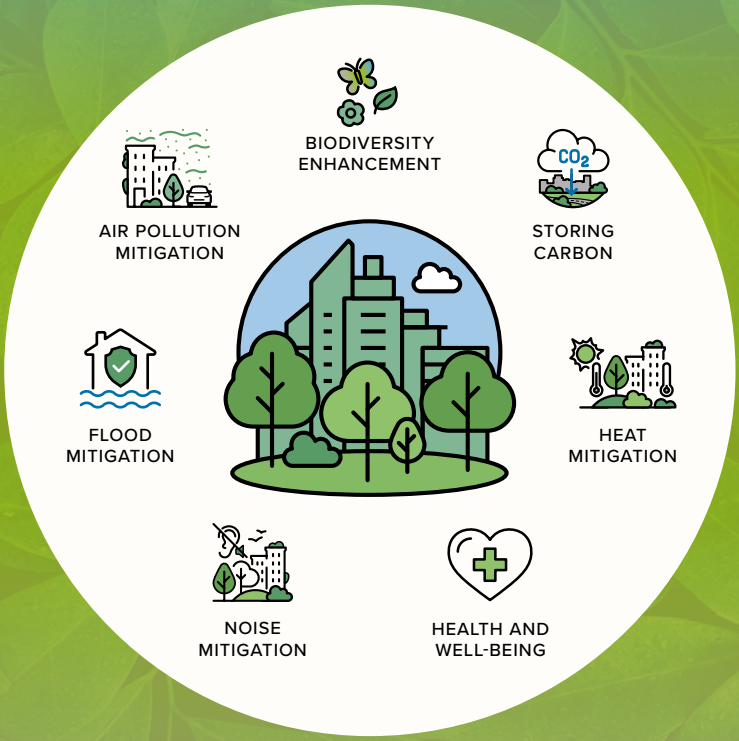
RECLAIM Network Plus

URBAN GREENING ‘HOW TO’ TOOLKIT

for Local Authorities, Councillors and Officers



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Definitions and Abbreviations

- **Advection currents:** the horizontal or vertical transport of heat, moisture, or pollutants by the bulk motion of a fluid, typically air or water.
- **Albedo effect:** the reflectivity of a surface i.e., how much incoming solar radiation (sunlight) is reflected back into the atmosphere rather than absorbed by the surface.
- **Anthropogenic:** effects, processes, or materials that are derived from human activities, as opposed to those occurring in natural environments without human influence.
- **Biodiversity:** the variety of animal and plant species within an ecosystem or geographic area.
- **Black carbon (BC):** a fine particulate matter composed of mostly carbon, formed by the incomplete combustion of fossil fuels, biofuels, and biomass (such as coal, diesel, wood, and crop waste).
- **Blue infrastructure (BI):** natural and engineered water-based elements within urban or rural landscapes that provide diverse ecosystem services (i.e. direct or indirect benefits that humans receive from hydrological ecosystems) and support environmental, social, and economic functions.
- **Carbon storing:** the process of capturing and storing atmospheric carbon dioxide (CO_2) in order to mitigate or defer climate change.
- **Cross-sectoral benefit stacking:** the integration or coordination of actions across multiple sectors (e.g. energy, water, agriculture, health) to achieve multiple, cumulative benefits from a single intervention or investment, particularly in the context of sustainable development and environmental management.
- **Elected members/councillors:** used to refer to elected members of Local Authorities (political party members and independents).
- **Evidence-based research:** a systematic approach to scientific inquiry that involves the use, generation, and integration of the best available evidence from well-designed studies and validated data sources to inform research design, methodology, conclusions, and decision-making.
- **Green infrastructure (GI):** a network of green spaces providing diverse ecosystem services (i.e. direct or indirect benefits that humans receive from ecosystems), as defined by the European Union Green Infrastructure Strategy.

- **Greenhouse gas emissions:** the release of gases into the Earth's atmosphere that trap heat by absorbing infrared radiation, contributing to the greenhouse effect and global warming.
- **Geomorphology:** the scientific study of landforms and the processes that shape the Earth's surface. It explores how natural forces like water, wind, ice, and tectonic activity create, alter, and erode landscapes over time.
- **Grey infrastructure:** human-engineered, built systems designed to support essential services such as transportation, water management, energy, and sanitation.
- **Habitat heterogeneity:** the spatial and temporal variability in habitat characteristics within an ecosystem, including differences in physical structure, resource availability, microclimates, and biotic components, which together support diverse species and ecological processes.
- **Hedges:** linear arrangements of densely planted shrubs, trees, or other woody vegetation that form a physical boundary or barrier, often found along field margins, roads, or property lines, and serve ecological, agricultural, and landscape functions.
- **Hydrological cycle:** the continuous, natural movement of water within the Earth's atmosphere, surface, and subsurface through various physical processes, including evaporation, condensation, precipitation, infiltration, runoff, and transpiration.
- **Lag-time (rainfall):** the delay between one connected process or event and another, such as between peak rainfall (when the most intense rain occurs) and peak runoff or discharge (when the river or drainage system experiences its highest flow).
- **Linear features:** elongated, continuous elements (natural, semi-natural, or built, for example riparian woodland) that extend across the landscape and facilitate connectivity, movement, and ecosystem functions.
- **Living Planet Index (LPI):** an indicator that synthesises data on the abundances of different species from many monitoring sites across the world.
- **Local authorities (LAs):** normally used to refer to councils in the UK of any type and tier.
- **Local councils (LCs):** decentralised administrative bodies or governance institutions that operate at the municipal, district, or community level, responsible for implementing local policies, services, and development plans, often within a legally defined jurisdiction.

- **Local Nature Reserve (LNR):** a protected area designated by a local authority in the UK under the National Parks and Access to the Countryside Act 1949.
- **Micro-scale centripetal thermal systems:** localised heat accumulation patterns where thermal energy converges toward a central point or area within a small spatial scale, typically observed in urban or built environments due to variations in material properties, geometry, and energy fluxes.
- **Nature-based Solutions (NbS):** are actions to address societal challenges through the protection, sustainable management and restoration of ecosystems, benefiting both biodiversity and human well-being (IUCN definition).
- **Officers:** used to refer to employees of Local Authorities.
- **One Health:** a transdisciplinary, collaborative concept that recognises the interconnectedness of human health, animal health, and environmental health, aiming to achieve optimal health outcomes across these domains through coordinated efforts at local, national, and global levels.
- **Organic carbon:** the carbon bound in organic compounds that originate from living organisms or their residues, including plant material, animal tissues, microbes, and their byproducts. It is a key component of the global carbon cycle and exists in soils, sediments, water bodies, and biomass.
- **Particulate Matter (PM):** a complex mixture of extremely small solid particles and liquid droplets suspended in the air. These particles vary in size, composition, and origin. PM originates from both natural sources (e.g. dust, sea spray, wildfires) and anthropogenic activities (e.g. vehicle emissions, construction, industrial processes, combustion of fossil fuels).
- **PM_{10}:** airborne particulate matter with an aerodynamic diameter of 10 micrometers or less. These particles can be inhaled into the upper respiratory tract (nose, throat, and bronchi) and are composed of dust, pollen, mould spores, and other coarse particles.
- **$PM_{2.5}$:** fine inhalable particles with an aerodynamic diameter of 2.5 micrometers or less. These particles can penetrate deep into the lungs and even enter the bloodstream.
- **Riparian woodlands:** forested ecosystems located along the banks of rivers, streams, and other freshwater bodies, characterised by vegetation that is adapted to periodic flooding, high soil moisture, and dynamic hydrological conditions.

- **Road verges:** the strips of land located alongside roads and highways, typically between the carriageway and adjacent land, which may include grasses, shrubs, or trees and serve both infrastructure and ecological functions.
- **Street canyons:** narrow urban corridors flanked by continuous rows of buildings on both sides, that significantly influences local airflow, microclimate, and pollutant dispersion.
- **Surface run-off:** the flow of excess water over the land surface, occurring when precipitation, irrigation, or snowmelt exceeds the infiltration capacity of the soil, leading to water movement across the ground toward streams, rivers, lakes, or drainage systems.
- **Urban greening:** the practice of incorporating vegetation and natural elements such as parks, woodlands, waterbodies, hedges amongst others, in an urban environment to improve environmental, social and economic conditions. It encompasses nature-based solutions and green-blue-grey infrastructure with the aim to build climate-resilient and liveable cities that support Sustainable Development Goals (SDGs).
- **Urban heat island (UHI) effect:** a climatological phenomenon where urban or metropolitan areas experience significantly higher temperatures than surrounding rural areas, primarily due to human activities and alterations in land surface properties which generate heat or increase heat retention.
- **Urban horticulture:** the science and practice of growing, managing, and utilising plants, particularly fruits, vegetables, herbs, ornamental plants, and trees within urban and peri-urban environments for food production, environmental enhancement and social well-being.
- **Wetlands:** transitional ecosystems between terrestrial and aquatic environments, characterised by the presence of water (permanently or seasonally), water-saturated soils, and vegetation adapted to hydric conditions.

Introduction

Importance and need

Towns and cities across the UK, Europe, and beyond are facing increasing challenges from rising temperatures, flooding, noise, poor air and water quality that compromise the urban environment adversely affecting inhabitants' health and quality of life.

Urban greening[1] initiatives encompass Nature-based Solutions[2] (NbS) that leverage natural ecosystem services to protect people, optimise infrastructure and safeguard a stable and biodiverse future. From tree-lined streets and ponds to green roofs and canals (depicted in Figure 1), urban greening blends nature with smart urban design while considering unique local conditions. These greening strategies improve residents' quality of life, enhance biodiversity, and promote sustainability while addressing climate change impacts.

A strategic approach to urban greening maximises the benefits of green spaces while ensuring their long-term effectiveness. Natural England's Green Infrastructure Framework and its Standards support local authorities and communities in planning, enhancing and maintaining local green infrastructure to create healthier and more prosperous neighbourhoods with thriving nature networks that reduce pollution, support sustainable drainage and build climate resilience. User Guides on green infrastructure planning are available for local authorities[3], communities and neighbourhood planning groups[4,5]. However, a public-facing 'how-to' toolkit is currently unavailable - this document aims to fill that gap.

1. Linear features
Street trees
Hedge
Cycle path
Footpath
Road verge
Railway corridor
Riparian woodland

2. Constructed GI
Green roof
Green wall
Roof garden
Pergola

3. Parks
Parks
Heritage garden
Nursery garden
Zoological garden
Pocket park
Botanical garden

4. Amenity areas
School yard
Playground
Sports field
Golf course
Shared open space

5. Other non-sealed urban areas
Grassland
Shrubland
Woodland
Arable agriculture
Sparsely vegetated land

6. Mixed
Trees & hedges
Trees & shrubs
Grass & treees

7. Other public space
Cemetery
Allotment
Adopted public space
City farm

8. Waterbodies
River
Wetland
Canal
Pond
Reservoir
Estuary
Sea
Lake

9. Hybrid GI
Permeable paving
Permeable parking
Attenuation pond
Flood control channel
Rain garden
Bioswale
Outdoor swimming pool

10. Gardens
Balcony
Private garden
Shared common area

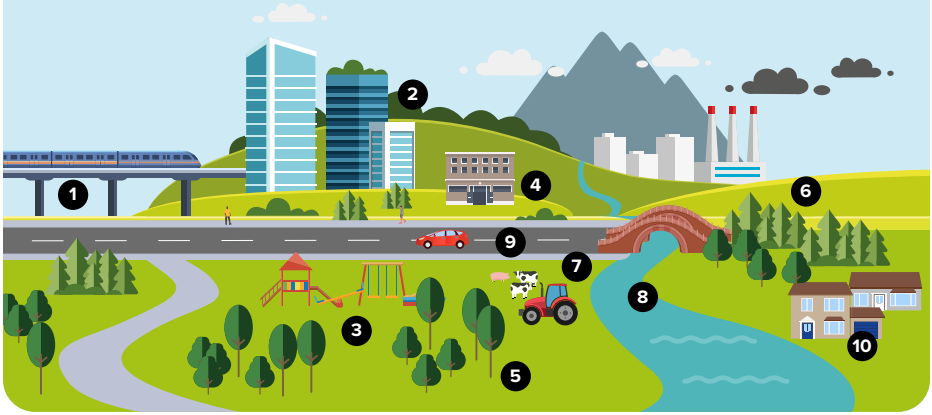


Figure 1: *Examples of common urban green infrastructures*[6]

What are we doing?

This urban greening "how to" toolkit will help local authorities and communities to harness the full potential of urban greening. This toolkit recommends specific actions involving urban greening as a potential solution to urban challenges including: air pollution mitigation, biodiversity enhancement, flood mitigation, health and well-being, heat mitigation, noise mitigation and storing carbon.

Why are we doing it?

Local authorities (LA) have the capacity and directive to implement urban greening solutions. It is therefore critical that LA councillors and officers have access to a credible resource that explains urban greening fundamentals, debunks myths, and outlines do's and don'ts while covering key issues, challenges, and possible alternatives. The information contained in this toolkit is based on evidence-based and peer-reviewed scientific research, much of which was conducted as part of the RECLAIM project. This toolkit therefore represents state-of-the art advice on urban greening for mitigating environmental challenges in urban areas.

Who is the target audience?

This toolkit is aimed at local authorities, councillors, officers and community service centers to respond to their specific needs and support them in navigating complex discussions by providing concise checklists and practical guidance. The toolkit has been co-created through an integrated process of engaging with the target audiences to ensure that the content meets their expectations.

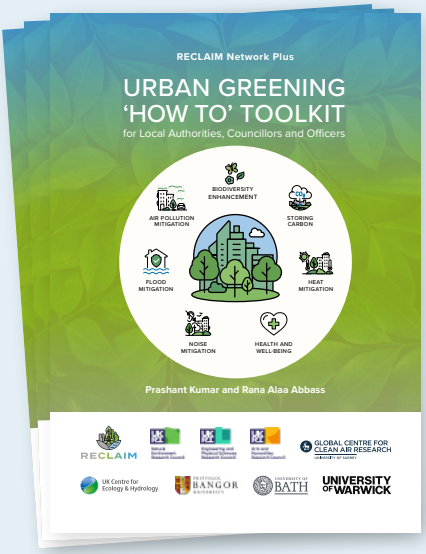
The toolkit adopts a clear and accessible structure to ensure its applicability and practical use. It takes a holistic approach to urban greening communication in order to support the development of specific projects within each stakeholder's area of responsibility (their individual portfolios of work) while demonstrating how these projects can create benefits across multiple sectors (cross-sectoral benefit stacking). For example, it shows how urban greening initiatives developed by transport planning departments can simultaneously deliver positive environmental impacts for environmental departments, creating efficiency and greater overall value.

Who are we?

RECLAIM
Network Plus

The toolkit is part of the efforts of the RECLAIM Network Plus funded by UK Research & Innovation (UKRI), to create a 'one-stop shop' for towns and cities to find the information and support needed to guide the development of urban greening solutions, and to connect people and entities with similar interests and experiences. Over 700 members of the Network include local authorities, business and industry, charities, communities, developers and construction companies, NGOs and academics, predominantly, but not exclusively, from the UK.

What is included in this toolkit?



AIR POLLUTION MITIGATION

BIODIVERSITY ENHANCEMENT

FLOOD MITIGATION

HEALTH AND WELL-BEING

HEAT MITIGATION

STORING CARBON

This toolkit is designed as individual fact sheets, each eight pages, focusing on one of seven challenges: air pollution mitigation, biodiversity enhancement, flood mitigation, health and well-being, heat mitigation, noise mitigation and storing carbon. The challenges are presented in alphabetical order, since the importance, severity and impact of each challenge will vary by location. For each challenge, the fact sheet outlines the role and benefits of urban greening in addressing the issue. It also presents recommended actions, practices to avoid, and key considerations for implementation.

References

[1]Kumar, P. et al. (2025). Urban greening for climate resilient and sustainable cities: grand challenges and opportunities. *Frontiers Sustainable. Cities* 7, 1595280. [2]IUCN (2020). Global Standard for Nature-based Solutions: A user-friendly framework for the verification, design and scaling up of NbS. First edition. Gland, Switzerland: IUCN. [3]Natural England (2024). Green Infrastructure Framework Process Guide for Local Authorities. [4]Natural England (2023). Green Infrastructure Framework Process Guide for neighbourhood planning groups. [5]Kumar, P. et al. (2019). Implementing Green Infrastructure for Air Pollution Abatement: General Recommendations for Management and Plant Species Selection. [6]Kumar, P. et al. (2024). Air pollution abatement from Green-Blue-Grey infrastructure. *The Innovation Geoscience* 2, 100100.

URBAN CHALLENGES FACTSHEETS

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Urban Greening for Air Pollution Mitigation

Challenge

- More than 90% of people worldwide live in areas where air pollution exceeds safe levels set by the World Health Organisation. Shockingly, air pollution causes 8.8 million premature deaths each year[1], making it one of the biggest environmental threats to global health. Cleaning up our air saves lives. Just as little as a 1 μg/m^3 drop in $PM_{2.5}$ across England could prevent about 50,900 occurrences of heart disease, 16,500 strokes, 9,300 asthma and 4,200 lung cancer cases over an 18-year period[2].
- Urban greening cleans air as well as providing several other co-benefits. In 2017 alone, trees and plants in British cities scrubbed enough pollution from the air to cut healthcare costs by £163 million[3], proving that green spaces are not just aesthetically pleasing, they are life-saving.
- More green means healthier lives. Natural England's Green Infrastructure Framework is driving a bold target: 40% green cover in urban residential neighbourhoods[4], because nature can help deliver cleaner air, cooler streets, and thriving communities.

How urban greening mitigates air pollution

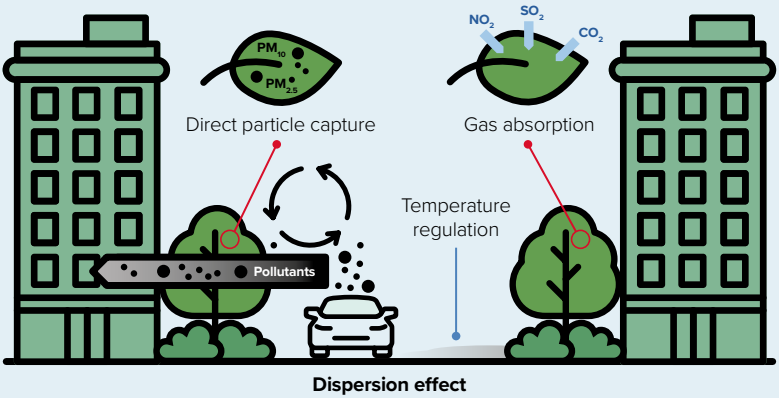


Figure 2: *Mechanisms of air pollution removal by green infrastructure.*

Urban greening reduces air pollution through different natural mechanisms (see Figure 2):

- **Direct particle capture**
  Leaves and bark trap airborne particulate matter ($PM_{2.5}$/PM_{10}), which are then washed away by rain or resuspended by wind. Urban forests, parks and gardens collectively enhance atmospheric dispersion and act as sinks for particles through dry deposition.
- **Gas absorption**
  Plants absorb harmful gases, such as nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and ozone (O_3), through their stomata during photosynthesis.
- **Dispersion effect**
  Green barriers - like hedges, trees, shrubs, or their combination - act as nature's air filters to disrupt flow of polluted air from roads, trapping or diverting pollution emitted by vehicles and protecting pedestrians, cyclists, and nearby residents from harmful exposure. In some locations, the pollution trapping can cause local pollution hot-spots in street canyons, which should be avoided.
- **Temperature interactions with air quality**
  Plants are nature's air conditioners by providing shade and releasing moisture into the air, cooling our cities. This cooling can also help slow the formation of harmful ground-level ozone on hot days.

Recommended Actions

Pick the best GI type to suit your purposes. While recent publications[1] provide a comprehensive oversight of GI effectiveness against air pollution, below are some key examples.

- **Hedges** along busy roadsides could reduce local pollution by up to 63%[5]. For instance, a study in Guildford assessed the impact of hedges on pollutant concentrations and found a reduction of 31% in ultrafine particles and of 52% in BC during peak traffic.
- **Green screens** could reduce local pollution by 44%[6]. For instance, a London based study found that green screens installed along the fences of schools significantly reduced PM concentrations in playgrounds.
- **Green gates** are light green walls made of fabric-based material that hold small plants attached to the existing gate without interfering with its function. The UK's first living green gate, installed at Sandfield Primary School in Guildford, reduced PM_{10} concentrations by 32% and $PM_{2.5}$ concentrations by 19%[7].
- **Street trees** have been shown to reduce PM concentrations by as much as 50% in open road conditions when no gaps or highly porous vegetation is present; however, trees with large spacing and trees in street canyons have shown the potential to increase local air pollution levels [1, 8, 9].
- **Urban trees** across the city collectively reduce air pollution concentrations. A UK assessment showed that the health benefit or air pollution removal by urban vegetation was worth £136m in 2015[10].

Choose plant species[11] wisely to achieve best results.

- **Stress tolerance** should be considered as plant species need to be tolerant to air pollution and other urban stresses such as salt spray or drought to ensure their health and effectiveness in mitigating air pollution.
- **Leaf surface** of the chosen vegetation should be complex, waxy and/or hairy. Taller species with a high leaf surface area increase the deposition and removal of particulate pollutants.

- **Seasonal effects** should be considered where consistent plant species need to be chosen to ensure their year-round effectiveness in mitigating air pollution.
- **Low-emitting plant species** should be prioritised over strong emitters of volatile organic compounds (VOCs). VOCs from urban vegetation can contribute to increased ground level ozone and particulate pollution, thus negating some of the benefits of green interventions[12].
- **Non-invasive** and where possible native species should be used so as not to adversely impact local ecosystems.
- **Non-allergenic and non-toxic** species are preferred specially near vulnerable populations such as school children to avoid cases of poisoning or allergic reactions.

Adapt urban greening design to fit local conditions.

- **Features (design elements)** such as tree distance, canopy height, tree stand porosity, and optimal coverage need to match the site layout. For example, for hedges to operate effectively in street canyons, it is recommended to have continuous hedges with no spacing or gaps, have a height of ~2m and a minimum thickness of 1.5m.
- **Location** relative to pollution sources and receptors where, in the case that the prime objective is to reduce exposure for pedestrians or cyclists, hedges should be planted close to the road or between the road and footpaths/bike paths.
- **Growth shape** should be taken into consideration in reference to site dimensions. For example, in a shallow street canyon, a medium-sized and low density, highly porous canopy species may be suitable, whereas in a deep street canyon, a naturally compact tree or shrub may be more appropriate[11].
- **Road safety** needs to be respected where vegetation barrier design should not impede accessibility nor the visibility of drivers, cyclists or pedestrians.

Combine urban greening types for better results.

- **Mixed GI types** such as installing trees and hedges has been shown to reduce roadside pollution by up to 52%[5] in open-road conditions compared to one GI type alone.
- **Blue infrastructure (BI)** such as lakes are reported to reduce PM concentrations by up to 89%[1] compared to spaces with no waterbodies, being associated with more open spaces, which enhance natural wind dispersion.

Support local research efforts in urban greening to fill current knowledge gaps.

- Research is needed on understudied urban greening typologies such as green corridors, cycle tracks, road verges, and BI (rivers, lakes, and wetlands) to understand their influence on air quality and avoid unintended consequences from poorly informed designs. Additional evidence is also required regarding the effectiveness of various urban greening approaches in reducing gaseous pollutants, as current data remains limited.

Further Insight

Align urban greening with climate policy, in reference to national and global legislations and commitments, such as:

- The National Planning Policy Framework[13] with focus on paragraph 136.
- Natural England's Green Infrastructure Framework (2023)[14] and its Accessible Greenspace Standard (AGSt).
- Relevant UNFCCC frameworks such as UK Nationally Determined Contributions (NDCs) relating to NbS and the co-benefits of urban nature.

Utilise available practical guidance, including:

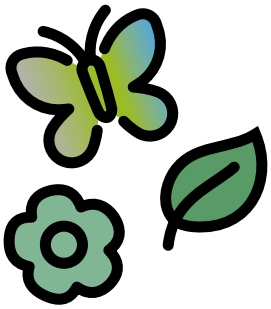
- Implementing Green Infrastructure for Air Pollution Abatement: General Recommendations for Management and Plant Species Selection (2019)[9].
- Natural England's Green Infrastructure Planning and Design Guide[15].
- Guides by Trees and Design Action Group (TDAG) such as First Steps in Urban Tree Canopy Cover.
- GI4AQ is a Green Infrastructure for Air Quality framework developed by the University of Birmingham and air quality and urban greening experts[16].

Employ online tools to help in understanding and designing urban green spaces, including but not limited to:

- HedgeDATE[17]: a decision-support tool developed to help urban planners, landscape designers, and policymakers evaluate and optimise the use of roadside trees and hedges for air pollution mitigation.
- City Explorer Toolkit[18]: GIS-based web tool developed by UKCEH to assist urban planners and policymakers in evaluating where to place GI and BI to maximise environmental and social benefits.
- Air Quality Green Infrastructure[19]: a practical guide developed in the UK to help schools reduce children's exposure to air pollution using GI.

References

[1]Kumar P., et al. (2024). Air pollution abatement from Green-Blue-Grey infrastructure. *The Innovation Geoscience* 2, 100100. [2]Public Health England (2018). Guidance - Health Matters: Air Pollution. [3]Environment Agency, Chief Scientist's Group (2021). The state of the environment: the urban environment. [4]Natural England (2023). Green Infrastructure Standards for England Summary. [5]Abhijith, K.V. et al. (2019). Field investigations for evaluating green infrastructure effects on air quality in open-road conditions. *Atmospheric Environment* 201, 132-147. [6]Abhijth, K.V. et al. (2022). Investigation of air pollution mitigation measures, ventilation, and indoor air quality at three schools in London. *Atmospheric Environment* 285, 119303. [7]Abhijith, K. V. et al. (2025). Demonstrating multi-benefits of green infrastructure to schools through collaborative approach. *Science of The Total Environment* 958, 177959. [8]Baldauf, R. (2017) Roadside vegetation design characteristics that can improve local, near-road air quality. *Transportation research* part D: *Transport and environment*, 52, 354-361. [9]Deshmukh, P. et al. (2019). The effects of roadside vegetation characteristics on local, near-road air quality. *Air Quality, Atmosphere & Health*, 12, 259-270. [10]Jones, L. et al. (2019). Urban natural capital accounts: Developing a novel approach to quantify air pollution removal by vegetation. *Journal of environmental economics and policy*, 8, 413-428. [11]Kumar, P. et al. (2019). Implementing Green Infrastructure for Air Pollution Abatement: General Recommendations for Management and Plant Species Selection. [12]Xu, J. et al. (2025). A model assessment of the relationship between urban greening and ozone air quality in China: a study of three metropolitan regions. *npj climate and atmospheric science*, 8, 184. [13]National Planning Policy Framework (2024). Department for Housing, Communities & Local Government. published on GOV.UK. [14]Natural England (2023). The Green Infrastructure Framework - Principles and Standards for England. [15]Natural England (2023). The Green Infrastructure Planning and Design Guide. [16]Redondo-Bermúdez, M. d. C., et al. (2022). Green infrastructure for air quality plus (GI4AQ+): Defining critical dimensions for implementation in schools and the meaning of 'plus' in a UK context. *Nature-Based Solutions*, 2, 100017. [17]Barwise, Y. et al. (2021). The co-development of HedgeDATE, a public engagement and decision support tool for air pollution exposure mitigation by green infrastructure. *Sustainable Cities & Society*, 75, 103299. [18]City Explorer Toolkit: https://www.ceh.ac.uk/city-explorer. [19]Air Quality Green Infrastructure: A Toolkit for Schools: https://www.groundwork.org.uk/



Urban Greening for Biodiversity Enhancement

Challenge

- Urbanisation threatens biodiversity through multiple interconnected mechanisms: habitat destruction and fragmentation, pollution (air, water, noise, and light), urban heat islands, altered water flows from impervious surfaces, introduction of invasive species, homogenisation of landscapes favouring adaptable species, disruption of ecosystem services like pollination, resource competition, and human-wildlife conflicts.
- The Living Planet Index (LPI) reveals a 73% decline in global wildlife populations since 1970, highlighting the severe and ongoing loss of biodiversity worldwide[1].
- Conserving biodiversity in urban settings is crucial for both ecological and human well-being, and cities can provide valuable habitat for many species. Ecologically, it maintains essential services like climate resilience, pollination and pest control. For humans, biodiverse urban environments improve physical and mental health, enhance quality of life, deliver economic benefits through reduced infrastructure costs, and create educational and public awareness opportunities. Urban conservation also preserves remnant habitats in biodiversity hotspots while fostering broader environmental awareness and stewardship.
- Urban greening restores and conserves biodiversity through developing urban nature recovery strategies that reduce the negative impacts of urbanisation.

How urban greening enhances biodiversity

Different urban greening types (see Figure 3) are recognised as a nature-based solution that enhances biodiversity through:

- **Habitat creation**
  Parks, gardens and lakes, amongst others, provide food and breeding habitat resources for birds, insects, small mammals, amphibians and different plant species.
- **Habitat connectivity**
  Green corridors (e.g. combinations of biodiverse parks, road verges, cycling and walking routes and engineered green infrastructure including rain gardens and green walls) allow species to move safely between habitats increasing diversity and reducing fragmentation and isolation.
- **Pollination**
  Green spaces offer safe habitats for bees and other pollinators to operate and boost ecosystems through pollination of different plant species and crops.

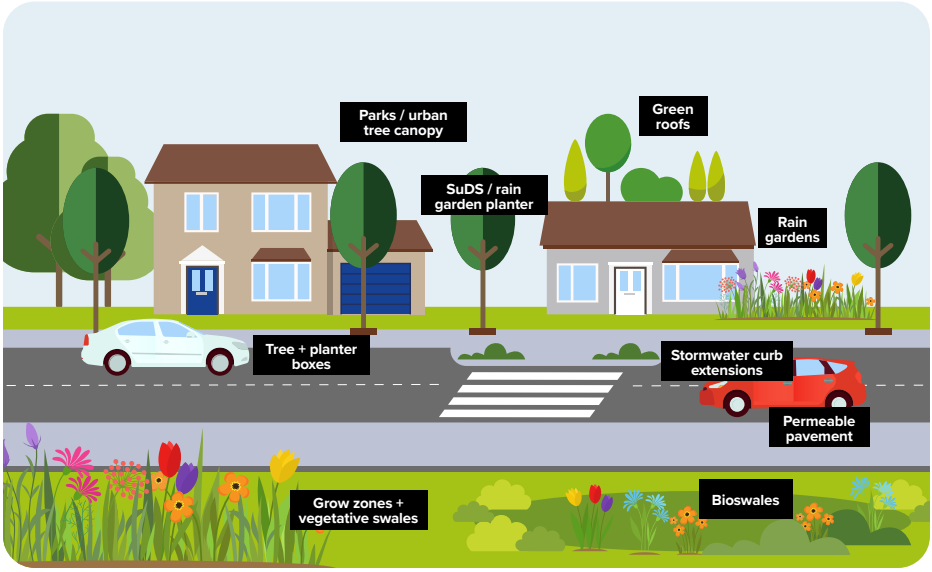


Figure 3: *Sustainable urban green solutions*[2].

- **Ecosystem protection**
  Reduced pollution and disturbance is achieved through low-traffic green zones that create buffers against noise, air and heat pollution, allowing ecosystems to develop.

  Healthy ecosystems help resist invasive species allowing for native species to flourish, while allowing beneficial microhabitats to develop supporting niche species[3].

- **Awareness**
  Community engagement in urban greening through citizen-science projects and initiatives improves awareness and a sense of belonging to communities and in turn improves protection of green spaces.

Recommended Actions

Opt for the most effective GI types, when possible.

- **Ground-level GIs** such as allotments, gardens and parks should be prioritised as they attract more insects than green roofs, which could limit insect accessibility, have typically smaller surface areas and shallow substrate depth which in turn places limitations on planting diversity.
- **Green walls**, despite being costly, are recommended when possible in urban spaces where horizontal area is limited[4].
- **Wildflower meadows** provide exceptional value for insects, even in small areas like roadside verges. Studies show they support higher arthropod biomass and species richness compared to traditional lawns, making them significantly more beneficial for urban biodiversity[5].
- **Spontaneous vegetation** plant species that naturally colonise urban spaces have been proven to better support local insect communities.
- **Beneficial GI** types can offer additional benefits for wildlife diversity through providing a more varied and complex habitat structure. For example, street-side rain gardens and drainage channels designed to manage stormwater and prevent flooding were found to support more insect species than ordinary lawns.

Consider factors that enhance biodiversity when designing and managing green spaces.

- **Diversity** of plant species combined with varied vegetation structure across different GI types, enhances overall biodiversity in urban environments[6].
- **Connectivity** of urban green islands facilitates species movement and colonisation, thereby enhancing insect abundance and richness by reducing isolation and minimising distances between green-blue spaces.
- **Heterogeneity** of habitats and resources GI, particularly gardens, demands deliberate planning to maximise the diverse microclimates that support robust insect communities through varied vegetation structure and rich plant species composition.
- **Invasive species**[7] must be avoided due their detrimental effects on other biodiversity, which requires careful selection of seeds and plants, alongside cautious design of water bodies—considering factors such as depth, size, and vegetation coverage—as these features may allow alien species to persist or spread.
- **Nature-friendly maintenance** practices – including avoiding excessive mowing and eliminating the use of pesticides and fertilisers – significantly protect diversity, as research shows reduced mowing frequency directly correlates with greater abundance and richness of arthropod communities.

Integrate urban greening in city-wide plans and strategies.

- **Land area** devoted to larger green-blue infrastructure islands within urban settlements demonstrates a positive correlation with insect abundance and richness, which is why the Green Infrastructure Framework's Urban Nature Recovery Standard recommends establishing specific targets for increasing wildlife rich habitats and urban greening across cities[8].
- **Local conditions** – including locally defined baselines, vegetation cover, site management, specific community needs, opportunities and constraints – must be thoroughly assessed when designing, planning and installing urban greenery to ensure optimal ecological outcomes and sustainability.
- **Strategies** encompassing urban greening targets, mandatory or recommended requirements for new developments, roadmaps and comprehensive implementation plans enable cities to allocate budgets effectively, make informed decisions and successfully install impactful urban greenery where it is most needed.
- **Nature recovery** strategies should include specific quantifiable targets, such as the recommended provision of one hectare of Local Nature Reserve (LNR) per 1,000 population[8], which serves the dual purpose of enhancing biodiversity conservation while creating spaces for public quiet enjoyment and connection with natural environments.
- **Nature conservation** should be established as a priority of urban planning, requiring both the enhancement of existing ecological sites and the strategic identification of new areas that meet the criteria for designation as Local Wildlife Sites, thereby creating a more comprehensive and resilient network of protected habitats.

Further Insight

Support local research efforts to address current knowledge gaps.

- Despite their importance for supporting biodiversity, blue infrastructures, including ponds, streams, wetlands and other small water bodies, remain understudied compared to their green counterparts, creating a substantial knowledge gap in urban ecological research. Moreover, climate change is expected to increase the risk of vector-borne diseases in the coming years, highlighting the need to fully assess the associated costs and benefits of mitigation and adaptation strategies.

Public engagement through citizen science programs have proven successful.

- Mobile phone applications such as eBird and iNaturalist have transformed citizen science by enabling community members to actively participate in biodiversity monitoring, allowing them to document and report species observations from their local neighbourhoods and broader environments, thereby contributing valuable data to ecological research.

References

[1]WWF (2024). Living Planet Report 2024 - A System in Peril. WWF, Gland, Switzerland. [2]Sustainable Urban Greening Solutions, Meristem Design. [3]Berthon, K. et al. (2021). The role of 'nativeness' in urban greening to support animal biodiversity. *Landscape Urban Planning* 205:103959. [4]Filazzola, A., et al. (2019). The contribution of constructed green infrastructure to urban biodiversity: A synthesis and meta-analysis. *Journal of Applied Ecology*, 56, 2131-2143. [5]Marshall, C. A., et al. (2023). Urban wildflower meadow planting for biodiversity, climate and society: An evaluation at King's College, Cambridge. *Ecological Solutions and Evidence*, 4, e12243. [6]Bowler, D. E., et al. (2025). Evidence-base for urban green-blue infrastructure to support insect diversity. *Urban Ecosystems*, 28, 1-14. [7]ADEPT (2023). The Value of Trees report. [8]Natural England. (2024). Green Infrastructure Framework Urban Nature Recovery Standard User Guide.

Urban Greening for Flood Mitigation

Challenge

- Urban infrastructure can alter the natural hydrological cycle, affecting processes such as rainfall, interception on buildings and vegetation, soil infiltration and storage, runoff generation, retention in lakes and ponds and the speed and direction of water movement[1].
- Urbanisation can also have a detectable impact on hydrology on a catchment-scale, including: a reduction in baseflow, changes in groundwater level, increased runoff rates and reduced lag-times; with effects resulting in increased peak flows and runoff volumes.
- Urbanisation of former natural land covers can have negative downstream implications for flood risk management, geomorphology, hydro-ecology and water resources.
- Managing surface water in urban areas is important to minimise flood damage and disruption, as well as preserving water quality in receiving waters.
- NbS that embrace green and blue infrastructure (see Figure 4) can be employed to rebalance the impacts of urban infrastructure on the natural hydrological cycle by mimicking it, slowing the flow of water whilst increasing retention and infiltration.

How urban greening mitigates flooding

- **Reduced run-off peaks**
  Plants, soil, and mulch layers in GI store rainwater temporarily, slowing down peak flow rates into stormwater systems and reducing the likelihood of sewer overflows and flash floods.
- **Soil Absorption and storage**
  Urban greening improves soil structure and organic content, increasing its ability to absorb and retain water during storms[2].
- **Drainage connectivity**
  Green corridors and bioswales can channel excess water safely to retention basins, rivers, or aquifers.

  Permeable pavements, wetlands, and swales are examples of urban greening infrastructure managing urban hydrology and reducing risks of flooding[3].
- **Pervious surfaces**
  Replacing paved areas with permeable vegetation reduces surface runoff as green streets, tree trenches, and bioswales help capture and filter stormwater on-site.

Figure 4: *Flood mitigation by urban greening in cities.*

Recommended Actions

Develop guidance frameworks focussing specifically on GBGI as holistic solutions to flood problems.

- **Measures for new developments** need to be set out to ensure compliance with the standards and principles provided in the Green Infrastructure Framework's Urban Greening Factor Standard[4], in cases where local planning policy does not specify requirements for urban greening.
- **Local policies and standards** need to be developed similar to, for example, the Urban Greening Factor guidance of London City Hall[5].

Set urban greening targets in reference to local frameworks.

- **Green cover percentage** of a minimum of 40% in urban residential neighbourhoods is recommended by the Green Infrastructure Framework's Urban Greening Factor Standard[4], where a larger percentage is encouraged and expected where possible .
- **Proportion of natural to man-made surfaces** is another local area characteristic that can be identified by consulting the 'Greenness Grid' in the Green Infrastructure Mapping Database[6].

Consider key factors when employing urban greening to ensure effectiveness.

- **Urban greening factors** such as dimensions of urban greening intervention, rainfall intensity and performance metrics must be critically considered to ensure optimal performance.
- **The choice of the type** of urban greening infrastructure is determined by available space and budget. The rarity and frequency of extreme rainfall events must be considered, as well as access to routine maintenance and public acceptance of the new scheme.

- **Climate, landscape and surface properties** need to be taken into consideration when designing and implementing urban greening solutions to effectively work, as they directly impact runoff generation and water flow.
- **Hydrological response** from urban areas can be predicted for better GI design and implementation, using tools such as EPA SWMM (Storm Water Management Model), Hydrological Engineering Center's Hydrological Modelling System (HEC-HMS) and ArcGIS Hydrology tool box.

Be mindful of runoff destinations to avoid unwanted consequences.

- **Unintended downstream flow** Planners and designers must make sure urban greening infrastructure does not unintentionally shift excess stormwater to downstream areas, which could overwhelm their drainage systems, increase their flood risk and cause ecological damage.
- **Order of preference** According to the National standard for Sustainable Drainage Systems[7], destinations of excess runoff is: (i) discharge to ground, (ii) discharge to surface water body, (iii) discharge to surface water sewer, and, as an absolute last resort, (iv) discharge to a combined sewer. Urban greening interventions should adhere to these recommendations.
- **Routine maintenance** of existing drainage networks to allow for slow infiltration and to act as sustainable drainage systems (SuDS).

Pay attention to the hydrological properties of urban surfaces.

- **Urban characteristics** such as the materials of construction, slope, age, condition and connectivity to the surface water drainage system, have a direct impact on hydrological properties that need to be taken into consideration. Urban greening infrastructure such as permeable paving can provide higher infiltration rates than traditional impervious surfaces.
- **Imperviousness** needs to be limited, when possible, as it disconnects soil moisture and runoff and increases sensitivity to rainfall.

Ensure maintenance of urban greening interventions for better performance.

- **Regular maintenance** of GI and BI ensure continuous and unimpeded performance during extreme rainfall events.
- **Maintenance activities** include cleaning of drains and culverts, removal of debris, removal of sediments, clogs and vegetation from infiltration systems such as pervious pavements, and maintaining vegetation in green systems such as green roofs and rain gardens.
- **Plan for maintenance** by ensuring it is appropriately assessed, funded and if possible legally secured.
- **Barriers to routine maintenance** need to be avoided such as poor design that results in inaccessible systems, or parts of system, last-minute reactive management, requiring people to work in adverse weather conditions (health and well-being challenges), and debris and/or sediment overload from upstream urban greening systems, e.g. leaves of branches causing blocking and clogging.

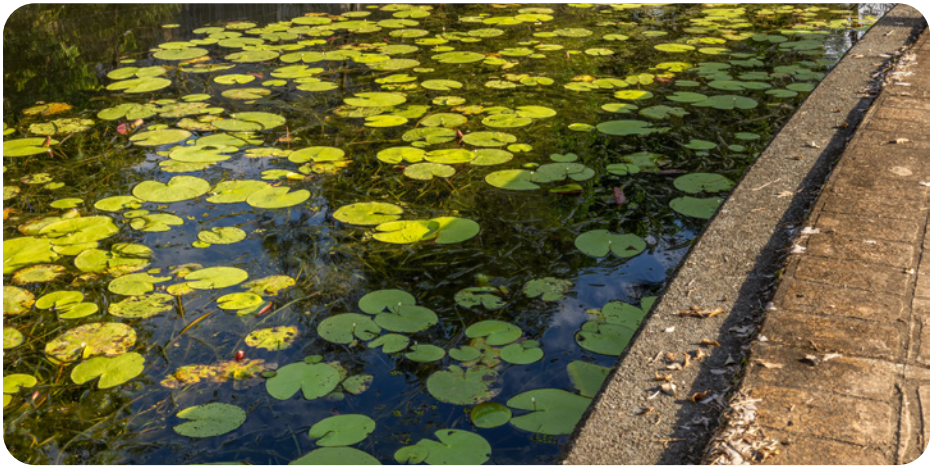
Further Insight

Account for the uncertainty involved in safeguarding against episodic events.

- Episodic events such as heavy rainfall and floods are accompanied with uncertainty towards the timing and intensity of their occurrence and hence, posing elements of risk and uncertainty in infrastructure design must be communicated carefully.

Consider variation in performance.

- Evidence of urban greening impact from scientific literature and case studies shows overall positive benefits, but performance can vary considerably hence, greening infrastructure should be assessed holistically based on effectiveness and impacts.



References

[1]Macdonald, N. et al. (2022). Understanding the impact of the built environment mosaic on rainfall-runoff behaviour. *Journal of Hydrology*, 604, 127147. [2]Fidal, J. et al. (2020). Accounting for soil moisture in rainfall-runoff modelling of urban areas. *Journal of Hydrology*, 589, 125122. [3]Redfern, T.W., et al. (2016). Current understanding of hydrological processes on common urban surfaces. *Progress in Physical Geography*, 40, 699-713. [4]Natural England (2023). Green Infrastructure Framework's Urban Greening Factor Standard User Guide. [5]Greater London Authority (2023). London Plan Guidance on Urban Greening Factor. [6]Natural England (2023). Green Infrastructure Mapping Database. [7]National Standards for Sustainable drainage Systems (SuDS) (2025). Department for Environment, Food and Rural Affairs, published by GOV.UK.

Urban Greening for Health and Well-being

Challenge

- Cities can negatively affect health due to high levels of noise and air pollution, traffic, as well as socioeconomic disparities and issues like poverty and crime. These factors can all contribute to an increased prevalence of chronic noncommunicable diseases and poor mental health.
- Living in a city is a risk factor for poorer mental health and it may be associated with a higher incidence of psychosis and depression. There are more than 0.7 billion 14-24-year-olds living in urban settings globally where 14% of 10-19 year-olds experience a mental health condition[1]. While in the UK, urban residents are 64% to report mental health concerns compared with their rural counterparts[2]. Public awareness on the importance of urban greenery is on the rise as 86% of children and young people surveyed stated that they would like to do more to look after the environment[3].
- The global prevalence of obesity has almost tripled over the last 40 years with urban areas seeing a particular increase[4]. In the UK, children in urban areas exhibited slightly higher obesity rates than children in rural areas[5].
- Urban greening has been associated with improved health and well-being of city dwellers owing to spaces provided for exercise, contemplation and social cohesion as well as the positive impacts of being close to nature (see Figure 5).

Figure 5: *Benefits of urban greening on health and well-being in cities.*

How urban greening improves health and well-being

- **Mental health benefits[6]**

  A connection with nature helps lower stress hormone levels, reduces the tendency to anxiety and depression and improves mood and emotional regulation through promoting calmness as well as cognitive and physiological restoration.

  Green and blue spaces, mediated by physical activity and restorative qualities, provide space for reflection and facilitate mindfulness practices.

  Gardens, parks, and urban farms encourage social interaction and community engagement where stronger social ties result in better mental health and resilience.

- **Healthier surrounding environment**

  Greenery ensures improved air quality leading to fewer respiratory and cardiovascular problems.

  Green areas mitigate urban heat via shade and evapotranspiration, reducing the risk of heat stress and heat stroke that cause mortality to vulnerable groups.

  Vegetation acts as a natural sound barrier, lowering urban noise levels and hence supports better sleep, reduces stress, and improves cognitive function.

- **Physical activity**[7]

  Parks and tree-lined streets provide safe and inviting spaces for walking, cycling, and recreation, which in turn reduce risks of obesity, heart disease, and diabetes.

  Integrating active transport spaces such as pedestrian paths and bike lanes within green spaces can potentially support healthier lifestyles.

Recommended Actions

Ensure that urban greenery, including greenspaces, consider aspects relevant to human health.

- **Prioritise NbS** in GI and BI solutions as it provides co-benefits that improve well-being, for example increasing urban tree cover provides shading for buildings, counteract urban heat island effect, help alleviate air pollution and provide opportunities for biodiversity and nature connection.
- **Quality** of urban parks needs to meet the Green Flag Award Criteria[8], and best practice in accessibility for all: By All Reasonable Means: Least restrictive access to the outdoors[9].

- **Accessibility** to green and blue spaces in neighbourhoods that have low amounts of accessible greenspace and high deprivation needs to be ensured, as per the Green Infrastructure Framework's Mapping Database[10] as well as the Fields in Trust standards[11]. Opportunities to green already accessible spaces is as important as making green spaces more accessible.
- **Capacity** where local authorities need to maintain at least 3 hectares of publicly accessible greenspace per 1,000 population and ensure no net loss or reduction in capacity of accessible greenspace per 1,000 population across the authority's area, as per the Green Infrastructure Framework's Mapping Database[10].
- **Proximity** ensures that everyone has access to good quality green and blue spaces within a 15 minutes' walk from home for health and wellbeing and contact with nature, in accordance with the Green Infrastructure Framework's Accessible Green Space Standards[12] (& Fields in Trust[11]) which clarify the quantity, quality and distance from home of the greenspace required to meet local needs.
- **Connectivity** as linking vegetation & paths from public spaces into residential areas creates habitat and access corridors and can encourage physical activity, nature connection and reduces risk of depressive symptoms.

Account for local conditions for better impact.

- **Spatial qualities and landscape composition** such as availability of shaded areas, open vistas & sightlines, spaces for active use, spaces for community gathering, and topographical features, need to be prioritised as they can influence attentional restoration, stress recovery and social connection.
- **Variations in climatic conditions** need to be considered as they affect frequency of long term maintenance and the management of the surrounding urban infrastructure.

Employ urban greening to meet community needs.

- **Target communities** who are most in need of urban greenery. High exposure to urban heat, air pollution, mental and physical health issues often goes together with low levels of urban greening. Guide decisions on investment in urban green spaces and parks as informed by the Index of Multiple Deprivation and local dialogue with communities.
- **Children** need to especially be accounted for through encouraging opportunities for unstructured play in urban parks. Unstructured play does not rely on standard equipment (swing sets/slides) but invites children to explore and create, examples include areas for den making, stepping stones, texture pathways, sensory gardens and water play.
- **Youth** at risk of anxiety and depression should be encouraged to seek adventure interventions and schools should consider how they can encourage and enable time in nature as part of the school day.
- **Equity** in access to GI and BI is important as children and young people from households with higher incomes are more likely to report spending time outside, often because they have access to a garden[3]. Hence granting public access to private urban greening spaces, should be considered. Furthermore, ensuring accessibility for people with disabilities and special needs is crucial to ensure benefit for all.
- **Safety** of green spaces must be ensured to make it comfortable for girls and women, and all groups who might otherwise not use green spaces due to fear of crime or anti-social behaviour.
- **Community engagement** ensures the co-design of urban greening with residents to address their physical, cultural and social needs, and encourages community-led initiatives that support physical activity, recreation and socialisation.

Align your urban greening agenda with national strategies and priorities.

- **Funding** of nature recovery and green infrastructure is possible through plausible investment mechanisms where evidence clearly shows that there is significant potential to scale up by developing sustainable urban greening investment models that bring together public, private and third sector funding. Furthermore, it is critical to align investment mechanisms with wider policies and strategies focusing on health and wellbeing and economic prosperity.
- **Advocate** for green spaces through seizing the opportunity to protect or construct urban greening of all sizes. Small urban parks can deliver many of the benefits to forest exposure, which lead to greater momentary mental wellbeing and positive affect on health compared to being on an urban street.
- **Revitalise** run-down natural assets to make up for the shut down of existing green and blue spaces due to densification.

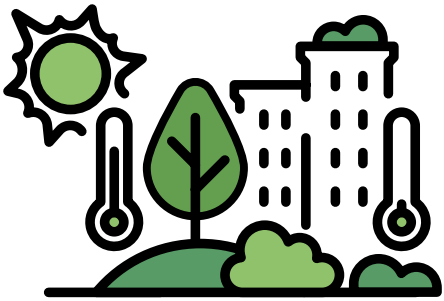
Further Insight

Support local research to fill current knowledge gaps to allow for better decision-making.

- Quantitative research on urban greening and well-being is limited with issues such as data heterogeneity, inconsistencies in methodologies and an overrepresentation of woodlands hence, it is important to support further research efforts for sound results and recommendations. The Woodland Trust's BioWell study[13] notes that many biodiversity experiences such as bird song are not specific to woodland.
- Studies rarely focus on the differences across urban greening typologies, so recommendations of the best suited urban greening to improve health and wellbeing cannot currently be made. Existing research focuses on understanding the processes that take place around urban greening which have the most impact on health and wellbeing, ranging from design features to exposure time and access.
- Longer term and longitudinal studies are needed to claim that urban greening on its own improves the overall health and wellbeing of a person. Existing studies are either cross-sectional studies looking at associations between greenspace and health issues, or are short-term experimental studies relying on participants' perception of temporary emotional change after visiting urban greening, and some of their physical conditions like heart rate and blood pressure have improved.

References

[1]Bray, I. et al. (2022). Exploring the role of exposure to green and blue spaces in preventing anxiety and depression among young people aged 14–24 years living in urban settings: A systematic review and conceptual framework. *Environmental Research*, 214, 114081. [2]Understanding Society (2023). Mental health: how living in the city and country compare - UK Household Longitudinal Study. [3]The Children's People and Nature Survey for England (2024). Update report by GOV.UK. [4]Smith, N., et al. (2021). Urban blue spaces and human health: A systematic review and meta-analysis of quantitative studies. Cities, 119, 103413. [5]Titis, E., Di Salvatore, J., & Procter, R. (2023). Socio-economic correlates of childhood obesity in urban and rural England. *Public Health Nutrition*, 26, 1815–1827. [6]Janeczko, E., et al. (2023). The Psychological Effects and Benefits of Using Green Spaces in the City: A Field Experiment with Young Polish Adults. *Forests*, 14. [7]Samus, A. et al. (2022). How do urban green spaces increase well-being? The role of perceived wildness and nature connectedness. *Journal of Environmental Psychology*, 82, 101850. [8]Ellicott, K. (2016). Raising the Standard The Green Flag Award Guidance Manual. Wigan, England: Keep Britain Tidy. [9]The Sensory Trust (2020). By All Reasonable Means: Least restrictive access to the outdoors. Commissioned by Natural England in collaboration with Natural 50 of 51 Resources Wales. Cornwall: The Sensory Trust. [10]Natural England (2023). Green Infrastructure Mapping Database: Green Infrastructure Map. [11]Fields in Trust (2025). Standards: Fields in Trust. [12]Natural England (2024). Green Infrastructure Framework: Accessible Greenspace Standard User Guide. [13]Woodland Trust (2022). Bio-well research: Mapping woodland biodiversity for human health and wellbeing.



Urban Greening for Heat Mitigation

Challenge

- The urban heat island (UHI) effect – where city temperatures significantly exceed those of surrounding non-urbanised areas – results from landscape transformations that alter natural energy exchange between the earth's surface and atmosphere, creating a feedback loop that intensifies as urbanisation continues. Buildings and man-made surfaces absorb solar energy and re-emit it as heat to a greater extent than natural vegetated surfaces or water. The activities we undertake and energy we consume in cities also emit large quantities of heat.
- Heatwaves are amongst the most threatening natural hazards that can have a significant impact on human health. In 2022, the UK witnessed a record-high temperature of 40.3°C. There are 791 yearly average excess deaths in England and Wales that have been accredited to extreme heat[1]. An assessment of 854 European cities demonstrates that under a low mitigation and adaptation scenario, climate change will increase temperature-related net mortality by 49.9%, resulting in 2,345,410 (95% confidence interval: 327,603 to 4,775,853) excess deaths between 2015 and 2099[2].
- Socioeconomic inequities create disproportionate vulnerability to urban heat impacts, with marginalised communities often facing greater exposure and fewer resources for adaptation[3].
- The synergistic effects between urban heat islands and climate change-driven heat waves create complex challenges that require multidimensional, context-specific mitigation approaches.

How urban greening mitigates heat in cities

Urban greenery has been shown to reduce land surface temperatures by up to 1 °C and air temperatures by up to 7 °C, while water bodies also play a significant role in cooling urban areas, as they can regulate ambient heat conditions by up to 8.8 °C[5]. This impact is achieved through different phenomena:

- **Shading**
  Trees and plants can decrease the amount of direct sunlight reaching the ground, therefore lowering surface temperatures and mitigating the UHI effect via creating a cooler micro-climate.
- **Evapotranspiration cooling**
  Plants release moisture, which further cools the surrounding air by converting sensible heat into latent heat (see Figure 6).
- **Insulation**
  Decreased heat absorption by buildings, and evaporative cooling (heat absorption, as water changes from liquid to a gas state in the air stream) are achieved by some GI elements such as green roofs, green walls, and roof gardens.

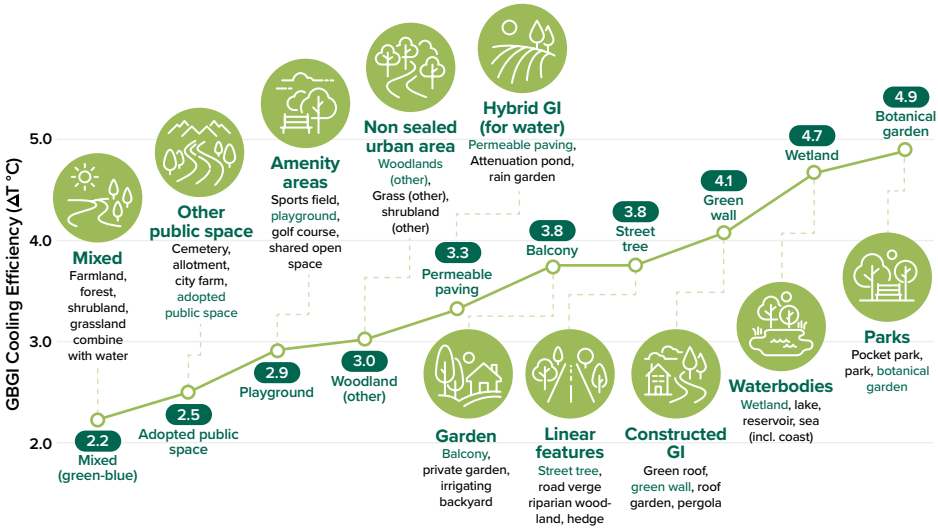


Figure 6: *Green infrastructure efficacy against urban heating[4]. The figure classifies Green-Blue-Grey Infrastructure (GBGI) into ten major categories (in capital letters), which are subdivided into 51 specific types. The types highlighted in green indicate those with available heat mitigation data. In contrast, those listed in black signify a major research gap, as their efficacy remains scientifically unevaluated[4].*

- **Altering airflow**

  Parks can act as natural air conditioners through the formation of micro-scale thermal reduction systems (park breeze) that generate low-level advection currents that draw air from cooler greenery toward warmer urban areas[6].

  Vegetation can act as windbreaks, modifying airflow patterns, and facilitating natural ventilation, ultimately dissipating heat.

  Linear green-blue infrastructure elements such as vegetated corridors, rivers and canals function as ventilation pathways, channelling cooler air masses from peripheral areas into urban centres and creating beneficial thermal circulation patterns throughout the built environment.

- **Impact of water bodies**

  BI mitigates heat through multiple mechanisms: evaporative cooling, groundwater recharge, and acting as a temperature buffer that absorbs and stores heat during the day[4].

  Diurnal temperature effects are significant with water bodies, which demonstrate a time-lag cooling impact by absorbing heat during daytime peaks and gradually releasing it during cooler night periods, thereby moderating the UHI effect when it is most intense[7].

  Seasonal variations affect cooling efficiency of water bodies, with maximum cooling benefits observed during summer months when urban heat stress is highest, while providing generally warmer temperatures during winter in temperate and cold climates.

  Larger urban water bodies can generate localised cooling breezes through air circulation patterns, where temperature differentials between water and surrounding built environments create convection currents that provide relief during hot weather[8].

  Moving water (e.g. rivers and streams) provides greater cooling capacity than still water (e.g. lakes, ponds). Deeper water bodies generally provide greater cooling capacity than shallow water bodies, although this is not always the case if the surface water layers become stratified.

Recommended Actions

Match urban greening and blue infrastructure types to the needed purpose.

- **Understanding** characteristics, functionality and constraints of GI/BI types as well as assessing the local context, environmental conditions, available resources and the budget is crucial to ensure long-term effectiveness and avoid possible drawbacks.
- **Recreational parks** can mitigate UHI effects.
- **Green roofs and walls** reduce energy consumption and in turn mitigate heat.
- **Trees** incorporated into walking and cycling routes provide shading.
- **Wetlands, ponds, lakes, swales and rain gardens** need to be prioritized into urban planning[4] where water availability allows. These features naturally store and release water, helping to moderate local temperatures during heat events.
- **Botanical, zoological, and heritage gardens** are effective in urban heat mitigation; however, they require high maintenance and substantial water, making them unsuitable in areas with limited irrigation access as this reduces their cooling capacity. Hence, assessment of local context, conditions, resources, and budget is needed to ensure long-term effectiveness.

Prioritise urban greening for heat-vulnerable regions and communities.

- **Spatial distribution and UHI severity** can help identify heat-vulnerable regions as per the Green Infrastructure Framework's Green Infrastructure Mapping Database for urban heat management information for your area[9].
- **Vulnerability and adaptive capacity of communities** need to be identified to increase the number of cooling shelters that utilize urban greenery to protect such groups, especially dwellers with no easy access to parks or outdoor areas.
- **Maximise size of urban green areas** in heat risk zones where a positive correlation is noted between the size of urban greenings and their cooling potential, hence larger urban greening would be recommended for vulnerable hotspots, when possible.
- **Assessment** of your local area's level of existing urban cooling function from urban green infrastructure and social vulnerability[5] to extreme heat (need for urban cooling) can be conducted by looking at the Urban Heat Management Maps in the Green Infrastructure Mapping Database[9].

Adopt policy frameworks and strategies to better empower urban greening.

- **Enact policy frameworks** that set design standards including through planning policies, planning guidance and design codes, as well as financial mechanisms to incentivise the adoption of urban greening.
- **Monitoring and evaluation frameworks** need to be implemented to quantify and optimise cooling benefits as well as assess urban greening performance in heat mitigation and identify improvements in design and management specific to a geographic region.
- **National frameworks** should be consulted such as the Natural England Green Infrastructure Framework's Urban Tree Canopy Cover Standard[10] that assesses Urban Tree Canopy Cover is increased by an agreed percentage based on a locally defined baseline and taking into account local needs, opportunities and constraints.

Further Insight

Consider the multifunctionality of urban greening.

- Green roofs and solar panels can enhance each other's performance as green roofs reduce ambient temperatures, helping solar panels operate more efficiently as solar PV output can drop at high temperatures.
- Green roofs equipped with rainwater harvesting systems can amplify cooling benefits and other co-benefits, including biodiversity enhancement and bolstering ecosystem resilience.

Encourage climate-related education and literacy.

- Climate education should be incorporated into the school curriculum to develop a deeper understanding of the causes and consequences of environmental heat[11].
- Climate literacy programs and public information campaigns are crucial in promoting positive action on urban heat and urban greening interventions.

Community engagement is crucial for success[12].

- It is vital to actively involve all stakeholders, including researchers, communities, urban planners, engineers, government bodies, non-profit organisations, and businesses, in the co-creation of urban greening initiatives to integrate diverse perspectives and foster a sense of shared ownership and collective responsibility.

Support local research on urban greening to address existing knowledge gaps[4].

- Monitor and evaluate GBGI within heat-vulnerable areas, to guide targeted selection of interventions for heat mitigation. This will ensure implementation options are evidence-based and guided by a holistic approach that maximises their multifunctional benefits.

References

[1]UKHSA (2025). Heat mortality monitoring report: 2022, UK Health Secuirty Agency at GOV.UK. [2]Masselot, P. et al. (2025). Estimating future heat-related and cold-related mortality under climate change, demographic and adaptation scenarios in 854 European cities. *Nature Medicine*, 31, 1294–1302. [3]Chakraborty, T. et al. (2019). Disproportionately higher exposure to urban heat in lower-income neighborhoods: a multi-city perspective. *Environmental Research Letters*, 14, 105003. [4]Kumar, P. et al. (2024). Urban heat mitigation by green and blue infrastructure: Drivers, effectiveness, and future needs. *The Innovation*, 5, 100588. [5]Jang, S. et al. (2024). Street-level urban heat island mitigation: Assessing the cooling effect of green infrastructure using urban IoT sensor big data. *Sustainable Cities and Society*, 100, 105007. [6]Ogce, S. et al. (2025). The interaction between urban heat island and urban parks: An in-situ measurement-based review. *Land Use Policy*, 157, 107628. [7]Jandaghian, Z. et al. (2024). The Role of Water Bodies in Climate Regulation: Insights from Recent Studies on Urban Heat Island Mitigation. *Buildings*, 14(9), 2945. [8]Zheng, Y., et al. (2021). Quantifying the Cooling Effect and Scale of Large Inner-City Lakes Based on Landscape Patterns: A Case Study of Hangzhou and Nanjing. *Remote Sensing*, 13, 1526. [9]Natural England (2023). Green Infrastructure Mapping Database Green Infrastructure Map. [10]Natural England (2025). Urban Tree Canopy Standard. [11]Kumar, P. et al. (2023). Using empirical science education in schools to improve climate change literacy. *Renewable and Sustainable Energy Reviews*, 178, 113232. [12]IURC (2025). Green infrastructure to mitigate urban heat island, International Urban and Regional Cooperation Program North Africa by the European Union.

Urban Greening for Noise Mitigation

Challenge

- Noise pollution is recognised by the World Health Organisation as a major environmental health risk. Prolonged exposure to elevated noise can cause hearing loss, cardiovascular disease, disrupted sleep, impaired cognition and increased stress. It also disrupts wildlife behaviour by interfering with communication, migration, and reproduction[1].
- Chronic noise exposure can lead to stress and anxiety through prolonged activation of the stress response and elevated cortisol levels, and is associated with a 4% increase in heart failure risk for every 10dB(A) rise in road traffic noise[2]. Vulnerable populations such as children, the elderly, and those with pre-existing health conditions are particularly at risk, leading to increased risk of mortality.
- Key urban sources of noise include transport-related noise (from cars, trains, buses and aeroplanes)[3], industrial and construction activities (such as factories, machinery, drilling and building work) and social or community noise (from loud music, entertainment venues, public events and densely populated areas).
- Strategically placed and designed urban greenery can be quite effective in attenuating noise pollution caused by the different urban sources.

How urban greening mitigates noise

Green infrastructure utilises four key mechanisms to mitigate noise (see Figure 7).

- **Absorption:** Vegetation, including stems, leaves and grass, is more effective at absorbing high frequencies.
- **Scattering and redirection:** Branches and foliage scatter sound waves, while tree trunks help redirect sound waves.
- **Soft ground effect:** Natural surfaces, such as soil or mulch, absorb low-frequency noise more effectively than hard pavements.
- **Masking:** Background sounds from vegetation (e.g. rustling leaves, birdsong) help mask intrusive urban noise, improving perceived acoustic comfort.

Urban infrastructure's noise mitigation effectiveness, from refection to absorption.

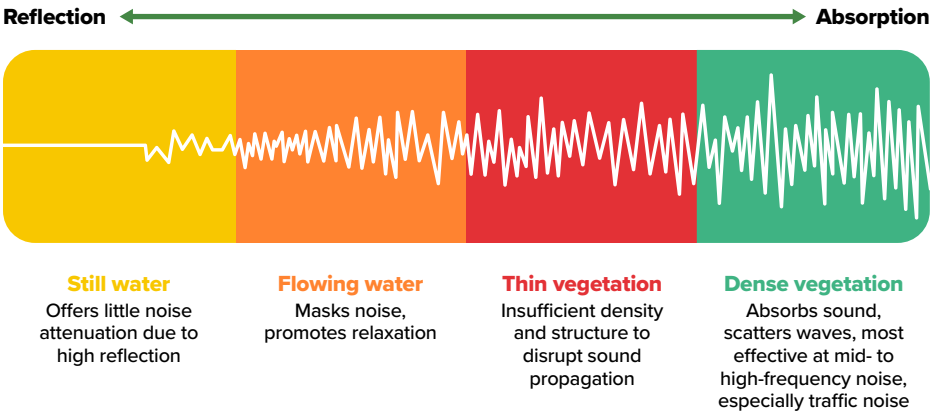


Figure 7: *Noise mitigation effectiveness of green and blue infrastructures from reflection to absorption..*

Blue infrastructure mitigates noise through:

- **Masking effect:** Continuous-flowing water features (e.g. fountains, streams) generate ambient sounds that mask intrusive urban noise.
- **Psychological comfort:** The soothing sound of water promotes relaxation and reduces stress linked to noise exposure.
- **Acoustic reflection:** Still or large water bodies primarily reflect sound rather than absorb it, limiting their physical noise-reducing capacity.

Recommended Actions

Pick the best GI type to suit your noise mitigation goals.

- **Tree belts** with widths ≥25 m can reduce noise by up to 7 dB(A), especially near major traffic corridors[4]. Targeted planting of urban trees in areas delivering maximum benefit (i.e. between busy roads and residential areas) could have substantial economic benefit, worth up to £1.2m in Birmingham with 4% additional tree cover planted[5].
- **Dense hedges and shrubs** around 1.5 m in height have been shown to reduce noise by 3–5 dB(A), with the greatest effectiveness when arranged continuously along roadways or boundaries[6].
- **Green gates** consisting of small potted plants fixed to existing barriers, can reduce noise by up to 5 dB(A), particularly effective for mid-to-high frequency noise like road traffic[7].
- **Dense vegetative screens** outperformed more open GI types such as parks or verges in urban noise reduction.
- **Flowing water features** such as fountains and small streams can mask background noise and improve the perceived sound quality and are more effective than static water in providing psychological relief[7].

Choose plant species wisely to achieve the best results.

- **Seasonality** should be considered through selecting year-round foliage species to ensure continuous acoustic performance, particularly in areas with persistent traffic. Also species with seasonal leaf drop should be avoided if consistent performance is needed throughout the year.
- **High density** foliage plants with fine, fibrous structures maximise scattering and absorption of sound waves.

- **Resilience** and tolerance towards urban stressors like drought or salt spray is critical for effective performance.
- **Toxic or allergenic species** should be avoided in public or high-use areas, particularly near vulnerable groups. Nevertheless, native taxa such as ivy or yew may be considered in less accessible locations, where they pose minimal risk to human health but contribute significantly to habitat provision and biodiversity support.
- **Non-invasive species** must be chosen to maintain long-term ecological balance and reduce maintenance.

Adapt urban greening design to fit local conditions.

- **Structure, location and spacing** of trees and shrubs must be matched to the surrounding built form to optimise acoustic attenuation.
- **Width of GI** is critical as it is advised against narrow plantings, tree belts narrower than 25 m, or hedges with gaps, are they are significantly less effective.
- **High porosity** substrates (e.g. coconut fibre) should be used in green gates to enhance low-frequency noise absorption.
- **Proximity** of vegetation to noise sources and recipients is critical, such as along roadsides or near residential zones, while avoiding visual obstructions for drivers and pedestrians.
- **Location of water features** is preferred near noisy zones (e.g. parks, plazas, roadside areas) for maximal benefit, considering both placement and continuity of flow for masking effects.
- **Strategic planting** in noise-sensitive areas such as schools, hospitals, and high-density housing, is advised.

Combine urban greening infrastructure for greater benefit.

- **Combining BI and GI**, such as ponds integrated with tree lines or green barriers, enhances both acoustic masking and psychological comfort[9].
- **Avoid monocultures** in GI design parks as the mixing of trees and shrubs have proven more effective than single-species landscapes.

Maintain and manage vegetation for long-term effectiveness.

- **Regular maintenance** needs to be ensured to retain vegetation density and height, preserving acoustic function.
- **Random or excessive planting** needs to be avoided instead, deploy well-placed GI in noise-vulnerable areas for maximum social and environmental impact.

Further Insight

Current knowledge gaps.

- It is difficult to compare effectiveness of different interventions for noise mitigation due to a wide range of different noise metrics used, and variety of experimental approaches. More studies comparing noise mitigation across multiple GI types would help address this knowledge gap, ideally using a more limited suite of standardised approaches.

Use spatial modelling to prioritise interventions.

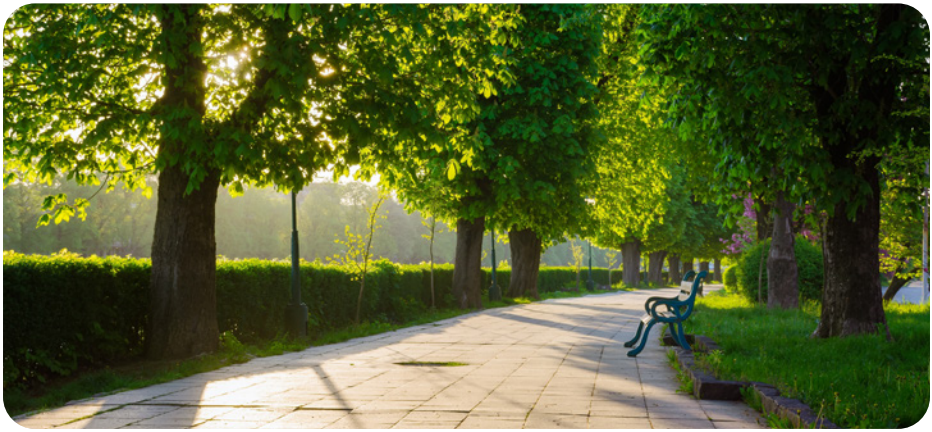
- Mapping noise hotspots and population exposure can guide the placement of small green spaces or hedges for maximum acoustic and social benefit.

Acknowledge the perceptual benefits of greenery.

- Even without measurable sound reduction, visual presence of vegetation can lower perceived noise levels by up to 10 dB(A), improving wellbeing in dense urban areas[5].

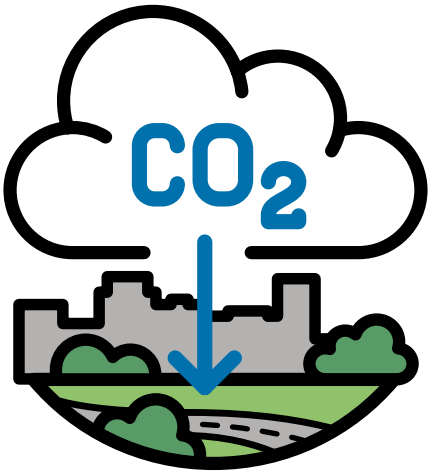
Align with policy frameworks.

- Ensure noise-mitigating GI is embedded within local environmental strategies and complements goals under the WHO Noise Guidelines and UN SDG 11.



References

[1]World Health Organization (2021). World report on hearing. Geneva: World Health Organization. [2]Münzel, T. et al. (2025). Noise causes cardiovascular disease: it's time to act. *Journal of Exposure Science & Environmental Epidemiology*, 35, 24–33. [3]Bonsen, G. et al. (2015). Foraging strategies determine the effect of traffic noise on bats. *Acta Chiropterologica*, 17(2), 347–357. [4]Van Renterghem, T. et al. (2012). Road traffic noise shielding by vegetation belts of limited depth. *Journal of Sound and Vibration*, 331, 2404–2425. [5]Fletcher, D.H. et al. (2022). Location, location, location: Modelling of noise mitigation by urban woodland shows the benefit of targeted tree planting in cities.Sustainability,14(12),7079.doi:10.3390/su14127079. [6]Van Renterghem, T. et al. (2014). Measured light vehicle noise reduction by hedges. *Applied Acoustics*, 78, 19–27. [7]Abhijith, K.V. et al. (2025). Demonstrating multi-benefits of green infrastructure to schools through collaborative approach. *Science of The Total Environment*, 958, 177959. [8]Pan, N. et al. (2017). On single-channel noise reduction with rank-deficient noise correlation matrix. *Applied Acoustics*, 126, 26–35. [9]Yates, G.E. et al. (2010). Factors for collaboration in Florida's tourism resources: Shifting gears from participatory planning to community-based management. Landscape and Urban Planning, 97, 213–220.



Urban Greening for Storing Carbon

Challenge

- Soil sealing due to urbanisation results in a loss of surface area and natural soil functions. This results in a smaller area over which soil carbon can be stored, either in above-ground vegetation or in soils, undermining the soil's ability to function as a carbon sink and support ecological functions[1] (see Figure 8).
- Disruption and mixing of soils is common in urban environments. This can cause substantial soil organic carbon loss, through soil removal during construction, frequent disturbance, and reduced vegetation cover. These disruptions diminish organic matter inputs, destroy soil aggregates that protect carbon and accelerate decomposition.

How urban greening protects and stores carbon

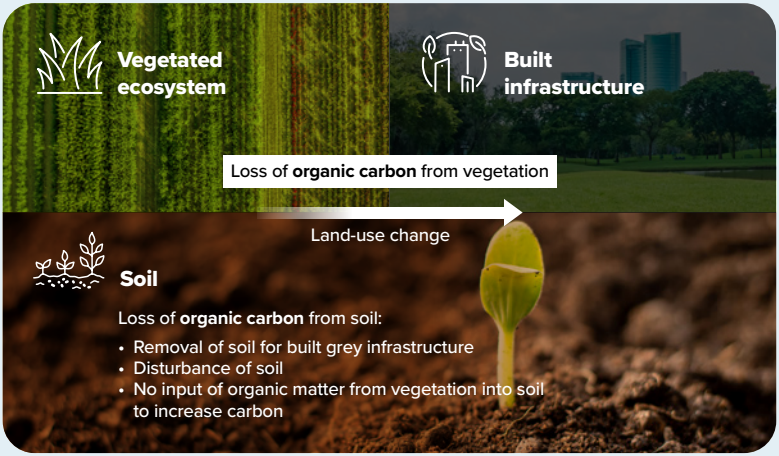


Figure 8: *Urban expansion has negatively impacted carbon pools.*

- **Atmospheric carbon capture**
  Plants in urban green spaces absorb carbon dioxide through photosynthesis, converting it to organic compounds stored in leaves, stems, roots, and woody tissue, providing small climate mitigation benefits while improving local air quality. This carbon builds up over time in woody vegetation, contributing to stored carbon in the vegetation of our towns and cities.

- **Soil carbon enhancement**
  Urban vegetation contributes to soil organic carbon storing through root systems and leaf litter soil incorporation. Some soil types can store much more carbon than others, but ultimately most of the organic carbon in soil comes directly or indirectly from plants. In UK cities, research shows total organic carbon averages 17.6 kg/m^2 with 82% held in soils, demonstrating a significant but often overlooked carbon storing potential[2]. Urban allotments provide further evidence - comprising just 0.0006% of British land yet contributing up to 0.14% of national soil carbon stocks and storing 150% more carbon per unit area than conventional agricultural soils[3].

- **Long-term carbon storage in trees**
  Urban trees, particularly in parks and woodlands, provide substantial carbon storage in woody biomass. When protected from removal, these trees represent stable carbon reservoirs that can persist for decades while providing multiple additional benefits.
- **Interactions with climate**
  Urban vegetation reduces the urban heat island effect through shade and evapotranspiration, lowering surface temperatures and energy demands for cooling. This indirect carbon benefit may reduce fossil fuel consumption.
- **Soil resilience**
  Whilst directly storing carbon, the roots of urban plants also physically protect soil from erosion, compaction, and degradation. By maintaining soil structure and enhancing biodiversity, urban greening creates more resilient ecosystems that can better withstand climate stresses while preserving carbon stocks.
- **Water cycle improvements**
  Urban vegetation and healthy soils increase water infiltration and retention, reducing runoff and enhancing groundwater recharge. This improved water management supports drought resilience and protects water.

Recommended Actions

Prioritise GI types that have higher carbon storage potential.

- **Urban trees and woodland** are the most effective for vegetation carbon storage compared to grassland.
- **Wildflower meadows and allotments** store >150% more carbon per unit area than conventional agricultural land and amenity grassland[4].
- **Incorporate shrubs and trees** into amenity grassland, lawns or gardens to increase carbon storage while supporting multiple ecosystem services.

- **Consider key factors** affecting carbon storage: vegetation input, soil type, disturbance frequency, plant community diversity, climate conditions and management intensity, cutting frequency and management.

Implement sustainable soil management practices.

- **Regularly introduce organic matter** (compost, manure, mulch) to enhance soil carbon content and improve soil structure[5].
- **Minimise soil disturbance** through reduced mechanical disturbances and maintaining continuous vegetation cover to preserve soil structure and protect existing carbon stocks.
- **Promote community-based urban agriculture** and gardening practices that naturally incorporate carbon-building techniques.
- **For areas with suspected contamination or legacy pollution**, implement professional management practices including appropriate soil testing, long-term monitoring and specialised planting strategies to avoid contaminant remobilisation and ensure public safety.

Protect urban greenery from the pressures of urbanisation.

- **Safeguard** green and blue infrastructure through conservation zoning, mapping existing and aspirational wildlife connectivity to protect and enhance these corridors, development restrictions, and buffer zones to prevent carbon loss.
- **Limit impervious surface expansion** in gardens and public spaces to maintain active urban soils and green spaces that can actively contribute to carbon storage and the other important benefits by soils and vegetation.

Further Insight

Capitalise on the potential of food production in urban environments.

- Urban horticulture is increasingly viewed by international organisations as a facet of ensuring future food security, and it has proven potential to provide 15-122% of a city's residents with fruit and vegetables if all available land was cultivated[3].
- Increasing urban greening for food production would enhance access to locally produced healthy food while potentially improving both soil health and urban biodiversity when following best recommended practices for urban gardening; however, this approach will have limited effects on carbon storage in urban vegetation.

Support local research efforts in urban greening to fill current knowledge gaps.

- Research is needed to develop urban soil carbon monitoring programmes that track changes over time, quantifying how different greening strategies affect carbon stocks and providing the evidence base needed to confidently integrate carbon goals into urban planning policies. Furthermore, systematic documentation of comparative local implementation studies across various urban greening approaches is essential to determine their relative impacts on their ability to store carbon, over timescales.

References

[1]Zhang et al. (2015). Effects of forest type and urbanization on carbon storage of urban forests in Changchun, Northeast China. *Chinese Geographical Science*, 25, 147-158. [2]Edmondson, J.L., et al. (2012). Organic carbon hidden in urban ecosystems. *Scientific Reports*, 2, 963. [3]Dobson, M.C. et al. (2021). An assessment of urban horticultural soil quality in the United Kingdom and its contribution to carbon storage. *Science of the Total Environment*, 777, 146199. [4]Davies, Z.G., et al. (2011). Mapping urban ecosystem services: quantifying above-ground carbon storage at a city-wide scale. *Journal of Applied Ecology*, 48, 125-1134. [5]Edmondson, J.L., et al. (2014). Urban cultivation in allotments maintains soil qualities adversely affected by conventional agriculture. *Journal of Applied Ecology*, 2, 963.

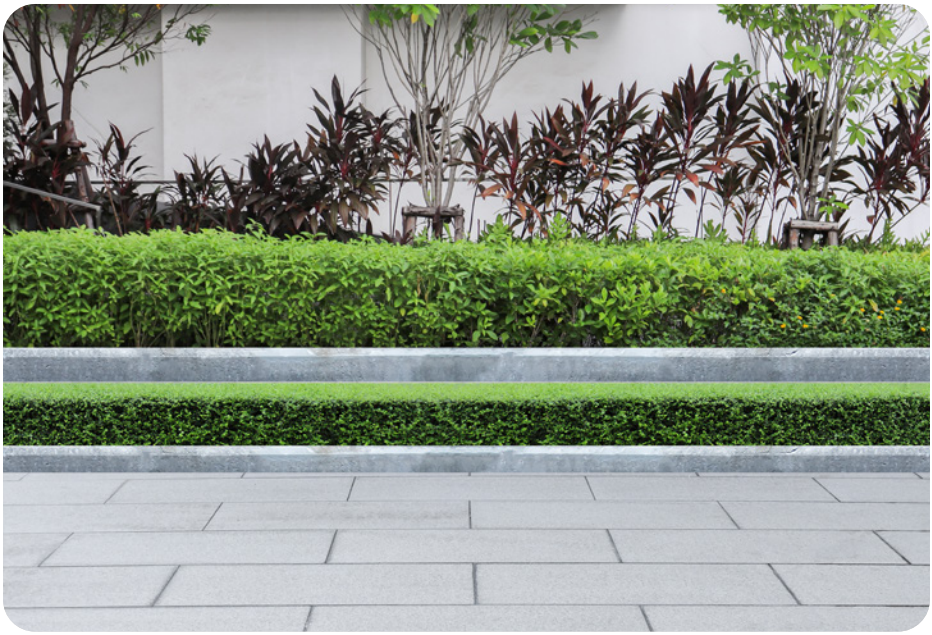
Key Takeaways

1 Choose the right GI for the right place to maximise their positive impacts

- **Match GI/BI to site conditions** consider climate, space, socio-cultural context, water availability and budget.
- **Prioritise GI types** that work for wildlife (parks, gardens, local nature reserves and allotments are biodiversity hotspots) and the environment (trees and shrubs are fundamental for soil retention and carbon capture). The shown matrix (Figure 9) reflects the efficiency of each type of GI/BI in providing different benefits, which helps in selecting the optimum solution for an individual challenge.
- **Consider multifunctionality** to capitalize on win-win opportunities in every project. For instance, planting a hedge or a green wall along a school boundary cuts air pollution, reduces noise, creates wildlife habitat, and provides children daily nature contact - all from one simple intervention (Figure 9).
- But keep in mind that there is no "perfect" solution, and **the decision is always a balance** between positive impacts, plant species requirements - water, air, maintenance, etc. - public support, budgets, and so forth.

A few examples:

- **Hedges along roads**, **green screens** at **schools**, and **green gates** at entrances all help mitigate PM, but also **parks and tree-lined streets** reduce UHI effects.
- **Urban trees and woodlands** are the top carbon capturers. **Street trees** are effective in open spaces but may trap air pollutants in narrow street canyons. Design placement carefully.
- **Green roofs and walls** cool buildings, boost biodiversity, and reduce air pollutants.
- **Shrubs and trees** boost carbon storage in every square meter.



Brief description	Object type	Object category	Food provision	Air pollution	Noise mitigation	Heat mitigation	Water quality mitigation	Water flow management	Maintaining carbon stocks	Supporting physical activity	Supporting social interactions	Restoring capacities - stress reduction and cognative restoration	Supporting biodiversity
Mainly private space linked to dwellings	Gardens	Balcony	L	N	N	N	N	N	N	N	L	H	L
		Private garden	M	L	L	M	M	M	L	VH	M	VH	H
		Shared common garden area	M	L	L	M	M	M	L	M	H	M	L
Mainly public space, but some access restrictions may apply	Parks	Pocket park	L	L	L	L	H	M	L	M	VH	H	M
		Park	L	H	H	H	H	M	H	VH	VH	VH	H
		Botanical garden	L	H	VH	VH	H	M	H	M	H	VH	VH
		Heritage garden	M	M	H	H	H	M	M	M	H	VH	H
		Nursery garden	M	M	L	L	H	M	M	L	M	M	L
Areas designed primarily for specific amenity uses	Amenity areas	Sports field	N	L	L	L	L	L	L	VH	H	M	N
		School yard	N	N	N	N	N	N	N	VH	VH	M	N
		Playground	N	N	N	N	L	L	N	VH	VH	M	N
		Golf course	N	M	L	L	N	M	L	M	H	H	M
		Shared open space (e.g. square)	N	N	N	N	N	N	N	M	VH	L	N
Areas designed primarily for spceific uses (not leisure); some access restrictions may apply	Other public space	Cemetery	N	M	M	M	M	M	H	L	L	VH	H
		Allotment / other growing space	VH	M	L	L	N	M	N	H	H	VH	H
		City farm	VH	M	L	L	N	M	N	M	M	H	M
		Adopted public space	L	M	L	L	L	L	N	N	L	M	L
Linked to routeways, geographical features and boundaries	Linear features/ routes	Street tree	L	H	L	H	L	L	M	N	L	H	M
		Cycle track (as green/ blue corridor)	L	L	L	L	L	L	L	VH	M	H	L
		Footpath (as green/blue corridor)	L	L	L	L	L	L	L	VH	VH	H	L
		Road verge	L	L	L	L	M	M	L	N	N	L	L
		Railway corridor	N	VH	VH	VH	L	M	H	N	N	L	VH
		Riparian woodland	L	VH	VH	VH	VH	H	VH	H	H	VH	VH
		Hedge	L	M	L	L	H	H	M	N	N	M	M
Contructed green and blue space, added to infastructure	Contructed GI on infrastructure	Green roof	N	L	N	L	L	H	L	N	N	L	L
		Green wall	N	M	M	L	N	L	L	N	N	M	L
		Roof garden	M	M	L	M	L	L	M	L	H	VH	M
		Pergola (with vegetation)	N	M	L	H	L	L	M	N	L	H	L
Infrastucture designed to incorporate some GBS components	Hybrid GI (for water)	Permeable paving	N	N	N	N	H	H	N	L	N	N	N
		Permeable parking/ roadway	N	N	N	N	H	H	L	N	N	N	N
		Attenuation pond	N	L	L	L	VH	VH	M	N	L	M	H
		Flood control channel	N	L	N	L	L	VH	L	N	L	N	L
		Rain garden	L	M	N	L	H	H	M	N	N	H	M
		Bioswale	N	M	L	L	M	VH	M	N	N	L	M
Bluespace features	Water-bodies	Wetland	N	M	L	M	VH	VH	M	L	M	VH	H
		River/stream	L	L	H	H	M	H	L	M	H	VH	H
		Canal	L	L	L	M	L	M	L	M	H	VH	L
		Pond	N	L	L	L	L	H	M	L	H	VH	H
		Lake	M	L	M	H	H	H	M	H	H	VH	VH
		Reservoir	L	L	M	H	H	VH	M	H	H	VH	M
		Estuary/tidal river	H	L	H	H	H	N/A	M	M	H	VH	VH
		Sea (incl. coast)	H	L	H	VH	H	N/A	VH	VH	VH	VH	VH
Other un-sealed features without specified use, often on private land	Other non-sealed urban areas	Woodland (other)	L	VH	VH	VH	H	H	VH	H	H	VH	VH
		Grass (other)	L	L	L	L	M	M	L	VH	H	M	M
		Shrubland (other)	L	M	L	L	H	H	M	M	M	H	H
		Arable agriculture	VH	M	L	L	N	L	N	L	N	L	L
		Sparsely vegetated land	N	N	L	N	L	L	N	M	M	M	L

N Negligible L Low M Medium H High VH Very high

Figure 9: *Matrix for urban GI/GBI to guide multifunctional planning of nature-based solutions (Source: Jones et al., 2022. Nature-Based Solutions, 2, 100041).*

2 Choose the proper plant species

- Use a rich **mix of plant species and layered vegetation** to create varied and thriving habitats and ensure resilience. If possible, prolong flowering/fruit period.
- **Prioritise maintaining existing vegetation** over new planting, for trees in particular. Their benefits grow over time so it takes time to get them replaced.
- Choose species based on **current and future climate**, ensure successional tree planting, and avoid peat. This requires reconsidering notions of "native" and "established" species, among other categories. This can be achieved by including a short list of proven performers for different urban contexts.
- Consider **growth times and cycles** as some have very long growth cycles, whilst others need to be replaced every year. Consider **seasonality** too as some plant species provide different services throughout the year.
- Consider **maintenance requirements** as different species require different levels of labor and resources - this should factor into selection and budgeting.
- Choose species that **tolerate urban stress**.
- **Consult with experts**, such as botanists, nursery managers, community gardeners, local wildlife groups and anyone with local knowledge for advice. Availability, durability and maintenance are important factors to consider.
- Keep in mind that, same as with GB/GI, there is no "perfect" species for a specific location, and **the decision is always a balance** between positive impacts, plant species requirements - water, air, maintenance, etc - maintenance, budgets, and so forth.

A few examples:

- Near schools, hospitals, and playgrounds choose **evergreen**, **non-invasive**, **non-toxic**, and **low-allergen** species.
- For year-round noise protection use **evergreen species**.

3 Design for the environment and human health, not just aesthetics

- Consider that many landscaping traditions were based on **aesthetic principles**, which are **not necessarily aligned with environmental and human benefits**. For instance, rewilded fields increase biodiversity with low maintenance, and yet they are disliked aesthetically by some people. It is primordial to expand what counts as a beautiful green-blue space.
- **Emphasise size consideration** where larger or connected green-blue spaces host richer ecosystems and provide greater benefits. But every corner counts! Even small wildflower patches on roadsides can support a surprising variety of insects.
- **Assess local baselines and needs**, including accessibility, types of users, functions - play, health, leisure, cultural, spiritual, etc - maintenance, safety, etc.
- **Improve connectivity** and **access** by linking public spaces to homes for daily nature contact and active lifestyles. Everyone should have green/blue spaces within a 15-minute walk from home, ensuring at least 3 hectares of accessible green space per 1,000 residents.
- Prioritise **GI that boost both mental and physical** well-being and focus efforts where residents are **most at risk** (elderly, low-income, or health-compromised populations).
- **Strengthen equity, inclusion and community** through designing for diverse users across ages, abilities, genders and economic and cultural backgrounds.
- **Include community co-design principles** by conducting stakeholder consultations ahead of large-scale projects to include their feedback and concerns in proposals, then consult again on the draft proposals and refine (if needed).
- **Add monitoring frameworks** to assess effectiveness post-implementation (species surveys/transects, surveys/people counters/mobile phone info on whether have increased visitors/usage, sensors for temperature/pollution etc, surveys/consultations for people's feedback).

A few examples:

- Plant **hedges close to the road**, between traffic and pedestrians or cyclists.
- Use **compact, dense plants** in deep urban canyons, and **porous canopy trees** in shallow ones to improve air quality.
- **Avoid paving/artificial turf** over gardens and minimise in public lands to preserve vegetation and soil function.
- Combine **Blue + Green Infrastructure** for both sound masking and mental wellbeing.

4 Implement effective management and maintenance strategies

- Develop **long-term maintenance plans** that include budget considerations, responsibilities, and schedules.
- Adopt **adaptive** management approaches to monitor performance and adjust maintenance as needed.
- Consider **seasonality** in maintenance regimes to accommodate different maintenance needs across seasons.
- Engage **communities in stewardship** through programs for volunteer maintenance can increase sustainability and community ownership.
- Address **potential disservices** by managing for potential negatives like allergens, fallen branches, or pest habitats.

5 Invest and support local research

- Invest in **local research** to understand what works best for your city's specific climate, pollution patterns, and built form.
- Specify research **priorities** by identifying key knowledge gaps (particularly around blue infrastructure which remains understudied).
- Consider **citizen science opportunities** through community monitoring can generate valuable data while building engagement.
- Embed **impact assessment methods** to include before/after measurements of air quality, temperature, biodiversity, etc.

6 Integrate urban greening into broader planning frameworks

- **Align with existing policies** so as to connect urban greening to climate action plans, biodiversity strategies, and public health initiatives.
- **Advocate for GI standards in planning policies and design codes** to recommend minimum requirements for new developments.
- **Develop cross-departmental collaboration** to encourage coordination between planning, parks, transportation, and health departments.
- **Create comprehensive urban greening strategies** to recommend city-wide approaches rather than piecemeal projects.
- **Consider lifecycle costs and benefits** that emphasise long-term economic benefits of urban greening.
- **Encourage private GI/BI** such as private gardens, rooftops, green walls and any other GB/GI in private property that contribute to the overall urban green-blue infrastructure.

Recognise GI's multiple benefits — air pollution mitigation, carbon storage, cooling, biodiversity, flood and noise control and human wellbeing — all in one space (Figure 10).

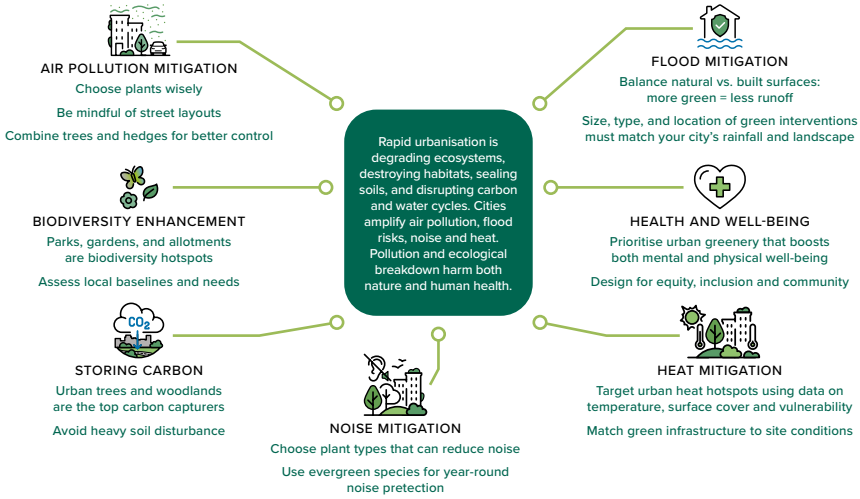


Figure 10: *Overview of the seven environmental and social challenges addressed through urban greening in the toolkit. For each challenge, the figure highlights recommended actions, and key considerations for successful implementation.*

Disclaimer

The content of this document reflects solely the views and experiences of the authors. It does not necessarily represent the positions of the funding agencies, supporters, reviewers, or their affiliated institutions. The recommendations in this document are based on evidence from peer-reviewed scientific literature. While the proposed interventions are valuable, they are not exhaustive. Due to limited research on certain topics, some conclusions remain provisional. As such, these recommendations should be viewed as general guidance rather than definitive or prescriptive. Ongoing research will continue to refine and enhance this resource over time.

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