Environmental and Socio-Ecological Performance of Greening at Household and Street Level

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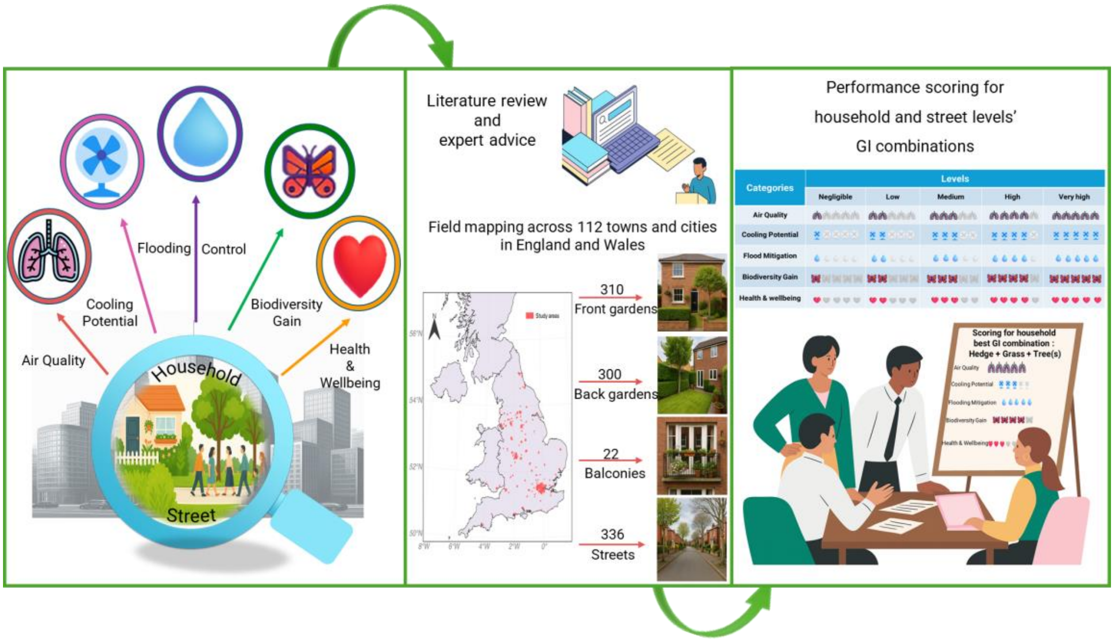
Graphical abstract



Abstract

Household- and street-level greening is a key strategy for enhancing urban resilience to climate change, yet gaps persist in understanding their environmental and socio-ecological performance. To address this gap, this study aims to identify the most common household and street-scale green infrastructure (GI) types in the UK, develop a structured scoring framework for evaluating their environmental and socio-ecological performance, and determine which configurations deliver the greatest multifunctional benefits. We surveyed 112 cities and towns in England and Wales, documenting a total of over 900 sites across front gardens, back gardens, and streets. Common types of greenery included grass, hedges, container plants, street trees, and low shrubs. A five-level scoring framework was developed to assess these configurations' environmental and socio-ecological performance across five impact dimensions: air quality, cooling, flood mitigation, biodiversity, and health and wellbeing. The framework was informed by 991 peer-reviewed studies (2015–2025), expert judgement, and remote visual assessments. The results reveal a clear performance gap between single-element and multi-element configurations. At the household level, combinations of hedges, grass, and trees scored highest in pollutant reduction, cooling, and surface water management. Adding container plants or vertical green screens further improved biodiversity and wellbeing, especially in front gardens. At the street level, the highest scores were associated with configurations that included street trees, roadside grass, hedges, and shrubs. Pocket gardens further enhanced socio-ecological performance through vegetation diversity and vertical layering. These findings underscore the role of plant diversity and spatial composition in maximising the multifunctional benefits of household and street-scale greenery and emphasise that collectively these provide the most benefit when planned as a multifunctional network of GI. The study offers a replicable, evidence-based reference to support DIY and community greening and supports equity and resilience in UK residential areas.

Keywords: Household greening; Street greening; Green infrastructure; Field mapping; Performance scoring

1. Introduction

Rapid urbanisation and climate change have intensified critical challenges in urban environments, including air pollution, rising temperatures, flood risk, and biodiversity loss (Parmesan et al., 2022). In response, nature-based solutions have gained prominence in urban planning (Debele et al., 2023). Among these approaches, green infrastructure (GI), which integrates vegetation within the built environment via a multifunctional network, are increasingly promoted as a strategy to enhance sustainability, resilience, and liveability. Recent studies highlight that GI can contribute to urban transformation by helping to mitigate climate hazards, support ecological restoration, and improve public health outcomes (Kumar et al., 2025a, Kumar et al., 2025b).

Evidence has shown that GI can contribute to environmental improvement across multiple domains. Vegetation can intercept rainfall and airborne pollutants such as $PM_{2.5}$ and NO_2, improving air quality and reducing surface runoff (Salmond et al., 2016; Xiao and McPherson, 2002). Tree canopies and vegetated surfaces reduce heat stress through shading and evapotranspiration, alleviating the urban heat island effect (Mihalakakou et al., 2023). In addition, elements such as rain gardens, bioswales, and permeable pavements help to manage runoff, mitigate peak flows, and reduce localised flood risks (Kasprzyk et al., 2022). Small green spaces, including household gardens, have also been recognised for their role in maintaining biodiversity and ecological function within fragmented city landscapes (Delahay et al., 2023).

These regulating services are increasingly complemented by studies into the social and health benefits of GI. Regular contact with greenery has been associated with lower stress levels, improved mental wellbeing, and increased physical activity (Hunter et al., 2019). Compact features such as pocket parks, planted street verges, and green façades can promote mood restoration, social interaction, and perceived safety, particularly in densely populated areas with limited access to public parks (Rosso et al., 2022).

In this context, decentralised GI features at the household and street levels, such as private gardens, street trees, container plants, and pocket green spaces, play a vital role in delivering localised environmental and socio-ecological benefits. These features are compact, adaptable to built-up areas, and frequently implemented through private or community initiatives. By embedding vegetation directly into residential streetscapes, small-scale greening can distribute environmental and health benefits more evenly than approaches that rely primarily on large parks or centralised green spaces. At the same time, recent research highlights that GI implementation may also generate inequities such as unequal access or green gentrification, particularly when benefits accrue disproportionately to more advantaged groups (Anguelovski et al., 2022; Kumar et al., 2025a; Kumar et al., 2025b). Incorporating household- and street-level greenery, therefore, plays a dual role: mitigating spatial disparities while complementing the wider GI network at neighbourhood and city scales. In addition to their environmental benefits, household and street level greening introduces an important social dimension by enabling direct public participation in climate adaptation (Planas-Carbonell et al. 2023). Unlike large-scale parks or professionally delivered interventions, domestic features such as small trees, hedges, planter boxes, or green façades can be implemented and maintained by residents themselves (Teerlinck et al. 2024). These accessible and low-cost forms of greening offer individuals a tangible sense of personal agency in addressing everyday challenges such as heat, pollution, and localised flooding. Growing evidence suggests that when people are able to contribute to greening their immediate surroundings, they become more engaged with environmental issues, more aware of the functioning of nature-based solutions (Kumar et al., 2024a, Kumar et al., 2024b), and more willing to adopt wider pro-environmental behaviours at the neighbourhood scale (Biswal et al., 2025).

Although the benefits of GI have been widely documented, most research focuses on large-scale interventions such as parks, green corridors, or city-wide networks. These studies offer limited insight into domestic and street-level greening within residential contexts (Cameron et al., 2012; Evans et al., 2022). Evaluations often centre on single outcomes such as air quality, cooling, or flood mitigation (Pugh et al., 2012; Bowler et al., 2010; Debele et al., 2019), while broader socio-ecological dimensions, including biodiversity and human wellbeing are rarely assessed using an integrated, multi-dimensional framework (Veerkamp et al., 2021; Kumar et al., 2025a; Kumar et al., 2025b). In addition, real-world GI configurations in household and street environments frequently involve multiple vegetation types in combination. However, existing studies and reviews often examine these elements in isolation, which limits understanding of their cumulative and intersecting performance (Cameron et al., 2012; Jones et al., 2022). As summarised in Table 1, recent review papers have primarily concentrated on policy-driven, urban-scale GI strategies, with limited attention to decentralised greening at the residential block or neighbourhood level. Examples of such underrepresented interventions include pocket parks, depaving, rain gardens, and street planters, which offer flexible and locally adaptive opportunities for climate resilience (Beute et al., 2023; Khalili et al., 2024; Muñoz and Duarte, 2025). Furthermore, while many studies explore effects on air quality, temperature, or flooding, few provide comparative assessments of co-benefits such as biodiversity enhancement or health and wellbeing at finer spatial scales. This study addresses these gaps by synthesising empirical evidence on the environmental and wellbeing performance of household and street-level greening and proposing a practical framework to support decision-making at the interface of private initiatives and public planning.

This study uniquely shifts attention from city-wide GI strategies to the often-neglected greening at the household and street levels. Rather than examining vegetation types in isolation, it explores typical combinations commonly found in front gardens, back gardens, and streetscapes, thereby making the case that they are an essential component of the GI. It expands the scope of environmental assessment by considering multiple outcomes, including air quality improvement, cooling, biodiversity enhancement, and health and wellbeing. One of the key contributions is the development of a structured scoring matrix, which enables comparative evaluation across these environmental dimensions. By combining field mapping with systematic evidence synthesis, the study highlights gaps between commonly observed practices and their demonstrated environmental performance. These insights can support more targeted and effective greening efforts within residential neighbourhoods.

This study presents a hybrid review that integrates original field-based mapping of household and street-level GI in England and Wales with peer-reviewed evidence on their environmental and socio-ecological performance. It aims to generate comparative ratings across five key dimensions: air quality, cooling, flood mitigation, biodiversity, and health and wellbeing. To achieve this, the study (1) identifies the most common greening types implemented in residential settings across England and Wales; (2) reviews empirical evidence evaluating how these greening types perform in relation to key environmental and health outcomes; and (3) applies a structured scoring framework to rate and compare their performance across these dimensions.

2. Scope, method and outline

The scope of this study is limited to identifying common GI types at the household and street levels in residential areas of England and Wales, and evaluating both individual and combined configurations in terms of their environmental and socio-ecological performance. It does not consider blue infrastructure or city-scale systems, as these are less frequently implemented at the street and household level.

This study employs a three-step methodology to evaluate and score the performance of residential greening interventions. First, commonly implemented GI types at the household and street levels were identified through systematic field mapping. Second, empirical evidence on their effectiveness was compiled from peer-reviewed literature published between 2015 and 2025. Finally, a structured scoring framework was applied to rate and compare individual and combined greening configurations across five key impact dimensions.

2.2.1 Mapping of household and street scale GI types

To inform the evaluation of greening configurations at the household and street levels, we first conducted a mapping survey to identify commonly implemented GI types in residential contexts. The typology used was adapted from an existing classification of 57 GI elements compiled by Kumar et al. (2024b) and Jones et al. (2022) (Figure S2), refined to include only those relevant to household gardens and adjacent streetscapes. Field mapping was carried out across 112 towns and cities in England and Wales, as defined by the Office for National Statistics (2023), using 2011 Census data. These areas represent urban centres with a residential or workday population exceeding 75,000 and were delineated based on the Ordnance Survey's Built-Up Area boundaries, as shown in Figure S1. In each selected location, three residential properties and three nearby street segments were randomly sampled to reflect diverse neighbourhood forms. Housing types included detached, semi-detached, terraced homes, and high/low-rise flats, situated in both residential and mixed-use areas. Street segments were defined as publicly accessible sections of road approximately 50–100 metres in length, adjacent to residential plots, and containing visible greening such as trees, verges, or low planting. Observations were conducted through field visits and analysis of Google Street View imagery, which varied in capture date across locations, with most images taken between 2022 and early 2025. To ensure consistency, only seasonally representative imagery (April to October) was used, capturing vegetation in its developed state. GI elements were categorised based on spatial location (e.g., front gardens, back gardens, balconies), structural form (e.g., hedges, container plants), and visibility within the public realm (e.g., whether the GI was visible from the street or other publicly accessible areas, such as sidewalks or alleyways).

2.2.2 Environmental impacts of GI at household- and street-scale

To examine the environmental and health impacts of greening interventions at the household and street levels, a comprehensive global literature review was conducted using major academic databases, including Web of Science, Scopus, and Google Scholar. The search strategy combined keywords related to vegetation-based GI types, household and street-level residential settings, and five key outcome areas: air quality, thermal comfort, flood mitigation, biodiversity, and human wellbeing (see Table S1 for full search terms). A total of 991 peer-reviewed publications published between 2015 and early 2025 were retrieved from the Web of Science Core Collection using targeted keyword searches in titles and abstracts. Table S1 provides the full keyword search strategy together with the complete list of the 991 retrieved publications, enabling the literature search to be fully reproduced by applying the same parameters.

This study focused on greening interventions commonly found in residential settings, particularly those that are structurally simple, small in scale, and widely implemented across UK neighbourhoods. These included street trees, grass verges, hedges, shrubs, container or hanging plants, and vertical greening systems such as green screens and green walls. For consistency, these GI types were defined as follows: hedges refer to continuous linear woody vegetation used as boundary or screening features; trees are single-stem woody plants located within private gardens or along public streets; shrubs denote multi-stem woody vegetation shorter than tree height; grass represents maintained lawn or herbaceous groundcover; container and hanging plants refer to vegetation grown in pots, planters, or suspended containers; green screens and green walls represent climbing plants supported by trellises or wall-mounted systems; street pots are freestanding containers with ornamental or functional vegetation; green medians are planted strips within road dividers containing grass alone or grass–shrub mixtures; and pocket gardens are small planting clusters integrated into widened pavements or roadside spaces. Emphasis was placed on greening configurations that are clearly visible at the household or street level and that reflect common, replicable practices within UK residential environments. To capture both breadth and thematic depth, a scientometric and thematic analysis was conducted using VOSviewer and CiteSpace. These tools enabled the visualisation of research trends and co-occurrence patterns, supporting a systematic understanding of how such localised greening strategies have been studied across disciplines and outcome dimensions.

2.2.3 GI performance assessment framework

This study employs a structured scoring framework to evaluate the environmental and socio-ecological performance of GI types commonly implemented at the household and street scales. The framework enables consistent comparison of different greening configurations across five key impact domains: air quality improvement, cooling potential, flood mitigation, biodiversity support, and health and wellbeing benefits (as visualised in Figure 1), represent the most widely studied and policy-relevant benefits of small-scale GI across urban environmental research and are consistently reported in existing reviews and empirical studies. While these domains capture the core environmental and socio-ecological functions of greening, we acknowledge that other impact areas, such as water quality, noise mitigation, or carbon sequestration, were beyond the present scope due to limited evidence at household and street scales. At its core, the framework adopts a five-level ordinal classification system, ranging from *Negligible* (L1) to *Very High* (L5), enabling consistent comparison of GI performance across the five environmental domains. L1 reflects minimal improvement over baseline, L3 indicates moderate and context-dependent benefits, and L5 captures substantial and consistently demonstrated effects reported across multiple empirical studies. This tiered structure is adapted from the multi-level ecosystem-service evaluation matrix developed earlier (Jones et al., 2022; Kumar et al., 2024a; Kumar et al., 2024b) and supported by recent fine-scale GI assessment work such as Biswal et al. (2025), all of which demonstrate that reproducible scoring can be achieved by anchoring each level to empirically derived performance ranges. In our study, this established logic is applied to household- and street-scale GI by allocating each vegetation type to a scoring level using defined quantitative thresholds informed by published evidence. Where empirical data for certain small-scale GI types are absent, such as container plants or street pots, expert judgement and observations from common UK residential practice were used to assign provisional scores, with full justification provided in Table 6.

The specific threshold ranges and level definitions applied in each evaluation domain are detailed in Table 2 and are summarised below, along with the supporting literature. Air quality is assessed based on GI's effectiveness in reducing concentrations of key urban pollutants such as $PM_{2.5}$, NO_2, and black carbon, with threshold values ranging from 5-50%, as synthesised from existing papers (Abhijith and Kumar, 2019; Kumar et al., 2024a). Cooling potential reflects the extent to which GI can lower ambient and surface temperatures during summer, with thresholds set between 0.5 °C and 4 °C, supported by empirical findings from both field and experimental studies (Doick and Hutchings 2013; Vaz Monteiro et al., 2016; Sun et al., 2021; Kumar et al., 2024b). Flood mitigation is assessed based on the percentage reduction in surface runoff during short-duration, high-intensity rainfall events. This reduction reflects the combined effects of infiltration and retention capacity, with thresholds ranging from 10-75%, informed by empirical case studies and hydrological modelling (Gonzalez-Meler et al., 2013; Li et al., 2019; Hayes et al., 2021). For biodiversity, since no universally accepted framework exists at the household or street level, this study uses increases in species numbers as the primary evaluation criterion. The approach is informed by the UK D4 indicator (Sobkowiak 2023) and supported by recent reviews that call for standardised assessment methods (Bowler et al., 2025), drawing on studies related to urban vegetation and habitat structure (Timberlake et al., 2019; Helen 2023; Zhang et al., 2024), with scoring levels defined by species gains ranging from 1-31 or more. Lastly, health and wellbeing benefits are classified based on documented changes in stress, depressive symptoms, and physical activity, using indicators such as cortisol concentration, PHQ-9 scores, and behavioural responses (Mytton et al., 2012; Kardan et al., 2015; Hunter et al., 2019; Gu et al., 2022), with scoring thresholds spanning 5-30% cortisol reduction or 1–5 point decreases in PHQ-9 scores. In most household or street-scale settings, multiple GI types are implemented together as composite configurations. To assess their environmental performance across the five domains, this study adopts a maximum-impact approach. Under this method, each composite setup is assigned the highest score achieved by any of its constituent elements within a given domain. This approach was selected because household- and street-scale GI configurations often feature spatially uneven contributions. For example, a single mature tree or a continuous hedge may dominate in terms of shading, pollutant removal, or runoff reduction, even when accompanied by lower-performing elements. The maximum-impact rule, therefore, provides a conservative and transparent means of capturing the upper bound of performance within mixed GI arrangements. However, we recognise that this method does not account for the proportional area, coverage, or functional weight of individual components, and may overemphasise high-performing elements in composite configurations. More refined approaches, such as area-based or function-based weighting, would better represent the relative contribution of each GI type and could improve accuracy in future assessments.

2.3 Outline

Following the introduction (Section 1) and the scope, methodology, and outline (Section 2), Section 3 presents the core findings of this review. Section 3.1 outlines the mapping results from 112 urban areas in England and Wales, identifying typical greening configurations at the household and street levels. Section 3.2 synthesises empirical evidence on the environmental and socio-ecological impacts of these greening types. Section 3.3 applies a structured scoring framework to comparatively evaluate their performance across five dimensions. Section 4 concludes with key insights, recommendations, and future research directions.

3. Results and discussion

3.1 Mapping results of common household and street-level GI types

Drawing on the original typology of 57 GI elements in the urban scale, we identified a subset of greening types most frequently observed at the household and street levels across 112 urban areas in England and Wales. The mapping focused on visible and functional vegetation in front gardens, back gardens, balconies, and along residential streets.

At the household level, frequently observed GI types included: trees, shrubs, hedges, grass, green roofs, green screens, container plants, and hanging plants (as shown in Figure 2). These features were typically located in private gardens or on local streets and were often informal or maintained by residents. The presence of vertical elements such as green screens and hanging plants reflects efforts to maximise greening within constrained residential spaces.

Front gardens, back gardens, and balconies show distinct greening patterns (Table 3). A total of 310 front gardens, 300 back gardens, and 22 balconies were analysed. In both front and back gardens, grass-only configurations were most common, representing 10.6% and 22.3% of cases, respectively. Front gardens exhibited greater diversity, with 50 vegetation combinations recorded, though many were structurally simple, often comprising a single element such as grass, shrubs, or hedges. This simplicity likely reflects spatial and functional constraints, where planting is shaped by visibility and aesthetic concerns. In contrast, back gardens featured fewer configuration types but more frequent integrated combinations, particularly those involving both hedges and trees. This suggests a multifunctional, semi-private role supporting ecological value and domestic use. Balcony greening was rare, with only five cases featuring combined elements like hanging baskets, container plants, and green screens. This limited uptake reflects the practical constraints of high-density housing, including space, structural load limits, and accessibility.

At the street level, commonly identified GI elements included: street trees, roadside grass, hedges, shrubs, planted pots, green medians (vegetated strips separating traffic lanes), and pocket gardens (small, planted areas integrated into streetscapes, often in underused or irregular spaces; Figure 2). These features were typically located within public rights of way such as sidewalks, road verges, and traffic islands. Their spatial distribution and maintenance levels varied across study sites, presumably reflecting local authority priorities and investment in urban greening.

Street-level GI across 112 UK cities and towns is predominantly characterised by the presence of street trees and roadside grass (Table 4). Among the 336 street segments analysed, each typically measuring 50-100 m in length, the most frequently observed configurations were street trees alone (21.4%) and street trees combined with roadside grass (19.9%). This pattern reflects a widespread use of linear greening, likely driven by space constraints, and aesthetic and streetscape design objectives rather than direct thermal regulation considerations. In contrast, 16.4% of street segments displayed no visible GI, highlighting the continued dominance of impervious unvegetated surfaces and the potential for targeted greening interventions. More complex arrangements, such as green medians, planted pots, or pocket gardens, were rarely observed, possibly due to space limitations or the greater maintenance requirements these elements entail.

3.2 Evidence base on the performance of household and street-level greening

The second stage of the study involved a comprehensive review of academic literature, policy documents, and technical reports to evaluate the environmental and health-related impacts of household and street-level greening interventions. Figure S3a shows the annual publication trend from 2015 to 2025, based on 991 peer-reviewed articles identified through targeted keyword searches in titles and abstracts. The number of relevant publications increased from 25 in 2015 to a total of 173 in 2024, reflecting a broader growth in sustainability research. While a steady rise is visible from 2019 onwards, similar patterns have been observed across other environmental domains and may partly reflect shifting priorities during the COVID-19 pandemic, when attention to local and neighbourhood-scale green spaces increased. However, without a comparative baseline (e.g. total GI-related publications), this trend should be interpreted with caution. Figure S3b presents the keyword co-occurrence network, which reveals several interconnected thematic clusters, including GI and runoff management, urban heat and vegetation, green space and mental health, and biodiversity and ecosystem services. While some of these topics are not specific to small-scale interventions, the emergence of keywords such as "local climate zone," "street canyon," and "urban green space" suggests increasing attention to spatially resolved, context-specific greening strategies. This aligns with the growing interdisciplinary interest in GI research that moves beyond single-function outcomes toward integrated urban systems thinking. Figure S3c shows the temporal evolution of research themes, with earlier work focusing primarily on air quality and thermal regulation, and more recent studies incorporating wellbeing, ecological value, and spatial planning dimensions. Although the visualised shift does not directly isolate household- and street-scale interventions, it signals a broader reorientation of GI research towards quantifying the multifunctional and context-sensitive applications.

3.2.1 Air pollution mitigation

Existing studies on air quality impacts of household and street-level GI (Table S2) are unevenly distributed across types and spatial scales. At the household level, research has mainly focused on vertical greening systems, particularly green walls and green screens. Green walls have been shown to reduce $PM_{2.5}$ and PM_{10} by up to 25–37% in outdoor settings (Srbinovska et al., 2021) and achieve up to 7.3% reduction in $PM_{2.5}$ in dense urban environments (Viecco et al., 2021). Indoor studies also highlight their potential for Volatile Organic Compounds (VOC) removal and species-level selection strategies (Shen et al., 2024). Green screens, though less studied, have demonstrated notable NO_2 reduction of 22.5% in real-world school settings (Tremper and Green 2018).

However, for other common household greening types, including hedges, trees, grass, shrubs, container plants, and hanging baskets, empirical evidence on their air pollution mitigation performance within domestic garden settings remains limited. Although such elements are prevalent in residential spaces such as gardens, balconies, and courtyards, most existing studies focus on urban or roadside environments, highlighting a critical gap in household-level environmental health research.

The street level shows a richer and more diverse body of research. Street trees have received the most attention, though findings are mixed. Depending on canopy density and canyon geometry, they can either reduce or exacerbate pollutant concentrations. For example, some studies report PM increases of over 100% due to obstructed airflow (Karttunen et al., 2020), while others show reductions in inhalable and thoracic PM by up to 59% under optimal spacing (Ren et al., 2023). Similarly, hedges and shrubs are widely studied and consistently show effective reduction of PM and black carbon, especially when densely planted and extending from ground to canopy (Deshmukh et al., 2019; Ottosen and Kumar, 2020).

A growing body of work also evaluates pocket parks, particularly those buffered from roads or containing diverse vegetation, which show reductions in $PM_{2.5}$ exposure and improvements in perceived air quality (Onur and Kahveci 2024; Li et al., 2025). Yet, despite their frequency in urban streetscapes, roadside grass, planters, and green medians remain largely absent from the literature on air pollution, underscoring a disconnect between practice and evidence.

A significant portion of research targets mixed vegetation systems, reflecting real-world streetscape complexity. When appropriately spaced and combined, trees, hedges, and shrubs arranged in continuous and dense formations can achieve substantial pollutant capture, up to 63% for black carbon and 31% for $PM_{2.5}$ (Baldauf 2017; Abhijith and Kumar 2019). These findings support a system-level design approach rather than isolated GI elements in street environments.

3.2.2 Cooling potential and thermal comfort

Turning to cooling potential and thermal comfort, at the household level, existing literature overwhelmingly focuses on the cooling and thermal comfort potential of green walls (Table S3). Studies have reported reductions in surface temperature exceeding 6 °C (Cuce 2017), improved humidity and indoor air quality (Galagoda et al., 2018), and significant energy savings in simulated residential blocks (Li et al., 2019). More recent findings suggest that green walls can also reduce pedestrian-level air temperature by up to 3.3 °C in Mediterranean climates (Oquendo-Di Cosola et al., 2023), confirming their effectiveness in enhancing microclimatic conditions in compact urban settings.

In contrast, evidence for other household-scale GI types such as hedges, grass, shrubs, container plants, hanging plants, and green screens remains very limited (Table S3). Among them, only one study has quantified the impact of hedges, demonstrating that belt-shaped configurations aligned with the wind direction can reduce physiologically equivalent temperature (PET) by up to 6.3 °C, while fragmented layouts are less effective (Sodoudi et al., 2018). For the remaining types, cooling potential and thermal comfort impacts are largely undocumented.

At the street level, street trees are the most extensively studied GI type. A wide range of research has shown their ability to lower air temperature, radiant heat, and thermal indices such as PET and the universal thermal climate index (UTCI). For instance, dense tree canopies have been associated with PET reductions of 4–12 °C and mean radiant temperature (MRT) drops of 20–22 °C (Jareemit and Srivanit, 2022), while increased canopy cover consistently correlates with improved outdoor comfort in both temperate and subtropical climates (Lachapelle et al., 2023; Wu et al., 2024).

Pocket parks also demonstrate clear cooling benefits. Studies report reductions in air temperature and UTCI ranging from 1.2-3.7 °C, depending on vegetation density and spatial configuration (Lin et al., 2017; Zhou et al., 2025). Design elements such as tree cover ratio and landscape type have been shown to influence thermal perception and user comfort (Chen et al., 2023).

Other street-level GI types, including street shrubs, roadside grass, street hedges, and green medians, have received relatively limited attention. Some studies have shown that shrubs can reduce surface temperatures by over 10 °C (Zhang 2020), and that low hedges can decrease local air temperature by ~2 °C (Mohammadi et al., 2022).

3.2.3 Flood control

While the flood mitigation potential of GI is well established at the city or catchment scale, empirical research at the household and street levels remains limited. This is notable given the prevalence of household and street-scale GI in residential settings, particularly in the UK. A growing body of studies, however, suggests that features such as rain gardens, permeable pavements, trees, hedges, green roofs, and walls can meaningfully contribute to stormwater regulation when designed appropriately.

At the household scale, rain gardens and permeable pavements are the most rigorously studied. Field experiments show that rain gardens can retain all runoff in up to 18% of rainfall events and reduce peak flows by over 50% (Davis 2008). Modelling work indicates that widespread adoption in high-density neighbourhoods could reduce total runoff by tens of millions of litres annually (Zhang et al., 2020). Similarly, permeable pavements in driveways or yards have demonstrated runoff reductions of up to 80% during low-intensity storms. Their performance, however, is strongly dependent on maintenance, soil conditions and rainfall intensity (Nascimento, 2022).

Evidence on other household GI types is more limited but emerging. Green roofs have been shown to retain 41-75% of rainfall in short-duration events and reduce peak volumes significantly under return-period storm conditions (Liu et al., 2020). Green walls, though less commonly studied, can function as vertical bioretention systems, with some experiments reporting runoff reductions of over 45% (Lau and Mah, 2018). Recent studies on hedgerows suggest that species selection plays a key role in regulating runoff. For example, shrubs such as *Cotoneaster* and *Crataegus*, which feature dense canopies and high water-use efficiency, have been shown to reduce surface runoff to less than 5% of rainfall volume and delay peak flows by up to 15 minutes under simulated conditions (Blanusa and Hadley, 2019). These effects are not driven by direct evaporation but result from pre-event water uptake through transpiration, which reduces substrate moisture and enhances subsequent infiltration during minor rainfall events. Additionally, broader ecosystem-based evaluations identify hedgerows as cost-effective flood protection options, particularly in rural or peri-urban contexts (Daigneault et al., 2016).

Nonetheless, many commonly used domestic greening elements, including lawns, shrubs, containers, and ornamental planting, remain largely absent from hydrological evaluations. Lawns are often compacted and provide limited infiltration capacity, while containerised vegetation lacks a functional connection to runoff pathways (Corrêa et al., 2021). Although results from rural experiments suggested that dense vegetation can enhance infiltration by more than an order of magnitude (Ariyarathna et al., 2023), such effects remain under-validated in urban household contexts.

At the street level, more evidence is available. Street trees are among the most frequently assessed features, offering benefits through canopy interception, root uptake, and infiltration into adjacent soil pits. Tree pits designed to capture stormwater not only enhance infiltration but also improve tree growth, as demonstrated in field experiments (Grey et al., 2018). Furthermore, canopy presence can buffer flood impacts by acting as a temporary storage. Experimental flood simulations indicate that tree groups situated near building frontages can significantly reduce water levels during intense events (Liu et al., 2023). Roadside bioretention cells and swales further contribute to peak flow reduction, particularly in moderate storms. Permeable pavements along curbs or parking areas have demonstrated runoff reductions between 26% and 98% depending on rainfall intensity (Sañudo-Fontaneda et al., 2018). However, system performance may be compromised by seasonal debris.

Experimental observations also confirm that urban drainage systems are highly sensitive to debris-induced obstruction.

Although household and street-scale GI offer demonstrable flood mitigation benefits, the current research remains focused on a narrow subset of interventions. More systematic assessment of underrepresented elements, particularly ornamental and passive greening types, is needed to guide effective design and implementation across diverse residential and street contexts.

3.2.4 Biodiversity

Common household and street-scale GI features can provide meaningful contributions to urban biodiversity, even though their spatial extent is smaller than that of parks or larger green corridors. These small interventions function as microhabitats and ecological stepping stones, supporting a variety of flora and fauna within built environments.

At the street level, elements such as street trees, verge plantings, and bioswales have demonstrated the capacity to support diverse faunal communities. A study in Brazil recorded 73 bird species using tree-lined streets, with species richness positively associated with canopy volume, native tree diversity, and the presence of mature individuals (Pena et al., 2017). In New York City, even the small, vegetated patches around street trees were found to host invertebrates from nine insect orders and over 50 families, including herbivores and their natural enemies (Lundquist et al., 2022). These findings suggest that street vegetation, despite being fragmented and exposed to human disturbance, can serve important ecological functions.

At the household scale, front gardens, hedges, lawns, and rain gardens also create valuable habitats. Domestic lawns, when maintained with ecological sensitivity, can support substantial biodiversity. In one suburban experiment, reducing mowing frequency allowed wildflowers to flourish and supported up to 93 bee species, equivalent to nearly a quarter of the study area’s recorded bee fauna (Lerman et al., 2018). Other studies have shown that gardens with structurally diverse vegetation, such as combinations of shrubs, trees, and flowering herbaceous plants consistently host greater bird and invertebrate richness (Delahay et al., 2023) whereas heavily manicured, pesticide-treated, or overly simplified yards have reduced biodiversity supporting fewer species (Delahay et al., 2023).

Household-scale GI also benefits below-ground biodiversity. Soils under vegetated elements such as swales or rain gardens often exhibit higher microbial richness than those under impervious or compacted surfaces, likely due to increased organic matter and better moisture retention (Gill et al., 2017; Joyner et al., 2019). These microbial communities play essential roles in nutrient cycling and ecosystem resilience, further enhancing the ecological value of domestic green spaces.

Green roofs and green walls add vertical habitat complexity and have shown promising biodiversity outcomes. A systematic review of green roofs highlighted their value for arthropods and native plants, particularly where substrate depth and vegetation diversity are maximized (Wang et al., 2022). In a comparative case study, a vegetated roof supported four times more bird species and seven times more arthropod taxa than a structurally identical bare roof (Wooster et al., 2022). Similarly, vertical greening systems have supported over 100 species of insects, spiders, and birds, vastly outperforming non-vegetated façades (Hecht et al., 2025).

Despite these findings, research on biodiversity impacts remains uneven across GI types. In the UK, many commonly implemented household and street-scale greening elements, such as container plants, hanging baskets, green screens, and certain types of evergreen hedges, have not been empirically evaluated for their biodiversity performance. While their aesthetic or thermal contributions may be recognised, their ecological value remains speculative. This lack of data creates a gap between practice and evidence, particularly at the scale of individual properties and neighbourhood streets.

Household and street-level GI has demonstrable potential to support urban biodiversity, both above and below ground. While it cannot substitute for large natural areas, it plays a critical role in habitat supplementation and ecological connectivity. However, future studies should expand beyond trees and rain gardens to assess a broader range of household and street-level greening practices that are currently widespread yet understudied in terms of their ecological function.

3.2.4 Health and wellbeing

GI at the household and street scale, including street trees, hedges, lawns, rain gardens, green walls, and container planting, has received growing attention for its potential to support human health and wellbeing. While the majority of research to date has focused on larger green spaces such as parks and forests, an increasing number of studies suggest that smaller-scale greening interventions may also yield tangible health benefits (Kardan et al., 2015; Gu et al., 2022). This was seen as particularly important during the COVID-19 pandemic when small localised green spaces were of significant value to communities (Reid et al., 2022). Recent nature-based public health studies underscore that proximity to and interaction with urban greenery, including courtyards, yards, and green façades, can deliver significant psychological and physiological benefits, particularly during stressful periods (Marques et al., 2021; Lin et al., 2023).

Mental health outcomes are among the most consistently reported benefits of household and street-scale GI. A recent systematic review found that even limited exposure to nature, including indoor green walls and potted plants, can significantly reduce stress and anxiety (Gu et al., 2022). Exposure to greenery has been associated with reduced antidepressant prescription rates in several national-level studies. Experimental studies show that introducing trees and plantings to street scenes improves mood and affective responses among residents (Navarrete-Hernandez and Laffan 2023). At the neighbourhood level, people living along greener streets have been found to report lower rates of antidepressant use, particularly in lower-income communities (Marselle et al., 2020). Additionally, a large-scale longitudinal UK study highlighted residential greenness as significantly lowering the risk of depression and anxiety, partly due to reduced air pollution (Wang et al., 2024). Similarly, an international survey across 18 countries found that recreational visits to green and blue spaces significantly improved positive wellbeing and reduced mental distress, underscoring active engagement with urban nature as crucial for mental health (White et al., 2021).

Physical wellbeing is also positively influenced by neighbourhood-scale greenery, often through reduced physiological stress linked to environmental pollutants (Lai et al., 2024). Greener neighbourhoods have reported lower cardiovascular disease rates and improved general health outcomes. A Toronto-based study found that an increase of ten street trees per block significantly improved self-reported health and reduced cardio-metabolic conditions, a benefit comparable to substantial income increases or age reductions (Kardan et al., 2015). Additionally, residential greenness has been demonstrated to lower composite physiological stress indices, especially in urban areas facing air pollution stressors (Lai et al., 2024). Greenery also promotes physical activity by creating more inviting walking environments and improving thermal comfort through shading and evapotranspiration, reducing heat stress. Such benefits are increasingly critical in the context of climate change (Halder et al., 2025).

Social wellbeing is likewise enhanced by household and street-scale GI. Greened streetscapes and visible household gardens encourage community interaction, enhance a sense of place, and improve perceived safety. Passive exposure, such as views of greenery from windows, has been linked to reductions in aggression and crime rates (Kardan et al., 2015). Studies in densely populated cities like São Paulo demonstrate that even modest green additions, such as grassed areas, significantly reduce anxiety and enhance social cohesion, especially benefiting socioeconomically disadvantaged groups (Moreira et al., 2022; Araújo et al., 2024). Such social and perceptual benefits, while subtle, significantly contribute to urban liveability, restoring vital ecosystem services in areas where they are often most needed (Wild et al., 2017; 2024).

Despite these promising outcomes, existing literature disproportionately emphasises larger green spaces. Empirical research on widely used GI types at the household and street level, such as hedges, container plants, green screens, and hanging baskets, remains limited. This gap indicates a misalignment between common residential green elements and the focus of health-related research.

While household and street-scale GI interventions may not offer the extensive ecosystem services associated with larger parks or greenways, their benefits for psychological, physical, and social health are meaningful and well-supported by emerging evidence. Future research should systematically assess these smaller interventions to expand our understanding of their roles in enhancing individual and community wellbeing.

3.3 Performance assessment of household and street-scale GI types

To enable structured comparison across common household and street-level GI types, a performance assessment was conducted based on the five environmental dimensions synthesised from the literature: air quality improvement, heat mitigation, flood regulation, biodiversity support, and health and wellbeing benefits. Each GI type was evaluated using a standardised five-level scoring system (Level 1 to Level 5), reflecting its relative effectiveness according to published evidence, expert judgment, and observed performance in urban practice. The methodological basis for this scoring system, including the threshold ranges, data hierarchy, and criteria used to assign each GI type to a performance level, is detailed in Section 2.2.3, with detailed justification for individual scores provided in Table 6.

3.3.1 Evaluation of common household and street level GI types in the UK

This subsection presents the performance assessment of the most commonly observed household- and street-level GI types in UK residential areas, based on the integrated findings from literature synthesis, expert judgement, and field-based observations. Table 5 provides a comparative overview of how each GI type performs across five key environmental and socio-ecological dimensions: air quality improvement, cooling potential, flood mitigation, biodiversity support, and health and wellbeing. These scores reflect relative effectiveness using a five-point ordinal scale. To support transparency and evidence-based interpretation, Table 6 offers detailed justifications for each score, drawing on empirical studies and context-specific insights. Together, the two tables offer a structured evaluation framework that enables comparison of GI performance across spatial settings and functional outcomes.

3.3.2 Scoring matrix for household and street-level GI

There is a clear distinction in performance between simple and composite GI configurations at both the household and street levels (Tables 7 and 8). At the household level, the most commonly observed configurations, such as grass only, shrub only, or hedge only, show limited effectiveness across the five environmental dimensions: air quality, cooling potential, flood mitigation, biodiversity, and health and wellbeing. These single-element types tend to provide only low to moderate benefits. In contrast, household configurations that combine multiple GI elements, such as trees, shrubs, container plants, and green screens, generally achieve higher scores across all performance categories. Notably, among front garden and back garden settings, the hedge, grass, and tree combination emerged as the most effective across core environmental functions. This basic triad consistently scored highly in air pollutant reduction, ambient cooling, and surface runoff mitigation, due to the complementary roles of dense boundary planting, ground cover, and vertical canopy structure. Moreover, expanded versions of this combination, incorporating additional elements such as container plants or green screens, tended to perform even better in terms of biodiversity support and health and wellbeing benefits, reflecting the cumulative value of multi-layered, diverse vegetation in enhancing ecological complexity and psychological restoration. For balconies, the most frequent and highest-scoring configuration was the combination of container plants and hanging plants. However, despite their popularity, such setups typically offer limited environmental impact, particularly in terms of pollutant removal and flood mitigation, due to their smaller biomass, restricted root systems, and minimal interaction with ambient airflow and water flows. Nonetheless, they may still contribute meaningfully to wellbeing and perceived greenness in high-density settings where space constraints limit the installation of larger GI systems.

A similar pattern is evident at the street level. Although street trees remain the most prevalent form of GI in urban streetscapes, their isolated implementation yields only moderate effectiveness across environmental and socio-ecological dimensions. In contrast, more integrated configurations, incorporating elements such as roadside grass, hedges, green medians, and pocket gardens, demonstrate significantly enhanced and more balanced performance profiles. Among the highest-performing combinations observed was the assemblage of street trees, roadside grass, hedges, and shrubs, which integrates a broader spectrum of street-level GI components. As an additional vegetation layer relative to typical household-scale arrangements, the inclusion of shrubs appears to generate measurable improvements in biodiversity support and health and wellbeing outcomes, likely due to the associated increases in vegetation complexity, vertical structure, and sensory exposure. Another configuration with consistently high composite scores consists of street trees, hedges, and pocket gardens. Although less spatially prevalent, this combination benefits from the multifunctionality and structural heterogeneity of pocket gardens, which often embed diverse GI elements ranging from groundcover and flowering species to small trees within compact public spaces. As a result, such configurations deliver elevated socio-ecological performance, particularly in terms of microhabitat provision, aesthetic value, and psychological restoration potential. Compared to mono-functional or single-element installations, these multi-layered and compositionally diverse street-level interventions offer demonstrably superior outcomes, reinforcing the importance of GI diversity and spatial integration in maximising ecosystem service delivery at the street scale.

4. Conclusions, recommendations and future outlook

This study assessed the environmental and socio-ecological performance of commonly implemented GI at the household and street scales. Using a combination of typological mapping, literature-based evidence synthesis, and a structured five-dimensional scoring framework, it evaluated how different GI types both individually and in combination contribute to air quality, cooling, flood mitigation, biodiversity, and health and wellbeing in residential environments.

The key findings are as follows:

- **Research on household and street-level GI is growing but remains fragmented.** A review of 991 publications from 2015 to 2025 shows increasing interest, particularly after 2019. However, most studies focus on city-scale interventions and overlook the spatial and functional realities of smaller-scale settings, limiting their practical application in neighbourhood design and community-led adaptation.
- **Mapping identifies dominant GI types and spatial constraints in the UK.** A survey of 112 urban areas in the UK found trees, hedges, and grass to be the most common elements at both household and street levels. While 50 unique combinations were observed in front gardens, they tended to be simpler than back gardens. Complex configurations in the public realm, such as pocket gardens and green medians, were rare, present in fewer than 5% of cases, likely due to space and maintenance constraints.
- **Air quality benefits of GI are supported by strong evidence for certain types, but many common elements remain under-evaluated.** Vertical greening and street trees show the most consistent pollution reduction, while household features such as hedges and container plants lack sufficient data. Effectiveness varies by vegetation height, density, and airflow, with GI combinations including hedges rated very high for air pollution reduction, exceeding 50%.
- **Cooling benefits are well supported for green walls and street trees, but evidence for other GI types is limited.** Street trees achieved the highest cooling scores due to their shading effect. In

contrast, elements like shrubs, lawns, and green medians are understudied, and findings for pocket parks remain context-specific.

- **Flood mitigation evidence is concentrated on engineered GI, while common vegetation types are underexplored.** Rain gardens and permeable pavements show strong runoff reduction, but lawns, shrubs, and ornamental plantings lack sufficient evaluation. Grass-based configurations performed best across both household and street levels, indicating potential for broader application in local stormwater planning.
- **Biodiversity and wellbeing benefits are supported at the household and street scale but vary by GI type and composition.** Features like parks, hedges, and green roofs support microhabitats and urban ecology, while ornamental or sparse vegetation show limited impact. Similarly, small interventions such as street trees or container plants can improve stress, walkability, and social connection. Higher scores in both dimensions were associated with more diverse GI configurations.
- **GI combinations received higher scores across multiple environmental and socio-ecological dimensions compared to single-element types.** At the household level, configurations combining hedges, grass, and trees achieved the strongest performance, particularly in air quality improvement, cooling, and flood mitigation. At the street level, arrangements that included street trees, hedges, grass, and shrubs delivered the most balanced and effective outcomes. These multi-element setups outperformed isolated GI types by providing synergistic benefits, especially in biodiversity enhancement and wellbeing. In contrast, single-element interventions, such as grass or shrubs alone, demonstrated limited effectiveness across most indicators. This demonstrates the importance of genuinely planning and delivering GI as a truly multifunctional network at the neighbourhood and city scale.

We drew the following recommendations from the discussions:

- **Broaden the GI typology used for performance assessment.** While this study covered the most observed household and street-level GI types, the current typology does not fully capture the diversity of greening practices in different urban contexts. Future work should include less-studied configurations such as green fences, vertical planters, or DIY based systems to improve inclusivity and global applicability.
- **Strengthen empirical validation of performance metrics.** The current scoring framework is informed by literature and expert judgment, but many GI types, particularly at small scales, lack experimental or model-based validation. Field measurements and simulations should be used to verify performance across impact categories such as cooling, runoff control, and air quality. Given the constrained scope of this small-scale study, the selected metrics were prioritised for their direct applicability. The omitted factors such as water quality improvement, noise mitigation, and carbon sequestration, while potentially significant in a broader context, require further quantitative substantiation to determine their efficacy and operational value within the specified performance assessment framework.
- **Refine composite configuration scoring using weighted approaches.** In this study, composite GI setups were assessed using the highest-performing element. A more comprehensive method would apply area-based weighting to better reflect the proportional contribution of each component. This would improve the accuracy and applicability of future assessments.
- **Integrate social and ecological metrics into household and street-scale GI planning.** Most environmental assessments still prioritise physical functions like temperature or runoff reduction. Future evaluations should also account for social and biodiversity co-benefits, especially in dense urban environments where access to nature is limited.

- **Recognise scale-related uncertainties in GI performance evidence.** Some performance estimates come from studies in different climates, spatial scales, or hydrological contexts, meaning they may not fully represent household or street conditions. Several common residential GI types also remain understudied. Future work should therefore prioritise fine-scale measurements and modelling tailored to residential environments.

- **Translate findings into practical local design and policy guidance.** To maximise the impact of household and street-scale GI, performance insights should be incorporated into planning tools, building guidelines, and community programmes. Decision-makers at the neighbourhood and street levels can use these data to inform greening strategies tailored to site-specific needs and constraints and ensure the creation of an optimised multifunctional network.

As cities confront intensifying climate and social pressures, household- and street-scale GI serves as a critical mechanism for fostering healthier, resilient, and inclusive urban environments. This study develops a performance matrix evaluating five key environmental and socio-ecological parameters of small-scale greening interventions. Despite these contributions, significant knowledge gaps persist regarding the performance of diverse GI typologies and their synergistic combinations, which is a critical research frontier for future studies. Addressing these gaps can inform evidence-based decision-making, enabling the systematic integration of greenery into neighbourhood design and advancing sustainable, human-centric urban development.

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6. Author credit

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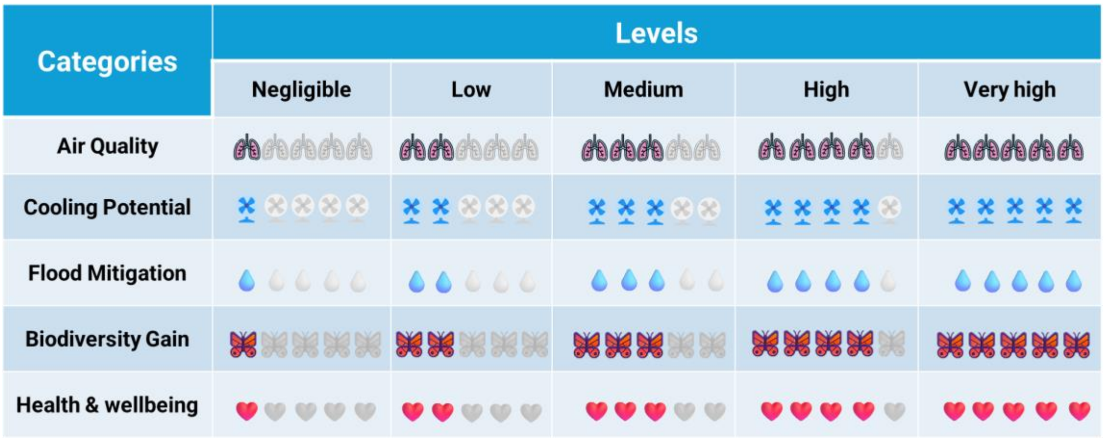

Figure 1. Scoring framework for assessing household and street-level GI across five environmental and socio-health dimensions.

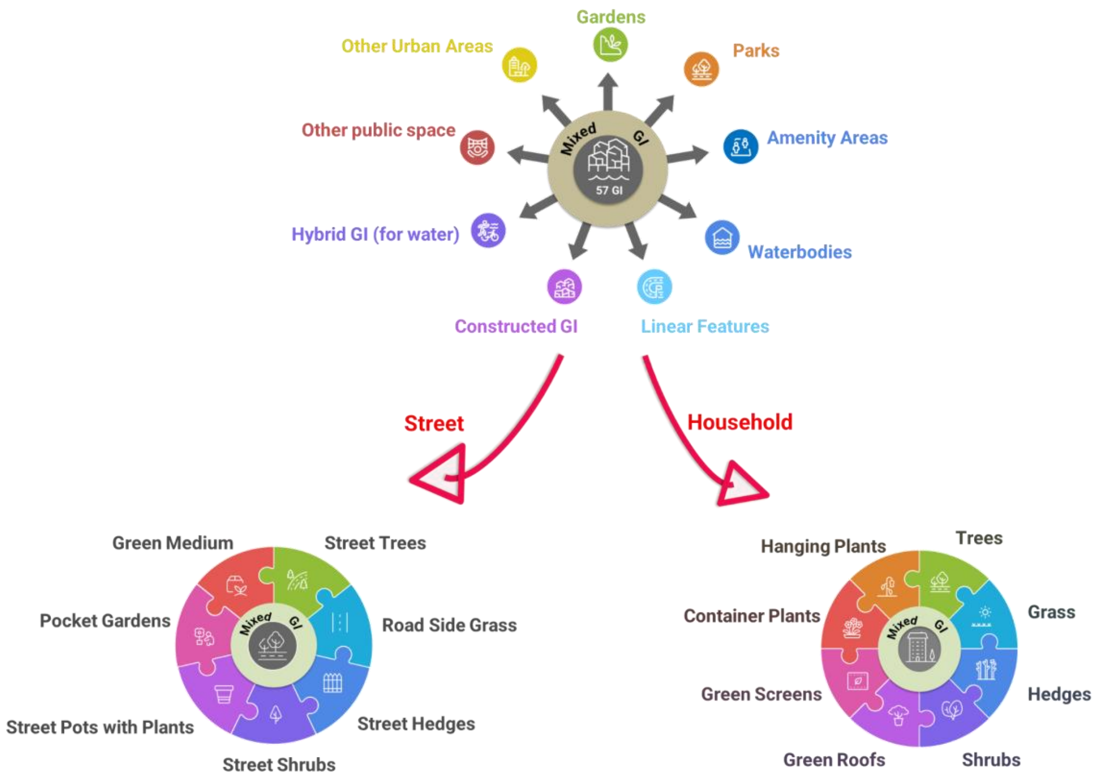

Figure 2. Simplified classification of 57 urban GI types and selection of common GI for household and street level.

List of Tables

Table 1. Summary of key reviewer papers from the past 10 years on GI research for environmental challenges.

Author (year)	Focus area	Environmental challenges(s)	Scale	Key gaps or findings
Li et al. (2025)	Environmental justice in Nature-Based Solutions (NBS) for urban hazard mitigation	Urban heat, flooding, wildfire, and air pollution	City	NBS interventions are unevenly distributed and lack inclusive design in vulnerable communities.
Muñoz and Duarte (2025)	Urban planning strategies to increase vegetation	Heat mitigation, urban runoff, biodiversity, thermal comfort	Street	Street-scale GI (e.g. depaving, pocket parks) can enhance microclimate and stormwater control.
Sobhaninia et al. (2025)	GI spatial planning methods for heat and stormwater mitigation	Urban heat, stormwater/flood risk	City	GI improves heat and flood resilience, but current spatial planning often fails to integrate both.
Khalili et al. (2024)	Evaluation methods for GI benefits	Heat, thermal comfort, air quality	Street	GI improves temperature and air quality; street-level assessments remain under-monitored.
Kumar et al. (2024b)	Effectiveness of GI types in mitigating urban overheating	Urban heat	City	Green walls, wetlands, and street trees are most effective for urban heat mitigation.
Kumar et al. (2024a)	Effectiveness of GBGI types in air pollution abatement	Air quality	City	Mixed GI configurations provide the greatest reduction in particulate pollution (PM2.5 and others).
Przestrzelska et al. (2024)	Global review of GI implementation and gaps	Flooding, drought, urban heat, and biodiversity	City	GBGI is less adopted in low-GDP regions; rain gardens and pocket parks offer adaptable solutions.
Beute et al. (2023)	Mental health benefits of green space types and characteristics	Mental health and wellbeing	City	Direct comparisons between green space types are limited due to high heterogeneity; evidence supports general

				benefits of greening, but effects by type remain unclear.
Debele et al. (2023)	Global case studies of NBS for hydro-meteorological risk	Flooding, drought, heatwaves, landslides, and water quality	City	NBS reduces multiple hazards with co-benefits for biodiversity, air and water quality, and climate resilience.
De Quadros and Mizgier (2023)	Urban Green Infrastructure （UGI ） strategies to improve pedestrian thermal comfort	Urban heat, thermal comfort	Street	Street trees, green walls, and parks significantly reduce heat at the pedestrian level; green roofs have a negligible effect.
Li and Lange (2023)	Urban GBGI and stress resilience in real-world settings	Wellbeing/stress	City	Reviewed 19 real-world studies; urban green spaces aid stress reduction.
Adnan et al. (2022)	Heat vulnerability and mitigation in Australia	Urban heat, thermal comfort	Street	GI and Water Sensitive Urban Design **(**WSUD) reduce local heat risk and improve thermal comfort.
Evans et al. (2022)	Ecosystem service delivery by urban agriculture and GI	Air quality, heat mitigation, biodiversity, soil fertility, recreation	City	GI improves climate and air quality; combining with urban agriculture enhances biodiversity and ecosystem multifunctionality.
Jones et al. (2022)	GI typology for multifunctional NBS planning	Air pollution, noise, heat, flooding, biodiversity, and health	City	Developed GI-service matrix; woodlands and riparian areas offer the highest multifunctionality for NBS design.
Almaaitah et al. (2021)	GI as climate change adaptation for heat and flooding	Urban heat, flooding	City	GBGI effectively reduces surface temperature and runoff volumes.
Kumar et al. (2021 a)	Monitoring methods for NBS performance against natural hazards	Flooding, drought, heatwaves, landslides, storm surge	City	Ground and satellite monitoring effectively assess NBS performance at the city scale.

Kumar, et al. (2021 b)	Evaluation methods for NBS performance against Hydro-Meteorological Hazards (HMH)	Flooding, droughts, heatwaves, landslides, storm surges	City	Reviewed modelling tools for evaluating NBS performance across different hazard types; identified appropriate tools for both local and catchment-scale assessments.
Veerkamp et al. (2021)	Assessment of ecosystem services delivered by urban GI	Temperature regulation, stormwater, air quality, waste, pollination, recreation	City	GBGI improves temperature, stormwater, and air quality regulation; parks and trees are the most frequently assessed GBI types.
Kumar et al. (2020)	Operationalisation of NBS for natural hazards	Floods, drought, storm surge, landslides, sediment/nutrient loading	City	NBS can reduce hydro-meteorological risks through site-specific, co-designed interventions; effectiveness varies by hazard and location.
Shah et al. (2020)	Development of a risk assessment framework and indicators for NBS	Floods, droughts, storm surge, landslides, and salinity	City	Outlined 135 indicators in a vulnerability-risk NBS framework; noted imbalance toward social metrics.
Debele et al. (2019)	NBS classification and effectiveness for HMH mitigation	Flooding, drought, heatwaves, landslides, storm surges	City	NBS are cost-effective for mitigating multiple hazards; green and hybrid types are most used for flood and heat management.
Venkataramanan et al. (2019)	Health and wellbeing outcomes of GI for stormwater/flood management	Flooding, wellbeing	Street	GI may increase property values and flood resilience, but evidence on health impacts is minimal.

Table 2. Five-level scoring criteria for evaluating the environmental and socio-ecological performance of household and street-level GI types.

Levels	Air quality improvement[a]	Cooling potential[b]	Flood mitigation[c]	Biodiversity gain[d]	Health & Wellbeing benefits[e]
L1 Negligible	Pollutant reduction ≤5%; minimal effect	Air temperature reduction ≤0.5 °C; minimal surface cooling	Runoff reduction <10% during short intense	0–1 added species; negligible species richness	No measurable health change; cortisol <5%, PHQ-9 <1 point, no activity increase
L2 Low	5–10% pollution reduction; localised impact	Air temperature reduction 0.5–1 °C; surface cooling <10%	Runoff reduction 10–25%	2–5 added species; low richness	Small improvement; cortisol 5–10%, PHQ-9 reduced by 1–2 points, slight activity rise
L3 Medium	10–20% pollution reduction; moderate local benefit	Air temperature reduction 1–2 °C; surface cooling 10–20%	Runoff reduction 25–50%	6–15 added species; moderate richness and habitat	Moderate improvement; cortisol 10–20%, PHQ-9 reduced by 2–4 points, modest activity gain
L4 High	20–50% pollution reduction; barrier vegetation common	Air temperature reduction 2–4 °C; surface cooling 20–40%	Runoff reduction 50–75%	16–30 added species; high richness and vegetation layering	Clear benefit; cortisol 20–30%, PHQ-9 reduced by 4 points or more, regular activity increase

L5 Very High	>50% pollution reduction; dense or layered vegetation	Air temperature reduction >4 °C; surface cooling > 40%	Runoff reduction >75%	≥31 added species; very high richness, native species support	Significant benefit; cortisol above 30%, PHQ-9 reduced by 5 points or more, sustained activity increase
Note: [a]Thresholds derived from Abhijith and Kumar (2019) and Kumar et al. (2024a), and divided into five levels based on percentage reductions in $PM_{2.5}$, NO_2, and black carbon concentrations. [b]Thresholds derived from Doick and Hutchings (2013), Vaz Monteiro et al. (2016), Sun et al. (2021), and Kumar et al. (2024b), and divided into five levels based on observed reductions in ambient and surface temperature. [c]Thresholds derived from Gonzalez-Meler et al. (2013), Li et al. (2019), and Hayes et al. (2021), and divided into five levels based on the percentage reduction in surface runoff during short-duration, high-intensity rainfall events. [d]Thresholds derived from the UK D4 indicator (Sobkowiak, 2023), Timberlake et al. (2019), Helen (2023), and Zhang et al. (2024), and divided into five levels based on increases in species richness. [e]Thresholds derived from Mytton et al. (2012), Kardan et al. (2015), Hunter et al. (2019), and Gu et al. (2022), and divided into five levels based on changes in cortisol concentration, PHQ-9 scores, and physical activity.					

Table 3. Percentage distribution of greening configurations observed in over 300 front gardens, 300 back gardens, and 22 balconies across UK residential properties

No.	Front Garden Scenario	Percentage (%)
1	Grass only	10.6%
2	No GI	10.0%
3	Hedge only	7.7%
4	Shrub(s) only	6.8%
5	Grass + Shrub(s)	6.1%
6	Hedge + Grass	4.2%
7	Container plant(s) only	3.9%
8	Hedge + Tree(s)	3.2%
9	Tree(s) + Shrub(s)	2.9%
10	Hedge + Grass + Shrub(s)	2.9%
11	Tree(s) only	2.6%
12	Tree(s)+ Container plant(s)	2.3%
13	Hedge + Shrub(s)	2.3%
14	Hedge + Tree(s) + Shrub(s)	1.9%
15	Shrub(s) + Container plant(s)	1.9%
16	Hanging plant(s) + Container plant(s)	1.9%
17	Tree(s) + Grass + Shrub(s) + Hanging plant(s)	1.9%
18	Hedge + Grass + Trees(s)	1.9%
19	Grass + Shrub(s) + Container plant(s)	1.6%
20	Hanging plant(s) only	1.3%
21	Shrub(s) + Green screen(s)	1.3%
22	Hedge + Tree(s) + Container plant(s)	1.3%
23	Shrub(s) + Hanging plant(s)	1.3%
24	Tree(s) + Shrub(s) + Container plant(s) + Hanging plant(s)	1.3%
25	Hedge + Grass + Tree(s) + Shrub(s)	1.0%

26	Grass + Container plant(s)	1.0%
27	Hedge + Shrub(s) + Hanging plant(s)	1.0%
28	Hedge + Shrub(s) + Container plant(s)	1.0%
29	Tree(s) + Grass + Shrub(s)	1.0%
30	Hedge + Shrub(s) + Container plant(s) + Hanging plant(s)	0.6%
31	Tree(s) + Grass + Hanging plant(s)	0.6%
32	Hedge + Grass + Tree(s) + Container plant(s) + Hanging plant(s)	0.6%
33	Grass(s) + Shrub(s) + Green screen(s)	0.6%
34	Hedge + Tree(s) + Shrub(s) + Container plant(s) + Hanging plant(s) + Green screen(s)	0.6%
35	Tree(s) + Grass + Green screen(s)	0.6%
36	Hedge + Grass + Shrub(s) + Container plant(s) + Hanging plant(s) + Green screen(s)	0.6%
37	Hedge + Hanging plant(s)	0.6%
38	Grass + Green screen(s)	0.6%
39	Hedge + Grass + Shrub(s) + Green screen(s)	0.6%
40	Grass + Hanging plant(s) + Container plant(s)	0.6%
41	Hedge + Hanging plant(s) + Container plant(s)	0.6%
42	Grass + Green screen(s) + Container plant(s) + Hanging plant(s)	0.6%
43	Tree(s) + Shrub(s) + Green screen(s)	0.6%
44	Tree(s) + Hanging plant(s) + Container plant(s)	0.6%
45	Hedge + Grass + Container plant(s) + Shrub(s)	0.6%
46	Tree(s) + Grass + Container plant(s)	0.3%
47	Hedge + Grass(s) + Container plant(s) + Hanging plant(s)	0.3%
48	Hedge + Grass + Green wall(s)	0.3%
49	Hedge + Grass + Tree(s) + Container plant(s) + Shrub(s)	0.3%
50	Container plant(s) + Hanging plant(s) + Shrub(s)	0.3%
		Total: 100%
No.	**Back Garden Scenario**	**Percentage (%)**

1	Grass only	22.3%
2	Hedge + Grass + Tree(s)	19.3%
3	Tree(s) + Grass	14.3%
4	Hedge + Grass	13.7%
5	No GI	9.7%
6	Hedge only	8.0%
7	Hedge + Tree(s)	5.7%
8	Tree(s) only	3.0%
9	Shrub(s) only	0.7%
10	Grass + Hanging plant(s)	0.7%
11	Grass + Shrub(s)	0.7%
12	Grass + Shrub(s) + Container plant(s)	0.7%
13	Tree(s) + Grass + Shrub(s)	0.7%
14	Tree(s) + Shrub(s)	0.3%
15	Hedge + Grass + Shrub(s)	0.3%
		Total: 100%
No.	**Balcony Scenario**	**Percentage (%)**
1	Container plant(s) only	63.6%
2	Hanging plant(s) + Container plant(s)	22.7%
3	Hanging plant(s) only	4.5%
4	No GI	4.5%
5	Green screen(s) only	4.5%
		Total: 100%

Table 4. Percentage distribution of greening configurations observed across 336 residential street segments in UK urban areas.

No.	**Street Scenario**	**Percentage (%)**
1	Street trees only	21.4%
2	Street trees + Roadside grass	19.9%
3	No GI	16.4%
4	Street tree + Roadside grass + Hedge	10.4%
5	Street trees + Hedge	5.1%
6	Roadside grass only	4.8%
7	Roadside grass + Hedge	2.7%
8	Street trees + Roadside Grass + Green median(s)	2.7%
9	Street trees + Street pot(s) with plant(s)	2.1%
10	Street trees + Roadside grass + Shrub(s)	1.5%
11	Pocket garden(s) only	1.2%
12	Green median(s) only	1.2%
13	Hedge only	1.2%
14	Street pot(s) with plant(s) only	1.2%
15	Street trees + Roadside grass + Hedge + Green median(s)	1.2%
16	Street trees + Roadside grass + Hedge + Shrub(s)	1.2%
17	Street trees + Green median(s)	0.9%
18	Shrub(s) only	0.9%
19	Street trees + Pocket garden(s)	0.6%
20	Roadside grass + Shrub(s)	0.6%
21	Street trees + Hedge + Pocket garden(s)	0.6%
22	Roadside grass + Street pot(s) with plant(s)	0.3%
23	Hedge + Pocket garden(s)	0.3%
24	Street trees + Roadside grass + Pocket garden(s)	0.3%

25	Street trees + Shrub(s)	0.3%
26	Roadside Grass + Hedge + Shrub(s)	0.3%
27	Street trees + Roadside grass + Hedge + Street pot(s) with plant(s)	0.3%
28	Street trees + Roadside grass + Hedge + Green median(s) + Shrub(s)	0.3%
29	Street trees + Roadside grass + Green median(s) + Shrub(s)	0.3%
		Total: 100%

Table 5. Evaluation of common household and street level GI types in the UK.

GI Type	Scale	Air Quality	Cooling Potential	Flood Control	Biodiversity Gain	Health & Wellbeing
Hedge	Household	4	2	2	4	2
	Street	5	2	3	4	3
Trees	Household	3	3	4	4	3
	Street (open/wide)	3	5	4	4	5
	Street (narrow)	2	5	4	4	5
Grass	Household	1	2	5	2	2
	Street	1	2	5	2	2
Shrub	Household	2	2	2	3	2
	Street	2	2	2	3	2
Container/Hanging plant	Household	1	1	1	1	2
Green screen	Household	4	2	1	3	3
Green wall	Household	4	4	3	3	3
Street pot with plants	Street	1	1	1	1	2
Green median	Street (grass only)	2	3	5	3	2
	Street (with shrubs)	3	3	5	3	2
Pocket Garden	Street	2	3	4	5	4

Rating Level: 1: Negligible; 2: Low; 3: Medium; 4: High; 5: Very High. Justifications for each scoring decision are provided in Table 6.

Table 6. Household and street level GI types of evaluation justification matrix.

GI Type	Air Quality	Cooling Potential	Flood Control	Biodiversity Gain	Health & Wellbeing
Hedge	Hedges are consistently effective at reducing near-road air pollution, especially fine particulate matter and black carbon. When maintained as dense and continuous structures, hedges above 1.5 m can reduce pollutant concentrations behind them by approximately 20 to 50 % (Abhijith and Kumar 2019; Kumar et al., 2024a).	Hedges provide limited cooling benefits through shading and evapotranspiration, primarily at the immediate microclimate scale. Studies have shown that vegetation surfaces of hedges can be up to 19°C cooler than adjacent hard surfaces (Zou et al., 2019), with some local air temperature reductions of approximately 0.5 to 2°C near dense, well-irrigated hedgerows. However, the overall effect on ambient air temperature remains minor and highly	Hedges intercept rainfall on foliage, enhance soil infiltration, and delay surface runoff. Field studies under moderate rainfall conditions have shown that such vegetated barriers can reduce peak runoff by up to 40% (Carroll et al., 2006), highlighting the potential for use of such features. At the household scale, hedges contribute to runoff reduction by increasing soil porosity and capturing rainfall adjacent to impervious surfaces, though effectiveness is modest due to limited extent.	Hedges enhance biodiversity by providing shelter, food resources, and ecological connectivity. Resembling woodland edges, they support a range of birds, invertebrates, and small mammals. Mixed-species hedges with flowers or fruits further increase ecological value (Atkins 2019). Their permeable structure facilitates species movement and reduces habitat fragmentation.	Hedges improve local environments by adding greenery, enhancing privacy, and offering minor noise or pollution buffering at the household scale. On streets, they provide broader visual and environmental benefits, improving streetscape quality and reducing exposure to urban stressors. These factors are linked to modest gains in perceived wellbeing and neighbourhood satisfaction (Mytton et al. 2012).

		localised (Kumar et al., 2024b).			
Trees	Trees can reduce airborne particulate matter through leaf surface deposition and influence gaseous pollutant dispersion. Well-spaced trees may reduce PM concentrations by 10-20% in open areas. However, in narrow street canyons, tall or dense tree canopies can trap pollutants and hinder ventilation. Effectiveness depends on canopy structure, species, and placement (Abhijith and Kumar 2019; Nemitz et al. 2020; Kumar et al., 2024a).	Trees provide significant cooling through shade and evapotranspiration. Garden trees create localised cooling of around 1°C. Street trees can reduce pavement surface temperatures by up to 20°C under shade (Rouquette and Holt 2017) and air temperatures by 1-3°C in surrounding zones (Kumar et al., 2024b).	Trees reduce runoff through canopy interception and infiltration via root systems. UK field studies show a 1 m^2 tree pit can cut runoff from adjacent hard surfaces by up to 62% (Rahman and Ennos 2016). Modelling suggests 20–25% reductions in runoff volume and peak flow (Armson et al., 2013). Trees improve soil permeability and intercept 10–25% of rainfall (Carroll et al., 2006).	Trees increase urban biodiversity by offering vertical structure, canopy cover, and essential resources such as nectar, seeds, and insect prey. Native species are especially valuable due to their high insect-hosting capacity (e.g., oaks support hundreds of insect species) (Southwood 1961). Studies show greater bird activity and species richness in treed streets, with mixed-species plantings supporting higher ecosystem functionality (Wood and Esaian 2020; Morton 2022).	Trees improve air quality, reduce stress, and enhance safety and social cohesion. Studies in Toronto and London show that more street trees are linked to better self-rated health and fewer antidepressant prescriptions (Kardan et al., 2015; Saraev et al., 2021). Household trees offer localised benefits such as shade, visual relief, and opportunities for light activity.

Grass	Grass offers minimal air quality benefits due to its low height and limited surface area. It may reduce dust resuspension near ground level, but does not intercept vehicle exhaust, which is typically emitted above 1 meter. Studies show vegetation must exceed 1–1.5 m in height to meaningfully reduce $PM_{2.5}$ or NO_2 at breathing level (Abhijith and Kumar 2019).	Grass cools the surface through evapotranspiration and retains less heat than pavement. UK studies show grass-covered areas can be 10 to 20°C cooler than asphalt on hot days (Zou et al., 2019). However, grass lacks a canopy and vertical structure, so its impact on air temperature is small, typically under 1°C.	Grass allows rainfall to infiltrate, greatly reducing runoff. UK field tests show grass can eliminate nearly all direct surface runoff under moderate rain (Rahman and Ennos 2016). Vegetated ground covers substantially reduce runoff, with turf-grass surfaces producing less than 1% runoff compared with over 50% on impermeable pavements (Armson et al., 2013). Even basic turf on uncompacted, permeable soils can eliminate nearly all direct surface runoff.	Grass offers limited biodiversity under conventional maintenance. Regular mowing suppresses flowering, leading to low nectar and habitat availability. However, if managed as wildflower strips or left unmown for part of the season, biodiversity can increase significantly. Trials show reduced mowing boosts flower abundance and insect activity (Wisdom 2018).	Grass provides limited health benefits. It improves visual greenness and may slightly enhance walkability and perceived aesthetics, but offers minimal shade, interaction, or stress relief (Mytton et al., 2012). At the household scale, lawns provide space for light activity or relaxation, yet the impact depends on active use.
Shrub	Shrubs can support minor pollution reduction via leaf deposition and local airflow disruption. If dense and taller than 1 m, they intercept some $PM_{2.5}$ near the source. Field	Shrubs reduce surface temperature via shading and evapotranspiration, particularly in clusters. A UK study showed shrub/tree sites had around 5.7°C cooler	Shrubs offer limited runoff reduction due to their small size and scattered layout. They absorb rainfall falling directly on them, but their overall impact is minor	Shrub beds add mid-layer vegetation that supports pollinators, birds, and insects. Flowering shrubs provide nectar and pollen, while dense foliage offers shelter and nesting space.	Shrubs provide minor visual relief and greenery but are too small to impact air quality, shade, or stress significantly. Their health benefit is minimal unless combined with larger GI elements (Roe et al., 2013).

	studies report modest pollutant reductions (10-20%) behind well-placed shrub rows, but sparse or low shrubs show negligible impact (Kumar et al., 2024a).	summer soil than grass-only areas (Edmondson et al., 2016). However, air cooling is highly localised and small in magnitude, typically lower than 1°C, and confined to the immediate area.	unless designed as rain gardens. Without wide coverage or connection to paved runoff, their effect remains local. Substantial runoff reduction requires broader vegetated cover (Armson et al., 2013).	Fruiting species attract birds. For example, dogwood attracts pollinators and provides berries for thrushes and blackbirds (Harriet 2024). Though less biodiverse than full tree canopies, well-chosen shrubs provide valuable habitat.	They may encourage light gardening, but have a negligible direct impact on physical or mental health on their own.
Container/Hanging plant	Both potted and hanging plants offer minimal impact on outdoor air pollution due to their small size, limited leaf area, and isolated placement. There is little empirical evidence supporting their effectiveness in removing pollutants. While choosing species with large, rough leaves may slightly enhance performance, their overall	Individual potted or hanging plants have virtually no measurable cooling effect on outdoor air temperature. Their transpiration and shading are too limited in scale to alter the microclimate. Any cooling is confined to a few centimetres around the plant and is undetectable at the household scale. Only large clusters may provide minimal local cooling.	These small planting units retain only limited rainwater in their soil before overflowing. Once saturated, they behave much like impervious surfaces, offering little delay or reduction in runoff. Because they usually cover only a small portion of patios or balconies, their overall impact on household stormwater is minimal.	Potted and hanging plants offer limited but consistent benefits to urban biodiversity. Flowering species like lavender or petunia provide nectar for pollinators, and some foliage may host insects. Their ecological value is constrained by soil volume, isolation, and limited habitat complexity. Still, evidence shows even small plantings help	Container plants and hanging plants offer small but positive effects on mental health. Studies show that just a few indoor or balcony plants can slightly reduce stress or improve attention (Gu et al., 2022). Though their impact is modest, they are cost-effective, space-efficient, and aesthetically valuable. Their primary value lies in symbolic connections to nature.

	contribution remains negligible.			pollinators (Tew et al. 2022).	
Green screen/wall	Green screens and green walls can significantly reduce air pollution when placed along building edges or fences by trapping airborne particles through dense foliage and slowing air movement. Studies show pollutant reductions of 20–40% behind green screens and walls with at least 25% coverage can reduce PM2.5 by about 25% in residential settings (Abhijith and Kumar 2019; Kumar et al., 2022; Kumar et al., 2024a).	Green screens (climbing plants on trellises) provide localised shading and can reduce wall surface temperatures by 5-8°C, though air temperature effects are small (≤1°C) (Turhan et al., 2025). Green walls cool through shading, moisture retention, and transpiration, reducing ambient air temperatures by 1.5-4°C and surface temperatures by up to 15°C (Kumar et al., 2024b; Ouldboukhitine et al., 2025).	Green screens intercept minimal rain with negligible runoff reduction. Green walls, with substrate layers, can retain 20-50% of rainfall on the covered surface. Simulations suggest up to 50% runoff reduction in small storms when integrated with drainage systems (Lau and Mah 2018). While unable to manage large volumes alone, green walls can slow and absorb a measurable portion of rain.	Green screens with climbers like ivy or honeysuckle offer nectar, berries, and shelter, supporting insects and birds. Green walls provide similar benefits by adding vertical flowering plants and foliage that attract pollinators and create micro-habitats (Morton 2022; Jessica 2023). Though limited in area, both features improve biodiversity when designed with varied species and good coverage.	Green screens offer visual relief, shade, and stress reduction benefits. Evidence from vertical greenery shows reduced cortisol and improved comfort (Kardan et al., 2015; Saraev et al., 2021). Green walls have stronger effects due to their scale and visibility. Experiments show that even small green walls lower stress significantly (Gu et al., 2022). Both features enhance wellbeing in compact spaces.
Street pot with plants	Street potted plants have a minimal impact on air pollution. While their foliage may capture some particulates, isolated pots	Individual or scattered potted street plants offer negligible cooling. While well-watered containers may release some	Street pots or planters have very limited capacity to manage stormwater. Their small soil volume holds	Individual or sparsely spaced street pots offer minimal habitat value. While flowering plants in planters can provide	Street potted planters introduce small patches of greenery and can modestly improve visual quality, offering minor psychological benefits such as

	are too small to alter airflow or pollutant concentration meaningfully. When arranged in dense rows, potted shrubs can act as partial barriers, reducing particulate levels slightly (up to 10%) immediately downwind, but the effect is much weaker than continuous in-ground hedges.	moisture and shade a small surface, their scale is too small to influence ambient air temperature. Studies show that significant cooling requires large vegetation cover, which isolated planters cannot provide. Any local effect (lower than 0.5°C) is minimal.	minimal rainfall, and once saturated, excess water typically drains onto adjacent impervious surfaces. Most are not connected to drainage or rain capture systems. While densely arranged planters might slightly delay runoff locally, the overall volume affected is minor.	nectar to some pollinators (e.g., bees, hoverflies), the small size, isolation from other vegetation, and lack of structural complexity limit their use by most wildlife. Planters rarely support nesting or shelter, and are often replaced seasonally.	mood or attention restoration for pedestrians (Gu et al., 2022). However, each planter contains few plants and lacks scale or continuity, so the overall health and wellbeing impact is limited.
Green median	Green medians separate traffic lanes and can reduce crossroad pollution. Grass-only medians offer little benefit beyond increasing distance. When planted with shrubs or low hedges, they can trap particles and promote upward dispersion. Studies show vegetated medians can lower $PM_{2.5}$ by 10–15% immediately	Vegetated medians cool streets via evapotranspiration and lower surface heat. When shrubs or trees are included, shading adds further benefit. Studies report air temperature reductions of 0.5 to 2–3°C depending on vegetation density (Kumar et al., 2024b). Though the effects are	Vegetated medians and swales collect and slow stormwater, promoting infiltration and reducing runoff volume and peak flow. Studies show they can reduce runoff by 15–82% and peak flows by up to 87% (Ekka et al., 2021). Well-designed systems often capture nearly all runoff from	Green medians introduce continuous vegetation into roadways and can act as linear habitats. Grass-only medians offer limited biodiversity, but those with wildflowers or shrubs support pollinators and small invertebrates. Studies show road verges and medians can host over half of UK grassland plant species (Perrett et al., 2023) and attract bees	Green medians improve streets visually and may reduce perceived traffic stress. Their greenery offers minor psychological benefits, such as small mood improvements and a slight boost for walking. However, they are usually narrow, inaccessible, and offer little space for rest or activity.

	downwind under certain conditions (Abhijith and Kumar 2019).	local, they exceed those of small planters.	typical storms, effectively removing it from drains.	and hoverflies, though activity is lower near heavy traffic (Phillips et al., 2019).	
Pocket Garden	Pocket gardens offer localised air quality benefits by trapping pollutants on plant surfaces and slightly increasing the distance from traffic. Their small-scale limits overall effectiveness. While they can reduce exposure within the green space itself, especially if bordered by shrubs or trees, the overall impact on roadside air quality is modest. Studies suggest urban green spaces reduce pollution by around 9% on average (Kumar et al., 2024a).	Pocket gardens create local cool islands through shading and evapotranspiration. Field measurements report daytime air temperature reductions of 1 to 3°C compared to adjacent paved areas (Kumar et al. 2024b). Denser vegetation and slightly larger pocket gardens reach the upper end of that range. Their effect is confined to the immediate surroundings.	Pocket gardens can absorb and delay runoff, functioning like mini rain gardens. Studies show they typically reduce annual runoff volumes by 50–80% and substantially lower peak flow rates during storms (Dunnett and Clayden 2007). Even small, vegetated patches intercept rainfall and nearby runoff if graded appropriately. Their compact design enables effective stormwater management in dense urban areas.	Well-designed pocket gardens support a rich variety of plants and urban wildlife. Despite their small size, they offer diverse habitats, flowers for pollinators, shrubs for shelter, and structures for nesting or overwintering insects. In London and other cities, pocket parks have shown impressive biodiversity outcomes, acting as stepping stones for species in fragmented urban areas (Tew et al. 2022; Ulrich and Sargent 2025).	Small green spaces embedded in urban blocks provide significant health and wellbeing benefits. Though limited in size, they are accessible and interactive, often including vegetation, seating, and community use. UK studies show users experience reduced blood pressure, stress, and mental fatigue compared to built-up areas (Xu et al., 2024). Pocket parks also support light physical activity and neighbourhood interaction.

Table 7. Composite performance scores of common GI configurations at household level.

GI Combinations	Score				
	Air Quality	Cooling Potential	Flood Mitigation	Biodiversity Gain	Health & Wellbeing
Grass only	●○○○○○	●●○○○	●●●●●	●●○○○	●●○○○
No GI	●○○○○○	●○○○○	●○○○○	●○○○○	●○○○○
Hedge only	●●●●●●	●●○○○	●●○○○	●●●●○	●●○○○
Shrub(s) only	●●○○○○	●●○○○	●●○○○	●●●○○	●●○○○
Grass + Shrub(s)	●●○○○○	●●○○○	●●●●●	●●●○○	●●○○○
Hedge + Grass	●●●●●●	●●○○○	●●●●●	●●●●○	●●○○○
Container plant(s) only	●○○○○○	●○○○○	●○○○○	●●○○○	●●○○○
Hedge + Tree(s)	●●●●●●	●●●○○	●●●●○	●●●●○	●●●○○
Tree(s) + Shrub(s)	●●●●○○	●●●○○	●●●●○	●●●●○	●●●○○
Hedge + Grass + Shrub(s)	●●●●●●	●●○○○	●●●●●	●●●●○	●●○○○
Tree(s) only	●●●●○○	●●●○○	●●●●○	●●●●○	●●●○○
Tree(s)+ Container plant(s)	●●●●○○	●●●○○	●●●●○	●●●●○	●●●○○
Hedge + Shrub(s)	●●●●●●	●●○○○	●●○○○	●●●●○	●●○○○
Hedge + Tree(s) + Shrub(s)	●●●●●●	●●●○○	●●●●○	●●●●○	●●●○○
Shrub(s) + Container plant(s)	●●○○○○	●●○○○	●●○○○	●●●○○	●●○○○

Hanging plant(s) + Container plant(s)	●○○○○○	●○○○○	●○○○○	●●○○○	●●○○○
Tree(s) + Grass + Shrub(s) + Hanging plant(s)	●●●●○○	●●●○○	●●●●●	●●●●○	●●●○○
Hedge + Grass + Trees(s)	●●●●●●	●●●○○	●●●●●	●●●●○	●●●○○
Grass + Shrub(s) + Container plant(s)	●●○○○○	●●○○○	●●●●●	●●●○○	●●○○○
Hanging plant(s) only	●○○○○○	●○○○○	●○○○○	●●○○○	●●○○○
Shrub(s) + Green screen(s)	●●●●●○	●●○○○	●●○○○	●●●○○	●●●○○
Hedge + Tree(s) + Container plant(s)	●●●●●●	●●●○○	●●●●○	●●●●○	●●●○○
Shrub(s) + Hanging plant(s)	●●○○○○	●●○○○	●●○○○	●●●○○	●●○○○
Tree(s) + Shrub(s) + Container plant(s) + Hanging plant(s)	●●●●○○	●●●○○	●●●●○	●●●●○	●●●○○
Hedge + Grass + Tree(s) + Shrub(s)	●●●●●●	●●●○○	●●●●●	●●●●○	●●●○○
Grass + Container plant(s)	●○○○○○	●●○○○	●●●●●	●●○○○	●●○○○
Hedge + Shrub(s) + Hanging plant(s)	●●●●●●	●●○○○	●●○○○	●●●●○	●●○○○
Hedge + Shrub(s) + Container plant(s)	●●●●●●	●●○○○	●●○○○	●●●●○	●●○○○
Tree(s) + Grass + Shrub(s)	●●●●○○	●●●○○	●●●●●	●●●●○	●●●○○

Hedge + Shrub(s) + Container plant(s) + Hanging plant(s)	5/5	2/5	2/5	4/5	2/5
Tree(s) + Grass + Hanging plant(s)	3/5	3/5	5/5	4/5	3/5
Hedge + Grass + Tree(s) + Container plant(s) + Hanging plant(s)	5/5	3/5	5/5	4/5	3/5
Grass(s) + Shrub(s) + Green screen(s)	4/5	2/5	5/5	3/5	3/5
Hedge + Tree(s) + Shrub(s) + Container plant(s) + Hanging plant(s) + Green screen(s)	5/5	3/5	4/5	4/5	3/5
Tree(s) + Grass + Green screen(s)	4/5	2/5	5/5	3/5	3/5
Hedge + Grass + Shrub(s) + Container plant(s) + Hanging plant(s) + Green screen(s)	5/5	2/5	5/5	4/5	3/5
Hedge + Hanging plant(s)	5/5	2/5	2/5	4/5	2/5
Grass + Green screen(s)	4/5	2/5	5/5	3/5	3/5
Hedge + Grass + Shrub(s) + Green screen(s)	5/5	2/5	5/5	4/5	3/5

Grass + Hanging plant(s) + Container plant(s)	🫁 (1/6)	🌀🌀 (2/5)	💧💧💧💧💧 (5/5)	🦋🦋 (2/5)	❤️❤️ (2/5)
Hedge + Hanging plant(s) + Container plant(s)	🫁🫁🫁🫁🫁🫁 (6/6)	🌀🌀 (2/5)	💧💧 (2/5)	🦋🦋🦋🦋 (4/5)	❤️❤️ (2/5)
Grass + Green screen(s) + Container plant(s) + Hanging plant(s)	🫁🫁🫁🫁🫁 (5/6)	🌀🌀 (2/5)	💧💧💧💧💧 (5/5)	🦋🦋🦋 (3/5)	❤️❤️❤️ (3/5)
Tree(s) + Shrub(s) + Green screen(s)	🫁🫁🫁🫁🫁 (5/6)	🌀🌀🌀 (3/5)	💧💧💧💧 (4/5)	🦋🦋🦋🦋 (4/5)	❤️❤️❤️ (3/5)
Tree(s) + Hanging plant(s) + Container plant(s)	🫁🫁🫁 (3/6)	🌀🌀🌀 (3/5)	💧💧💧💧 (4/5)	🦋🦋🦋🦋 (4/5)	❤️❤️❤️ (3/5)
Hedge + Grass + Container plant(s) + Shrub(s)	🫁🫁🫁🫁🫁🫁 (6/6)	🌀🌀 (2/5)	💧💧💧💧💧 (5/5)	🦋🦋🦋🦋 (4/5)	❤️❤️ (2/5)
Tree(s) + Grass + Container plant(s)	🫁🫁🫁 (3/6)	🌀🌀🌀 (3/5)	💧💧💧💧💧 (5/5)	🦋🦋🦋🦋 (4/5)	❤️❤️❤️ (3/5)
Hedge + Grass(s) + Container plant(s) + Hanging plant(s)	🫁🫁🫁🫁🫁🫁 (6/6)	🌀🌀 (2/5)	💧💧💧💧💧 (5/5)	🦋🦋🦋🦋 (4/5)	❤️❤️ (2/5)
Hedge + Grass + Green wall(s)	🫁🫁🫁🫁🫁🫁 (6/6)	🌀🌀 (2/5)	💧💧💧💧💧 (5/5)	🦋🦋🦋🦋 (4/5)	❤️❤️❤️ (3/5)
Hedge + Grass + Tree(s) + Container plant(s) + Shrub(s)	🫁🫁🫁🫁🫁🫁 (6/6)	🌀🌀🌀 (3/5)	💧💧💧💧💧 (5/5)	🦋🦋🦋🦋 (4/5)	❤️❤️❤️ (3/5)
Container plant(s) + Hanging plant(s) + Shrub(s)	🫁🫁 (2/6)	🌀🌀 (2/5)	💧💧 (2/5)	🦋🦋🦋 (3/5)	❤️❤️ (2/5)

Tree(s) + Grass	4/6	3/5	5/5	4/5	3/5
Grass + Hanging plant(s)	1/6	2/5	5/5	2/5	2/5
Tree(s) + Shrub(s)	4/6	3/5	4/5	4/5	3/5
Green screen(s) only	5/6	2/5	1/5	3/5	3/5

Table 8. Composite performance scores of common GI configurations at street level.

GI Combinations	Score				
	Air Quality	Cooling Potential	Flood Mitigation	Biodiversity Gain	Health & Wellbeing
Street trees only	4/6	5/5	4/5	4/5	5/5
Street trees + Roadside grass	4/6	5/5	5/5	4/5	5/5
No GI	1/6	1/5	1/5	1/5	1/5
Street tree + Roadside grass + Hedge	6/6	5/5	5/5	4/5	5/5
Street trees + Hedge	6/6	5/5	4/5	4/5	5/5

Roadside grass only	🫁 (1/5)	🪭🪭 (2/5)	💧💧💧💧💧 (5/5)	🦋🦋 (2/5)	❤️❤️ (2/5)
Roadside grass + Hedge	🫁🫁🫁🫁🫁 (5/5)	🪭🪭 (2/5)	💧💧💧💧💧 (5/5)	🦋🦋🦋🦋 (4/5)	❤️❤️❤️ (3/5)
Street trees + Roadside Grass + Green median(s)	🫁🫁🫁 (3/5)	🪭🪭🪭🪭🪭 (5/5)	💧💧💧💧💧 (5/5)	🦋🦋🦋🦋 (4/5)	❤️❤️❤️❤️❤️ (5/5)
Street trees + Street pot(s) with plant(s)	🫁🫁🫁 (3/5)	🪭🪭🪭🪭🪭 (5/5)	💧💧💧💧 (4/5)	🦋🦋🦋🦋 (4/5)	❤️❤️❤️❤️❤️ (5/5)
Street trees + Roadside grass + Shrub(s)	🫁🫁🫁 (3/5)	🪭🪭🪭🪭🪭 (5/5)	💧💧💧💧💧 (5/5)	🦋🦋🦋🦋 (4/5)	❤️❤️❤️❤️❤️ (5/5)
Pocket garden(s) only	🫁🫁 (2/5)	🪭🪭🪭 (3/5)	💧💧💧💧 (4/5)	🦋🦋🦋🦋🦋 (5/5)	❤️❤️❤️❤️ (4/5)
Green median(s) only	🫁🫁🫁 (3/5)	🪭🪭🪭 (3/5)	💧💧💧💧💧 (5/5)	🦋🦋🦋 (3/5)	❤️❤️ (2/5)
Hedge only	🫁🫁🫁🫁🫁 (5/5)	🪭🪭 (2/5)	💧💧💧 (3/5)	🦋🦋🦋🦋 (4/5)	❤️❤️❤️ (3/5)
Street pot(s) with plant(s) only	🫁 (1/5)	🪭 (1/5)	💧 (1/5)	🦋 (1/5)	❤️❤️ (2/5)
Street trees + Roadside grass + Hedge + Green median(s)	🫁🫁🫁🫁🫁 (5/5)	🪭🪭🪭🪭🪭 (5/5)	💧💧💧💧💧 (5/5)	🦋🦋🦋🦋 (4/5)	❤️❤️❤️❤️❤️ (5/5)
Street trees + Roadside grass + Hedge + Shrub(s)	🫁🫁🫁🫁🫁 (5/5)	🪭🪭🪭🪭🪭 (5/5)	💧💧💧💧💧 (5/5)	🦋🦋🦋🦋 (4/5)	❤️❤️❤️❤️❤️ (5/5)
Street trees + Green median(s)	🫁🫁🫁 (3/5)	🪭🪭🪭🪭🪭 (5/5)	💧💧💧💧💧 (5/5)	🦋🦋🦋🦋 (4/5)	❤️❤️❤️❤️❤️ (5/5)
Shrub(s) only	🫁🫁 (2/5)	🪭🪭 (2/5)	💧💧 (2/5)	🦋🦋🦋 (3/5)	❤️❤️ (2/5)
Street trees + Pocket garden(s)	🫁🫁🫁 (3/5)	🪭🪭🪭🪭🪭 (5/5)	💧💧💧💧 (4/5)	🦋🦋🦋🦋🦋 (5/5)	❤️❤️❤️❤️❤️ (5/5)
Roadside grass + Shrub(s)	🫁🫁 (2/5)	🪭🪭 (2/5)	💧💧💧💧💧 (5/5)	🦋🦋🦋 (3/5)	❤️❤️ (2/5)

Street trees + Hedge + Pocket garden(s)	🫁🫁🫁🫁🫁	🪭🪭🪭🪭🪭	💧💧💧💧(💧)	🦋🦋🦋🦋🦋	❤️❤️❤️❤️❤️
Roadside grass + Street pot(s) with plant(s)	🫁(🫁🫁🫁🫁)	🪭🪭(🪭🪭🪭)	💧💧💧💧💧	🦋🦋(🦋🦋🦋)	❤️❤️(❤️❤️❤️)
Hedge + Pocket garden(s)	🫁🫁🫁🫁🫁	🪭🪭🪭(🪭🪭)	💧💧💧💧(💧)	🦋🦋🦋🦋🦋	❤️❤️❤️❤️(❤️)
Street trees + Roadside grass + Pocket garden(s)	🫁🫁🫁(🫁🫁)	🪭🪭🪭🪭🪭	💧💧💧💧💧	🦋🦋🦋🦋🦋	❤️❤️❤️❤️❤️
Street trees + Shrub(s)	🫁🫁🫁(🫁🫁)	🪭🪭🪭🪭🪭	💧💧💧💧(💧)	🦋🦋🦋🦋(🦋)	❤️❤️❤️❤️❤️
Roadside Grass + Hedge + Shrub(s)	🫁🫁🫁🫁🫁	🪭🪭(🪭🪭🪭)	💧💧💧💧💧	🦋🦋🦋🦋(🦋)	❤️❤️❤️(❤️❤️)
Street trees + Roadside grass + Hedge + Street pot(s) with plant(s)	🫁🫁🫁🫁🫁	🪭🪭🪭🪭🪭	💧💧💧💧💧	🦋🦋🦋🦋(🦋)	❤️❤️❤️❤️❤️
Street trees + Roadside grass + Hedge + Green median(s) + Shrub(s)	🫁🫁🫁🫁🫁	🪭🪭🪭🪭🪭	💧💧💧💧💧	🦋🦋🦋🦋(🦋)	❤️❤️❤️❤️❤️
Street trees + Roadside grass + Green median(s) + Shrub(s)	🫁🫁🫁(🫁🫁)	🪭🪭🪭🪭🪭	💧💧💧💧💧	🦋🦋🦋🦋(🦋)	❤️❤️❤️❤️❤️