SPECIAL EDITION

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NATURE
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THESIS

URBAN GREEN SPACE

UNPACKING THE CONCEPT FROM SOCIAL SCIENCE AND URBAN PLANNING PERSPECTIVES

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UNPACKING THE CONCEPT OF URBAN GREEN SPACES FROM SOCIAL SCIENCE AND URBAN PLANNING PERSPECTIVES

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Julie Vuillermoz

Table of Contents

Abstract

Purpose. Rapid urbanization, environmental degradation, and widening health disparities represent some of the most pressing challenges facing contemporary society. While these issues are deeply rooted and complex, enhancing our capacity to adapt and respond (by increasing urban resilience) offers a promising pathway forward. A crucial first step in building this resilience is developing a shared understanding of the problems at hand and the role that Urban Green Space (UGS) can play in mitigating both environmental and public health pressures.

Aim. This study aims to clarify and illuminate the multifaceted benefits of UGS within the broader framework of Planetary Health, recognizing the conceptual fragmentation that often hampers effective planning and implementation. Adopting a multidisciplinary lens, this research integrates insights from environmental science, urban planning, and public health to explore how UGS is currently understood and applied.

Method. A scoping review of 81 academic articles was conducted using the snowballing method to map key concepts, dimensions, and benefits associated with UGS. To assess how these academic insights translate into practice, six semi-structured interviews were conducted with stakeholders operating at various institutional levels: national, municipal, and neighbourhood.

Result. The findings reveal a significant disconnect between theory and practice. The concept of UGS is often used without a clear or consistent definition, and monitoring practices remain limited, further contributing to ambiguity and inconsistency in implementation. These gaps underscore the urgent need for a shared conceptual foundation to enable effective cross-sectoral communication and strategy development. To address this, the study introduces a protocol designed to guide the consistent description, reporting, and framing of UGS.

In conclusion, while urban planning is inherently complex, this research contributes to simplifying and structuring that complexity by synthesizing diverse perspectives into a coherent, actionable framework. By promoting clearer conceptualization and fostering a shared understanding, this study lays the groundwork for more coordinated, inclusive, and strategic approaches to the planning and implementation of UGS.

Keywords: Urban Green Space, Planetary Health, Scoping review, Stakeholders perspectives, Interdisciplinary research, Public Health, Environmental Resilience.

Introduction

Unpacking Planetary Health

The escalating challenges of the Anthropocene era—characterized by rapid urbanization, environmental degradation, and widening health disparities[1]— necessitate an urgent re-evaluation of the relationship between human health and natural system[2]. At the forefront of this discourse is the concept of Planetary Health, a framework that highlights the profound humanitarian implications of Earth's environmental crises. As Sam Myers poignantly observes, "The Earth crisis now represents a humanitarian crisis"[3]. First introduced in 2015[4], Planetary Health builds upon earlier holistic medicine paradigms from the 1970s through 2010[5], transcending disciplinary boundaries to integrate social, political, and environmental dimensions of health[6]. At its core, this multidisciplinary paradigm illuminates the critical interdependence between human well-being and the ecological systems that sustain it[7]. Despite its growing prominence, Planetary Health remains a complex and evolving concept, with ongoing debates surrounding its precise definition and practical applications. In non-scientific contexts, it is often characterized as a "solutions-oriented, transdisciplinary field and social movement" aimed at tackling global ecological and health challenges[8]. In contrast, academic literature defines it more broadly as "the health of human civilization and the state of the natural systems on which it depends"[7p.01]. Its academic framing spans multiple dimensions, including health, equity, governance, and resilience, while emphasizing the importance of knowledge, comprehension, and adaptability[7,9]. By spanning multiple levels, from broader natural ecosystems to individual human dimensions[10], Planetary Health seeks to guide actions and policies that ensure the health and well-being of both people and the planet. These principles recognize the interconnectedness of human health, environmental resilience, and global collaboration.

Central to this discourse is the pursuit of a "planet-proof" society[11], which calls for effective mitigation strategies to minimize humanity's impact on planetary systems. With 70% of the global population projected to reside in cities by 2050[12] a promising approach to addressing environmental stressors in urban settings lies in the strategic reintegration of nature into city landscapes. By reducing pollution[13], noise[14], and extreme heat[15], green spaces enhance overall living conditions as well as contribute to broader urban resilience. Beyond their role in mitigation, green spaces support restoration by replenishing mental and physical capacities[16]—facilitating attention renewal and reducing stress—while also fostering instoration[15], which involves creating new capacities such as promoting physical activity and strengthening social connections. Despite the recognized benefits of green space, translating the principles of Planetary Health into concrete urban planning strategies remains a significant challenge. Effective policies must bridge the gap between human and environmental health, ensuring that urban development is guided by an integrated, health-focused approach[17]. However, achieving this integration requires reconciling environmental governance, urban development, and public health policies, which remains an ongoing challenge in the context of urban green space (UGS).

Urban Context and Pressures

Urban areas are at the heart of this Planetary Health paradigm, acting simultaneously as drivers and victims of ecological and public health vulnerabilities[18]. They collectively account for 71 to 76% of global

CO_2 emissions[19], exacerbating climate-induced flooding, extreme heat, and declining air quality that now affect millions worldwide[20]. Socioeconomic factors[21,22], including overcrowding, unemployment, and poverty, further exacerbate health disparities, as urbanization is closely tied to rising rates of Non-Communicable Diseases (NCDs) such as obesity, cardiovascular diseases, and diabetes[24–26]. In addition, urban stressors such as climate change, noise pollution and reduced social cohesion have been linked to increasing rates of depression, anxiety, and eco-anxiety[27,28]. Beyond health concerns, the metabolic demands of cities—encompassing land conversion, energy consumption, and waste production—contribute significantly to biodiversity loss and ecological imbalances[29]. Scholar describes cities as "the only parasite in the biosphere"[13p.1], reflecting their disproportionate resource consumption and environmental degradation. Addressing these interconnected challenges requires a systems approach that integrates urban resilience, health equity, and sustainability-oriented planning.

Green Space: A Promising Yet Wicked Challenge

Amidst these growing concerns, UGS have emerged as a promising intervention to counteract these pressures, offering benefits such as improving air quality, mitigating heat stress, and enhancing mental and social well-being[13,30]. However, realizing the full potential of UGS is hindered by inconsistent definitions of what qualifies as green space and what does not[31], leading to discrepancies in planning and implementation. These inconsistencies added to difference in geographical coverage and study design make it difficult to draw clear conclusions about the benefits of green spaces and to compare findings across studies [32]. However, research has indicated that specific types of green spaces, such as individual trees, grassy areas, parks or forest, can influence various mental health outcomes. These include perceived physiological stress, general stress, affect, restorative experiences, and subjective well-being. From an environmental perspective, the type of green space is equally important. For instance, tree cover has been shown to outperform grass in several key functions: tree shading can reduce surface temperatures by up to 8.0°C, decrease runoff by 14%, and intercept up to 42% of rainfall before it reaches the ground[33]. Moreover, UGS intersect with multiple disciplines, areas of focus, and stakeholders concerns[34], complicating efforts to develop cohesive strategies. A critical aspect of this complexity is the issue of green space justice and unequal access, which has been explored across various disciplines[35]. Access to and availability of UGS is often significantly lower in low socioeconomic status (SES) neighbourhoods, reflecting broader patterns of socio-environmental inequality[36] and reinforcing the need for policies that prioritize inclusivity and accessibility. Therefore, these interrelated challenges highlight the necessity of a multidisciplinary approach that integrates ecological, public health, and urban planning perspectives to ensure that UGS are not only designed effectively but also equitably distributed to maximize their societal and environmental benefits. Ecosystem Services and Biophilic City provide two crucial lenses for understanding how green spaces can enhance urban resilience. While the Ecosystem Services framework highlights the functional benefits of natural ecosystems, emphasizing benefits such as air purification, temperature regulation, and flood mitigation[37], the Biophilic City concept focuses on the intrinsic human need to connect with nature, advocating for urban designs that foster mental restoration and community well-being[38].

Yet, despite these conceptual frameworks, UGS remains an overwhelming and multifaceted concept, entailing complex social, ecological, and governance dimensions. While increasing green spaces may appear as an intuitive solution, the reality of UGS planning is far more intricate, characterized by competing priorities, stakeholder interests, and systemic inequalities. This complexity positions UGS as a wicked problem for urban planning, requiring nuanced, context-sensitive strategies that extend beyond simplistic approaches.

Study Aim and Structure

This study seeks to add clarity and elucidate the complexities and multifaceted benefits of UGS within the broader context of Planetary Health. Recognizing the conceptual fragmentation that hinders the effective planning and implementation of UGS, this research adopts a multidisciplinary approach, integrating insights from environmental science, urban planning, and public health. The objective is to identify and articulate the key frameworks, layers, and influencing factors that shape UGS planning and execution. By addressing these complexities, the study aims to contribute to a more coherent understanding of UGS as both a critical ecological asset and a pivotal element in enhancing urban resilience and well-being. The research is guided by the following central question:

RQ: What common conceptual ground can be identified across academic literature and stakeholder perspectives to support a shared understanding of environmental and health co-benefits of UGS?

Q1: What are the key factors and conceptual dimensions identified in the literature that are essential for integrating environmental and health co-benefits into UGS planning?

Q2: How do stakeholders identify, navigate, and prioritize trade-offs when designing and implementing UGS interventions?

This research begins by establishing the conceptual foundation of UGS, drawing first on the Ecosystem Services framework (Section 1.1), followed by the Biophilic City approach (Section 1.2), and concluding with a focus on the specific roles and functions of UGS (Section 1.3). The study is structured in two main parts: the first involves a scoping review aimed at answering Research Question 1, while the second builds on these insights through stakeholder interviews to address Research Question 2. Each part is guided by its own methodology, results, and discussion. Finally, a general discussion (Section 4) synthesizes findings from both parts, offering implications for future research and urban policy. The paper concludes by highlighting the key outcomes and drawing final conclusions.

Theoretical framework

1.1. Ecosystem Services: The Functional Role of Nature in Urban Systems

As cities seek to balance environmental resilience and public health, the Ecosystem Services framework has become a key conceptual tool for integrating nature into urban environments[39]. This framework describes the diverse benefits that humans derive from natural ecosystems, categorized into four primary types: provisioning services (e.g., food, water), regulating services (e.g., air purification, climate control), supporting services (e.g., nutrient cycling, soil formation), and cultural services (e.g., recreation, aesthetic experiences)[13,40]. Although the Ecosystem Services concept originated in the 1970s and gained prominence in the 1980s[41], its application in urban contexts remains complex. Originally designed as a universal model, the framework has proven difficult to standardize, as the assessment and prioritization of services often vary across geographic regions, social contexts, and policy agendas[41,42]. In response to these limitations, more recent approaches such as Nature-Based Solutions (NBS) have sought to adapt the framework to urban realities by emphasizing targeted interventions. These include strategies that address specific challenges like urban heat mitigation, carbon sequestration, and the promotion of mental well-being[43]. Building on this evolution, the concept of Urban Ecosystem Services (UES) has emerged to better tailor ecosystem service thinking to the realities of city life. Unlike traditional approaches that focus primarily on natural or rural landscapes, UES incorporates the complexities of urban systems, acknowledging the interplay between green spaces, built infrastructure, governance structures, and socio-economic dynamics[39]. Applying this perspective requires a more integrated approach that recognizes the multifunctionality of urban green spaces in delivering environmental, social, and economic benefits. Operationalizing ecosystem services in urban planning thus requires embedding these concepts into practical decision-making processes that explicitly link ecological functions with human well-being.

Nevertheless, both traditional and urban-oriented Ecosystem Services frameworks have been critiqued for their limited engagement with the social and psychological dimensions of human–nature interactions. This gap is increasingly addressed by the Biophilic Cities framework, which places emphasis on emotional, cognitive, and experiential connections to nature, offering a complementary lens that extends beyond the functionalist orientation of ecosystem services.

1.2. Biophilic Cities: Integrating Nature into the Urban Experience

While the ecosystem services framework emphasizes the functional and utilitarian value of nature, the Biophilic City concept shifts the focus toward the intrinsic human need to connect with nature. Rooted in the biophilia hypothesis, which suggests that humans possess an innate biological affinity for natural environments[44], this framework has gained traction in urban planning as a way to redefine cities as nature-inclusive spaces[45]. The term biophilia is derived from the Greek word bios (meaning “life”) and philia (meaning “love” or “affection”) and was first introduced by social psychologist Erich Fromm in 1964[46]. Biophilia is described as a passionate love of life and all that is alive[47p.365]. Wilson later expanded on this concept, arguing that human well-being is deeply tied to interactions with natural elements [44].

Biophilic urbanism operationalizes this idea by embedding nature into city planning and design, integrating elements such as green roofs, urban forests, public parks, and water features[48]. Unlike the ecosystem services model, which emphasizes quantifiable environmental functions, biophilic cities focus on psychological, emotional, and social benefits, including mental health restoration, increased physical activity, and enhanced social cohesion[16,38]. Historically, biophilic elements have been central to architecture and urban planning, from the Hanging Gardens of Babylon to the Italian Renaissance villa gardens[48]. However, contemporary urbanization has distanced people from nature, creating cities that prioritize efficiency over well-being. Addressing this disconnect requires embedding biophilic principles into urban governance, design policies, and community engagement strategies.

1.3. Urban Green Spaces: Bridging Ecosystem Services and Biophilic Design

A key component in realizing both biophilic and ecosystem service goals is the integration of UGS into city planning and design, as they represent the most immediate and accessible manifestation of these concepts in urban environments [13,30]. Despite growing recognition of UGS as essential to healthy and sustainable cities, their definition varies across disciplines. Taylor and Hochuli identified six types of definitions[31], ranging from general descriptions of vegetation to specific examples of green environments, often lacking coherence. While green space is broadly defined as vegetated areas[49], in many studies there is no differentiation between green spaces in terms of size, type of green space (individual park, grass, bushes, park, etc) and biodiversity (e.g., a field of grass versus a park incorporating many types of vegetation)[31]

To address these inconsistencies and guide effective urban greening, the World Health Organization (WHO) has established benchmarks for urban greening standards: the 3-30-300 rule[50]. It recommends that each person should see at least three trees from their home, neighbourhoods should have at least 30% tree canopy coverage, and a green space should be accessible within 300 meters[51,52]. However, implementation challenges persist, as green space distribution often reflects socioeconomic inequalities. In the Netherlands, the average distance to a park or public garden is approximately one kilometer[53,54], far exceeding WHO recommendations. Similar accessibility gaps are evident in other European cities, such as Rouen (1.9 km), Luxembourg (1.7 km), and Brussels (1.4 km). These distances are based on a rather generic definition of UGS (i.e. “any publicly accessible space with natural elements in either small or large quantities”[55p.4]) which may have impacted the outcomes. This lack of definitional consistency further complicates efforts to assess and compare accessibility across contexts. Addressing these disparities is critical to advancing Sustainable Development Goal 11, which aims to ensure inclusive, safe, and resilient cities by 2050[56]. Moreover, there remains a limited understanding of how different types of UGS relate to specific mental health outcomes[32], as they are often aggregated into broad categories such as parks, forests, or grassy areas. This generalization limits the ability to draw precise conclusions about which types of UGS are most effective in promoting health. Developing more nuanced insights which allow to compare the type of UGS would enable more targeted recommendations and inform policies that promote equitable access to green spaces, ultimately enhancing urban health and environmental resilience.

This theoretical framework explores the intricate interconnections between ecosystem services and biophilic cities, in the realm of UGS, demonstrating their shared relevance in addressing the pressing challenges of urbanization, environmental degradation, and public health disparities. While these concepts provide valuable insights individually, their overlapping dimensions often result in fragmented approaches and inconsistent terminologies. To support conceptual clarity and ensure consistency throughout this study, an overview of key terms and definitions is provided in Table 1. Building on this synthesis, the next section details the methodological approach employed to systematically explore these dynamics, providing a foundation for uncovering key trends, factors, and stakeholder priorities that shape the relationship between green spaces and human health.

Table 1. Overview of Key Concepts and Definitions Used in This Study

Terminology	Definition / What it Encompasses
Type of UGS	Physical forms of urban green space, including trees, grass, parks, forests, gardens, and green roofs.
Characteristics of UGS	Structural and perceptual attributes of green spaces, such as spatial morphology, size, accessibility, and perceived quality.
Biodiversity of UGS	Variety of plant species within green spaces, including different types of vegetation such as trees, flowers, shrubs, and grasses.
Functional Benefits of UGS	Environmental and health-related outcomes provided by green spaces, including air purification, temperature regulation, flood and heat mitigation, and support for mental, physical, and social well-being.
Mechanism of UGS	Core processes through which UGS exert their influence on human health and well-being: mitigation (reducing harm), instoration (promoting healthy environments), and restoration (facilitating recovery).
Conceptual dimension	Theoretical frameworks used to understand the value and function of UGS, including Planetary Health, Ecosystem Services, and Biophilic Cities.

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PART 1

SCOPING REVIEW

Q1: What are the key factors and conceptual dimensions identified in the literature that are essential for integrating environmental and health co-benefits into UGS planning?

2.1. Methodology

2.1.a. Corpus selection

To develop a comprehensive understanding of the components related to green space, urban dweller health, and environmental health in urban settings, a scoping review methodology was selected as the most appropriate approach. Scoping reviews are particularly effective for synthesizing evidence across emerging or complex topics, where the goal is to explore the breadth and scope of existing knowledge rather than answer a narrowly defined research question or assess the quality of individual studies[57]. This method is well-suited to fields like UGS, where multidisciplinary perspectives and heterogeneous data sources converge, enabling the identification of knowledge gaps and characterization of evidence[58]. Unlike systematic reviews, which aim to draw firm conclusions, scoping reviews focus on mapping the extent, range, and nature of research activity, thereby providing a foundation for future, more targeted studies.

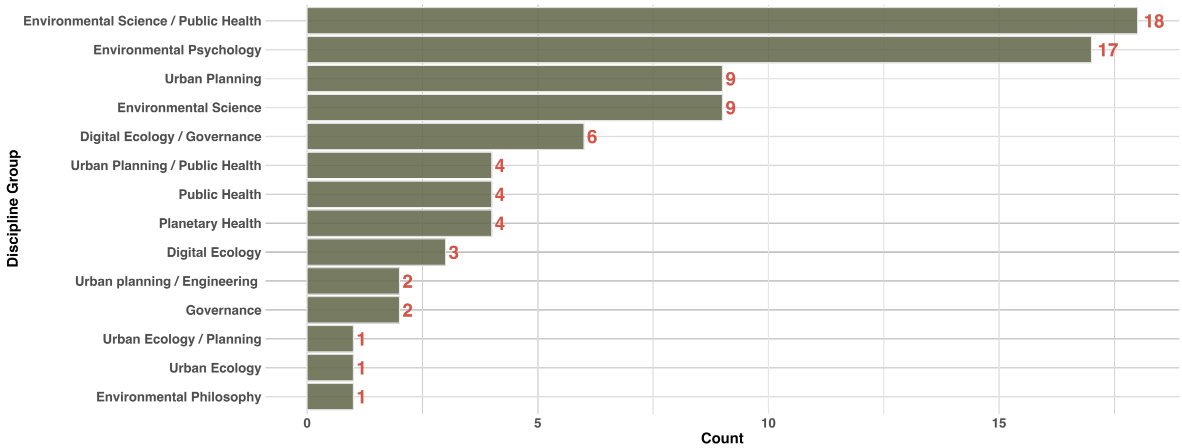
To ensure a broad yet structured literature base, an initial corpus of studies was compiled in September 2024, focusing on key thematic areas: (1) UGS and its benefits for environmental resilience, (2) UGS and its benefits for urban dwellers health, and (3) the integration of green space strategies in urban planning. These initial studies were identified through a combination of expert recommendations, key institutional reports (e.g., WHO and UN-Habitat), and foundational academic literature on the topic. The selected corpus provided a preliminary landscape of the field, allowing for the identification of major themes and recurring research frameworks.

Given the multidisciplinary and evolving nature of research on UGS, health and environmental impact in urban context, the snowballing method was employed to expand the review beyond the initial corpus. Snowballing, guided by Wohlin's principles[59], allows for a more organic and iterative identification of relevant literature by tracing citations and references in key articles. This approach is particularly advantageous in fields with fragmented or evolving literature, where studies may not yet be extensively indexed in traditional systematic review databases. To streamline and visualize the snowballing process, Research Rabbit was utilized. This tool offers an interactive representation of citation networks, enabling the identification of influential studies, thematic clusters, and emerging trends across disciplines. The search process was not a one-time exercise but an iterative cycle. As new insights emerged while reviewing articles, certain areas required further exploration and refinement, prompting re-explorations of the topic to ensure clarity and conceptual completeness. A key challenge was achieving a comprehensive yet manageable scope, given the breadth of research across multiple disciplines. The final corpus comprises 81 papers (Appendix A).

2.1.b. Corpus characteristics

The corpus spans publications from 2007 (n=2) to 2024 (n=5), demonstrating a significant increase in scholarly interest since 2015, peaking in 2023 with 29 publications (Annex 2, Figure 2). Geographically, the corpus includes studies from diverse regions (Annex 2, Figure 1), with strong representation from the United States (n=13), Europe (n=43 across multiple countries), and Asia (n=10 across several nations). This distribution shows the global relevance of the topic. The disciplinary spread reveals a strong multidisciplinary focus (Figure 1), with 31 papers engaging multiple disciplines, such as combinations of environmental science, governance, and public health. In contrast, 50 papers were categorized as mono-disciplinary, though even within these, diverse perspectives are present. For instance, environmental psychology (n= 17) integrates insights from psychology, sociology, and environmental science to explore how individuals interact with their surroundings. Similarly, fields like urban planning (n=9) often adopt multidisciplinary approaches by considering ecological, social, and policy dimensions. Furthermore, the study designs (Annex 2. Figure 3) are largely theoretical and conceptual papers (n=24), followed by structured review papers (n=13) and empirical survey research (n=10) as well as case studies (n=10), highlighting the dominance of conceptual frameworks and systematic syntheses in this field. Regarding the methodological approaches employed in the corpus (Annex 2. Figure 4), they predominantly feature literature-based analyses (n=30), systematic reviews (n=15), survey-based studies (n=12), and data-driven approach (n=11) including Geospatial Information System, Deep Learning Method, Natural Language Processing.

Figure 1. Distribution of Studies by Discipline Group



2.1.c. Corpus analysis

Two complementary analyses were conducted on the corpus to capture quantitative dimensions. A bibliometric analysis using VOSviewer identified thematic clusters within the dataset. This visualization illustrates the relationships and influence of papers based on citation metrics. The size of each node represents the number of citations a paper has received. For example, if a paper like Markevych (2017) shows 1,390 citations, it indicates its high academic influence. Links between nodes indicate citation connections within the dataset, showing how studies are interrelated. For instance, if Markevych (2017) has 16 links, it signifies citations to or from 16 other papers in the corpus. This analysis provides insights into influential works and the structural connectivity of research within the field (Annex 4).

To further explore thematic relationships, a co-occurrence analysis of key terms was performed using VOSviewer. Terms appearing at least five times in titles and abstracts were selected, yielding 167 terms out of 2,511. To enhance readability, the dataset was refined to the top 100 terms, revealing key thematic clusters.

2.1.d. Corpus review

Lastly, to ensure the coherence of the final corpus, the dataset underwent also a qualitative review. Papers were grouped based on thematic similarities, facilitating the identification of conceptual overlaps and complementary insights across disciplines.

This process allows the integration of fragmented perspectives into cohesive narratives that bridge environmental science, urban planning, and health studies. The combined approaches that include bibliometric analysis, co-occurrence term mapping, and manual review, provided a structured yet flexible synthesis, capturing both citation trends and qualitative thematic relationships. This dual lens helped identify overlapping insights, research gaps, and emerging trends in the intersection of green spaces and human health.

2.2. Results

2.2.a. Bibliometric Analysis

The bibliometric analysis (Figure 2) revealed a complex network of thematic clusters that reflect the multidisciplinary nature of research on urban green spaces. Cluster 1, represented in red, focuses on the Human-Nature relationship and perceptions of UGS, comprising 12 papers primarily from environmental science (n=6), environmental psychology (n=4), and urban planning (n=2). Cluster 2, depicted in green, concentrates on the health impacts of green spaces and the pathways through which these impacts occur. This cluster includes eight papers, with a strong presence of environmental psychology (n=5), highlighting the psychological and physiological mechanisms linking green space exposure to improved health outcomes. Cluster 3 (blue) delves into the social impacts of green spaces, integrating studies from environmental science/public health (n=4), environmental psychology (n=2), and urban planning (n=2). This thematic area explores how green spaces foster social cohesion, community well-being, and equitable access to natural environments.

A key observation is the limited integration of Cluster 4 (yellow), which represents Planetary Health skills and literacy. Despite its growing prominence, this cluster remains poorly connected to others, corroborating the gap highlighted in the aforementioned paragraph about the holistic integration of Planetary Health principles within urban green space research. Further thematic clusters include Cluster 5 (purple), focusing on the characteristics and geospatial configurations of green spaces, and Cluster 6 (orange), which addresses smart cities and governance. Clusters related to equity in green space planning (light blue), urban forests and edible cities (brown), and green infrastructure (pink) also emerged, each contributing unique insights to the broader discourse. The detailed thematic clusters are presented in Annex 4 and summarized in Table 2 (below) for clarity, illustrating the diversity of research themes and their corresponding disciplinary affiliations.

Figure 2. Bibliometric analysis

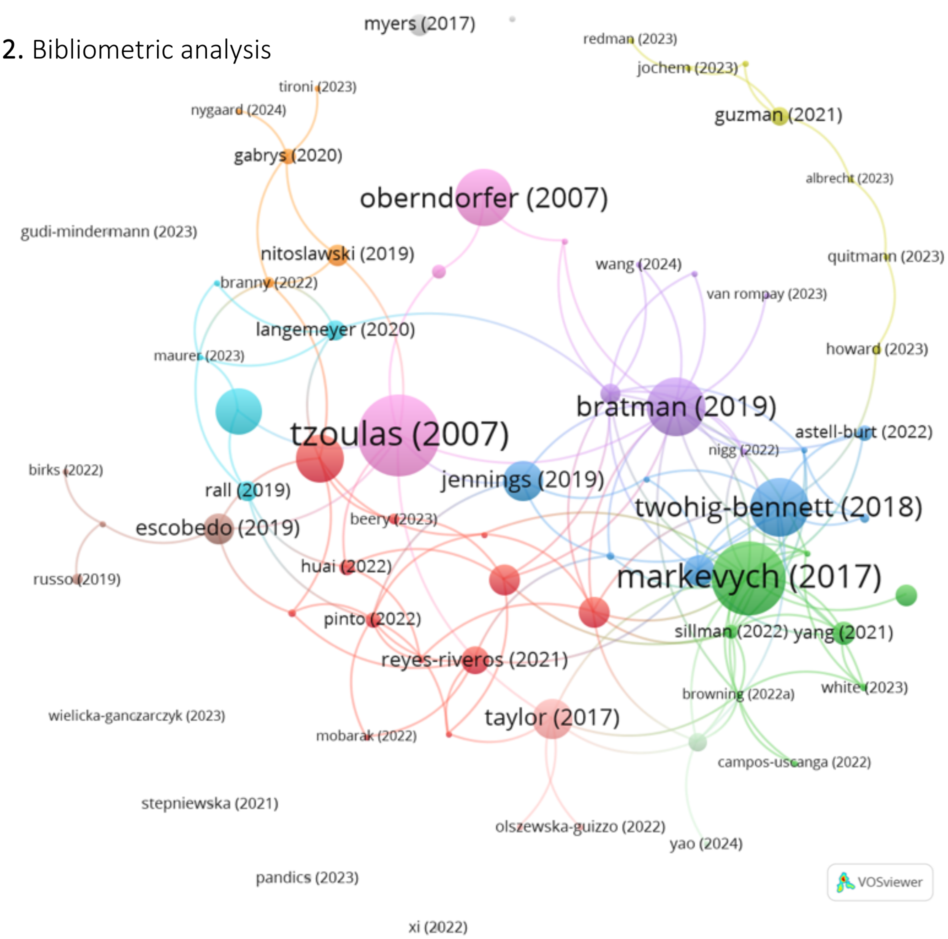


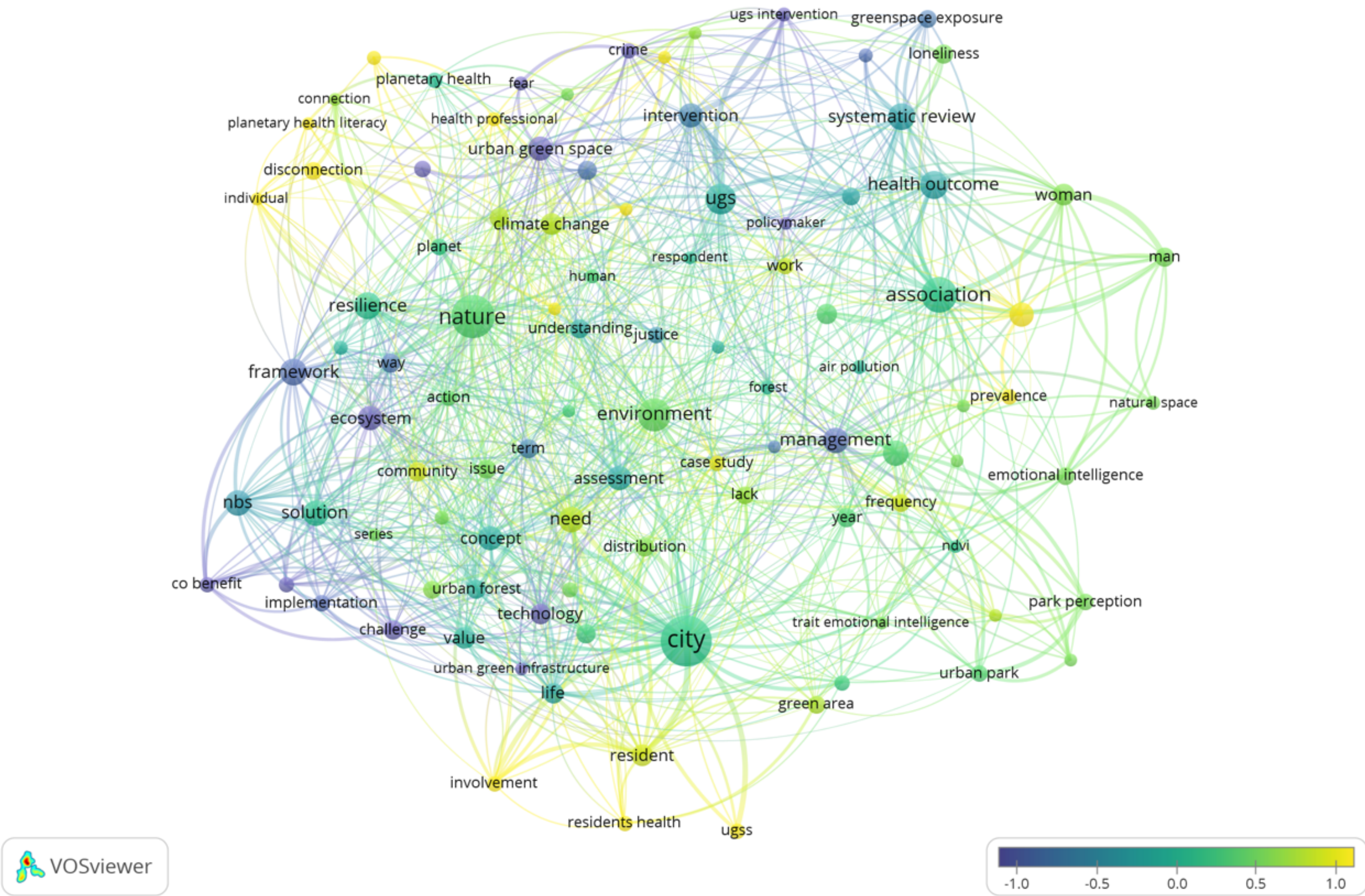
Table 2. Thematic Clusters

Colour	Theme	Fields involved
Red	Human-nature relationships and perceptions of GS	Environmental Science (n=6), Environmental Psychology (n=4), Urban Planning (n=2)
Green	Health impacts of green spaces and pathways	Environmental Psychology (n=5), Environmental Science (n=3),
Blue	Social impact of GS	Environmental Science/Public Health (n=4), Environmental Psychology (n=2), Urban Planning (n=2)
Yellow	Planetary Health skills and literacy	Environmental Science/Public Health (n=3), Planetary Health (n=3), Governance (n=1)
Purple	Characteristic and geospatial configuration	Environmental Science/Public Health (n=3), Environmental Psychology (n=2), Urban Planning (n=1)
Orange	Smart cities, smart governance	Digital Ecology/Governance (n=4), Urban Planning (1)
Light blue	Equity and fair GS planning	Urban Planning (n=3), Governance (n=1), Environmental Psychology (n=1)
Brown	Urban forest and edible cities	Urban Planning (n=3), Environmental Science (n=1)
Pink	Green infrastructure	Environmental Science (n=2), Urban Ecology (n=1), Urban planning (n=1)
Light red	Defining GS	Environmental Science (n=2), Environmental Psychology (n=1)
Light Green	Importance of green space	Environmental Science (n=2),
Grey	Long environmental exposure	Environmental Psychology (n=1)
Grey	Long environmental exposure	Environmental Science / Public Health (n=1)
Grey	Exposome	Urban Planning / Public Health (n=1)
Grey	Governance	Digital Ecology / Governance (n=1)
Grey	Solution	Urban planning / Engineering (n=1)
Grey	Regulating and cultural ecosystem services	Environmental Science (n=1)
Grey	Planetary health overview	Planetary Health (n=1)

2.2.b. Co-occurrence Analysis

The co-occurrence analysis revealed a chronological shift in research focus, moving from technical and structural concepts in older studies to more socially oriented and health-related considerations in recent works. Early research emphasized terms such as "ecosystem," "framework," and "policymaker," reflecting a focus on governance structures, environmental management, and technical expertise. In contrast, more recent studies highlight terms like "community," "loneliness," and "social cohesion," indicating a growing interest in the psychosocial dimensions of urban green spaces. This evolution is evident in the clustering of keywords, where older studies gravitate towards hard skills related to environmental policy and implementation, while newer studies emphasize soft skills such as stakeholder engagement, empathy, and health literacy. Thematic clusters include concepts related to environmental challenges (dark blue), assessment and intervention strategies (dark green), action-oriented frameworks (light green), and community engagement (yellow). Central terms such as "city," "environment," and "resilience" exhibit high connectivity, illustrating their foundational role in the discourse, whereas emerging terms like "planetary health literacy" and "climate-sensitive health counselling" reflect recent interdisciplinary expansions. This dynamic landscape underscores the evolving priorities in urban green space research, with increasing attention to human well-being alongside environmental sustainability. The visualisation of these findings is presented in Figure 3, while a detailed table of the keywords is provided in Annex 5.

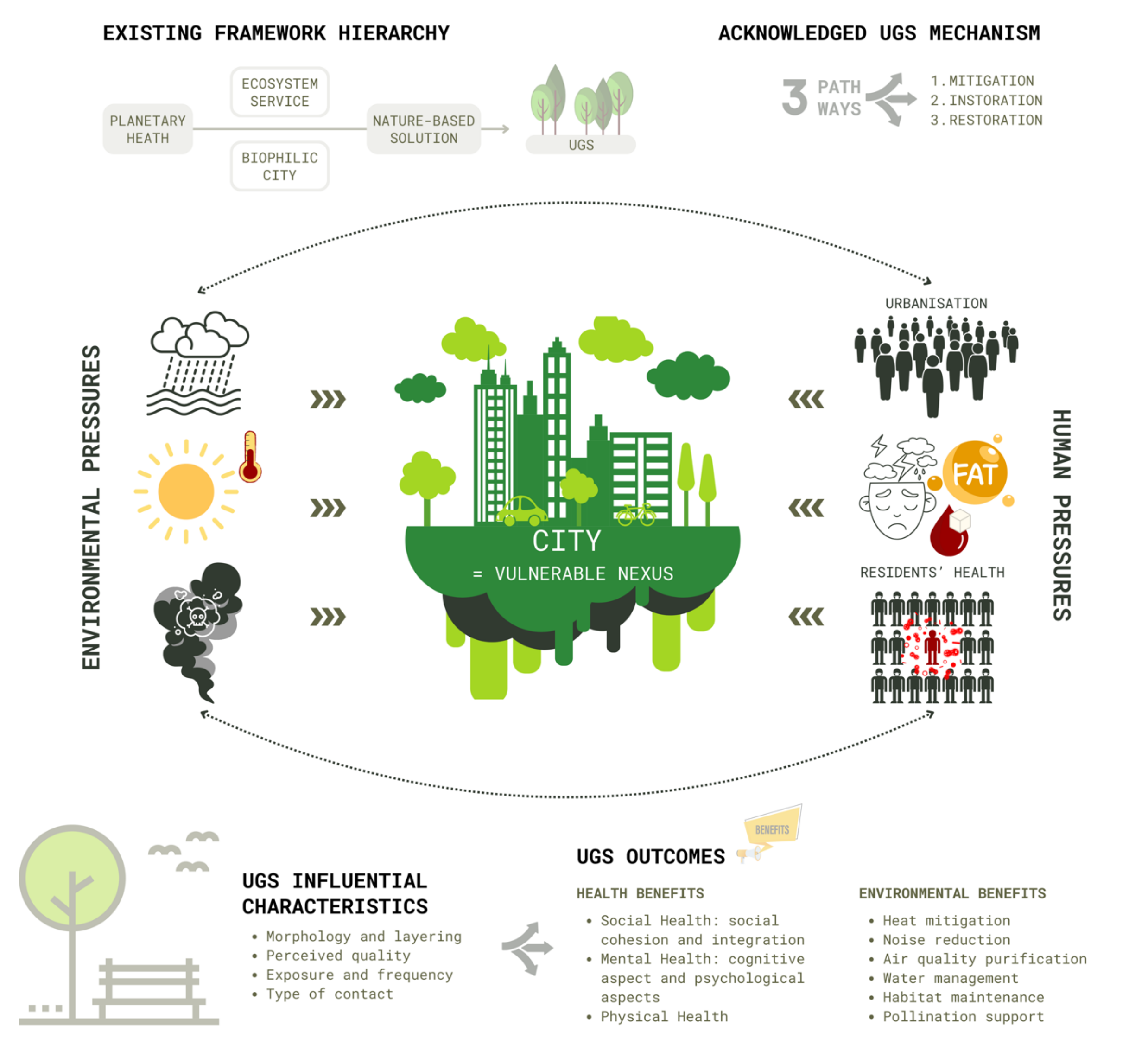
Figure 3. Co-occurrence per year



2.2.c. Scoping Review Findings

The results of the scoping review are presented through three complementary formats to ensure a comprehensive understanding of the findings. Firstly, a visual representation (Figure 4) provides an overview of the key concepts and their interrelated layers, offering a clear and intuitive grasp of the conceptual structure. Secondly, the most critical findings are highlighted and discussed in the accompanying text, emphasizing the primary insights and their implications. Lastly, a more detailed and granular presentation of the results is provided in Table 3, offering in-depth information and supporting data for each identified element.

Figure 4. Urban Green Space Nexus: A Conceptual Overview of Influences and Benefits



UGS conceptual dimensions. Across the reviewed literature, three conceptual dimensions were identified. "Planetary Health" emerged as an overarching term applied at a higher conceptual level. For instance, Jochem et al.[7] and Guzmán et al.[60] employ this term as a holistic perspective encompassing individual, societal, and global scales, maintaining a broad scope that references human civilization and its interconnection with nature. Howard et al.[61] position "Planetary Health" at the same conceptual level as "climate change," where the former pertains to the health of human civilization on a planetary scale, while the latter relates to the health of the environment. However, the Planetary Health framework remains conceptual and does not provide practical, actionable solutions [5,7]. In the remaining corpus, the Biophilic Framework and the Ecosystem Services Framework were commonly applied, along with references to NBS in studies addressing a practical or applied focus. Among the 81 reviewed papers, 36 explicitly aligned with one of these four frameworks. For the remaining studies, the specific conceptual framework was not clearly identified. Regarding the mechanisms underlying the impact of

UGS on health and the environment (Instoration, Mitigation and Restoration), these were explicitly stated in eight papers[15,16,32,62–66].

Environmental Benefits of UGS. The reviewed literature confirms that UGS play a crucial regulatory role[14] in the urban environment by contributing to climate mitigation, air quality improvement[67,68], noise reduction[14,15], water management[14,69,70], and biodiversity support[68,69]. One of the primary regulatory functions of UGS is their cooling effect[14,15,37,71], which helps mitigate urban heat and enhances thermal comfort. This effect is particularly relevant in dense urban areas, where green spaces can be strategically implemented to counteract the urban heat island effect[61]. In addition to temperature regulation, UGS contribute to air quality improvement by acting as natural air filters[69,72]. However, the effectiveness of this function varies depending on the morphology, density, and distribution of vegetation, with some configurations providing stronger pollutant absorption than others[68]. Similarly, UGS help reduce noise pollution by acting as physical and acoustic barriers, particularly in high-traffic areas[15]. UGS also play a key role in urban water management by enhancing water absorption and retention, thereby mitigating flood risks [14,69,70]. The concept of sponge cities[69], where green infrastructure is integrated to regulate excess water, is a notable example of how UGS can improve urban hydrological resilience.

Finally, the literature highlights the importance of UGS in supporting biodiversity, particularly through the creation of ecological corridors and green patches that facilitate species movement across urban landscapes[73]. The presence of interconnected green networks is emphasized as a critical factor in maintaining ecological balance within cities, reducing habitat fragmentation, and enhancing urban biodiversity.

Health Benefits of UGS. UGS provide significant benefits for physical, mental, and social health[14]. Physically, they are linked to improved birth outcomes[18], better sleep quality[18,74], increased physical activity[15,65,75,76], and reduced risks of diseases like heart disease[73], diabetes[77], and obesity[18]. Green spaces enhance physiological health by boosting immunity[77], lowering heart rates, and improving blood pressure [18]. Mentally, exposure to green environments supports cognitive functions[18,65], reduces stress[74,78,79] and depression[14,18], and enhances emotional stability[65]. Socially, UGS foster a sense of purpose[14], belonging[80], and community cohesion[14,65] by promoting social interactions[77], and reducing loneliness[81]. Additionally, well-designed UGS contribute to cultural ecosystem services[71,81], strengthening social capital and community engagement.

The relationship between UGS and health outcomes is influenced by SES, gender, ethnicity, and contextual characteristics[15]. The concept of the ‘equigenic effect’ posits that contact with nature may yield disproportionately greater health benefits for socioeconomically disadvantaged groups, who typically experience poorer baseline health, higher exposure to environmental pollutants, and limited mobility, factors that increase their reliance on nearby green spaces[62]. However, the potential of UGS to reduce health disparities can be undermined by issues related to quality and safety. In many low-SES areas, UGS are often poorly maintained, perceived as unsafe, or lack amenities, thereby constraining their use and limiting their associated benefits [30,78]. Moreover, while investments in green infrastructure can enhance neighbourhood liveability, they may also trigger processes of green gentrification[14,37,82], driving up property values and living costs, and displacing the very populations intended to benefit. As a result, such developments risk reinforcing, rather than reducing, spatial and health inequalities.

Addressing these disparities is therefore crucial to ensuring equitable access to UGS and delivering their full health potential across all communities.

Morphology, Perception, and Exposure: Characteristics of UGS impacting Health. The morphology of UGS has a direct impact on health outcomes. Studies show that connected green spaces, such as a "Green Belt," are associated with better health outcomes compared to isolated parks[68]. Moreover, high fragmentation of green spaces correlates with increased mortality rates[68], highlighting the importance of spatial configuration in urban planning. The type and composition of green space also influence health benefits. For instance, the layering of vegetation, which ensures visibility across the foreground, middle ground, and background, has been associated with a greater sense of freedom and psychological comfort[83]. Furthermore, as the amount and diversity of vegetation increase, health benefits initially improve, but only up to a certain threshold[84]. If vegetation becomes too dense, complex, or excessive, benefits may decline. This decline is attributed to factors such as reduced visibility, perceived disorder, lower accessibility, and feelings of enclosure or insecurity. These findings reinforce the importance of designing green spaces that balance environmental richness with accessibility and comfort to maximize health outcomes.

Perception of UGS further shapes its health impact. Elements such as naturalness, cleanliness, safety, and maintenance significantly affect how residents perceive and appreciate green spaces[85]. These perceptions are further shaped by cultural backgrounds, highlighting the importance of culturally sensitive design and management practices to enhance user satisfaction and well-being[85]. In addition to these practical and cultural dimensions, research underscores the significance of immersive and aesthetically engaging landscapes in promoting psychological restoration. Specifically, environments that evoke a sense of awe and offer opportunities for mental escape (without inducing disorientation) are found to be particularly effective in supporting emotional well-being[86].

The way individuals engage with UGS can be understood through the lens of contact motivation, which distinguishes between indirect, incidental, and intentional forms of contact[65]. Indirect contact refers to mediated experiences of nature, such as watching nature videos or viewing greenery through a window, which can still offer restorative benefits. Incidental contact occurs unintentionally, for example, passing through a green space during a commute or perceiving natural sounds or smells from home. Intentional contact, by contrast, involves purposeful activities like gardening, exercising in a park, or visiting green areas for relaxation. These motivational categories often align with the type of exposure experienced [77]: incidental and indirect contact tend to result in more passive exposure, where benefits are primarily derived from environmental functions such as air purification or thermal comfort. Intentional contact, on the other hand, is typically linked to active exposure, involving conscious interaction with nature through physical or social activity. Additionally, multi-sensory engagement significantly influences both perception and the health benefits derived from UGS[73]. While all five senses contribute to the overall experience, auditory (natural sounds) and somatosensory (touch) stimuli have been found to exert a stronger influence on perception compared to visual input. Diverse sensory stimulation plays a crucial role in promoting stress reduction, mood improvement, and a deeper sense of connection to the natural environment[73].

The frequency and duration of exposure are also critical for health outcomes. Experimental research demonstrates that even brief, virtual exposure to nature can have measurable effects: for instance, a 10-minute video depicting everyday natural scenes (such as trees, vegetation, or water) significantly facilitated physiological recovery from stress within 4 to 7 minutes [79]. This was evidenced by reductions in blood pressure, muscle tension, and skin conductance, compared to participants exposed to urban environments under similar conditions. However, Yao et al.[87] highlight the presence of a plateau effect, indicating that beyond a certain point, increasing UGS exposure does not yield additional health benefits. This plateau is observed both in terms of contact frequency and green space composition. Health benefits tend to peak with exposure 4-5 times a week, totalling around 120 minutes weekly, or within 12 minutes of a single visit.

Remaining Gaps and Missing Dimensions in the Corpus. The reviewed literature reveals several critical gaps. A primary challenge is the lack of standardization, both in defining "green space" and in establishing uniform metrics to assess its ecological and social impacts. This inconsistency limits comparability across studies and complicates the synthesis of findings. Additionally, research on threshold effects remains inconclusive, particularly regarding the optimal size, morphology, and distribution of UGS necessary to maximize health benefits.

Beyond spatial and ecological considerations, cultural and sensory variability in UGS perceptions are largely absent in the corpus. Few studies examine how different cultural backgrounds shape experiences of UGS, and limited research has been conducted on the influence of sensory elements—such as soundscapes, olfactory stimuli, and visual aesthetics—on user well-being. Motivational and behavioural factors affecting UGS use are also under-researched, particularly regarding why certain individuals or communities engage less with green spaces. This lack of focus contributes to an unequal research distribution, where subjective quality assessments of UGS in low-income neighbourhoods are notably scarce, and cross-cultural comparisons remain insufficient. Furthermore, exposure patterns have not been adequately examined, with limited insights into how individuals interact with UGS in their daily lives, whether through routine visits, commuting routes, or virtual nature experiences.

From a policy perspective, research on the longitudinal effects of UGS exposure on public health and urban resilience is notably absent in the reviewed studies. There is also a need for policy monitoring to better quantify the regulatory benefits of green space, such as its contributions to air quality, noise reduction, and biodiversity support. Financial considerations and socio-environmental trade-offs in UGS planning remain underexplored, particularly in balancing the benefits of green infrastructure with potential risks such as eco-anxiety and green gentrification. Additionally, it would be valuable to explore more extensively the co-benefits of UGS, particularly how environmental benefits—such as climate mitigation and biodiversity support—interact with health benefits like stress reduction and improved well-being. More broadly, existing frameworks often suffer from a lack of multidisciplinary integration, making collaboration across urban planning, environmental science, and public health disciplines challenging. Finally, the complex interactions between different green space benefits—such as their simultaneous roles in mitigation, restoration, and instoration—remain difficult to isolate due to a lack of longitudinal data and robust methodologies capable of capturing these interrelated social, ecological, and health processes.

Table 3. Thematic result of the review

Theme	Dimension	Details	Key Findings	Identified Gaps within the corpus	Studies	References
UGS Characteristics	Structural Characteristics	Structure (number of green spaces, percentage of vegetation cover and size, connectivity), biodiversity, naturalness	• Well-designed and biodiverse green spaces are linked to improved health outcomes, enhanced safety, better social relationships, and greater personal autonomy. • Higher naturalness in these spaces is associated with mental health benefits such as increased calmness, a positive mood, and enhanced psychological restoration.	• **Standardization Issues:** There is a lack of agreed-upon, quantitative definitions of "green space," which hampers comparability across studies. • **Measurement Consistency**: A need exists for uniform metrics that can reliably assess both the ecological functions and social impacts of green space features.	n= 4	32,37,68,88
	Morphology	• Degree of fragmentation • Average size and shape of green spaces • Level of connectedness and aggregation	• Increased connectivity and aggregation of green spaces are linked to lower rates of non-communicable diseases. • "Green belts" (interconnected green areas) tend to provide more health benefits than isolated parks. • Complex shapes may reduce disease risks more effectively than simply increasing size. • High fragmentation correlates with higher mortality from cardiovascular and respiratory diseases. • Beyond a certain size, parks yield diminishing additional health benefits. • The arrangement and composition of vegetation can influence stress reduction in a non-linear (reverse U-shaped) manner.	• **Threshold Effects:** More research is needed to determine the size and morphological thresholds for optimal health benefits across diverse urban settings. • **Planning Guidance:** There is insufficient guidance for urban planners on how to integrate these morphological features. • **Context Specificity:** Studies should address how different environmental and demographic contexts affect these relationships.	n= 4	68,87,89,90
	Feature	• The influence of colour (e.g., the prominence of green) • Levels of tranquillity (calmness, peacefulness) • Density and natural appearance of vegetation	• While the color green generally elicits positive psychological effects, cultural context can modulate these responses. • High tranquility in green spaces contributes to better mental restoration and relaxation. • Views that include distant landscapes help reduce stress, in line with Prospect-Refuge theory. • Diverse, natural-looking vegetation is linked with reduced stress and improved emotional well-being, supporting ideas from the Biophilia hypothesis.	• **Cultural Variability:** There is a lack of cross-cultural research on perceptions of color and tranquility in green spaces. • **Sensory Impact:** More work is needed to understand how different sensory elements (e.g., visual, auditory) affect various populations.	n= 5	31,37,80,83,84

	Perceived Quality	• Biophysical elements such as greenery and water features • Non-physical aspects including safety, cleanliness, and maintenance	• Perceptions of green space quality are influenced by both natural elements (e.g., lush vegetation, water bodies) and factors like safety and maintenance. • For instance, parents prioritize safe, well-lit play areas for children. • There is often a divergence between ecological quality (e.g., areas left unmown, which attract wildlife) and human-centered perceptions focused on aesthetics and security. • Overall, positive attributes of a park tend to outweigh the negative features.	• **Underrepresented Areas:** Subjective quality factors are less studied in low-income neighborhoods. • **Cross-Cultural Comparison:** There is insufficient research comparing how diverse urban populations perceive green space quality. • **Enhancement Strategies:** More evidence is needed on how to improve park attractiveness and usage through participatory planning.	n= 5	[31,85,91–93]
UGS Contact	Type of exposure	• Types of exposure: ○ **Active Exposure:** Involves direct participation (e.g., exercise, aesthetic appreciation) ○ **Passive Exposure:** Benefits derived without direct interaction (e.g., mitigating urban heat island effects) ○ **Consumptive Exposure:** Interaction through the use of products or services (e.g., tourism, clean water) • Frequency, availability, accessibility, and visibility of green spaces	• Most ecosystem services from green spaces are delivered through passive exposure, while active exposure drives cultural and social benefits. • Studies have shifted from qualitative to quantitative dose–response assessments, showing that health benefits may follow non-linear patterns. • Optimal mental health benefits are seen with moderate frequencies of engagement (e.g., 4–5 visits per week or around 120 minutes of exposure), with diminishing returns beyond these thresholds. • Brief exposures (as little as 4 minutes) can achieve efficiency thresholds, with benefit thresholds observed at around 12 minutes.	• **Exposure Variability:** There is limited research on individual exposure habits, including differences between park visits, commuting, or vacation exposures. • **Data Resolution:** Higher-resolution spatial data are needed to better capture the quality of green spaces beyond mere quantity. • **Standardization:** Development of a standardized codebook for green space assessments would enhance cross-study comparability. • **Virtual Exposure:** Further exploration is needed to determine if virtual reality-based nature exposure yields similar health benefits.	n= 11	[16,37,63,64,68,77,79,84,87,94,95]
	Experience	• Types of nature contact: ○ **Indirect:** e.g., watching nature documentaries ○ **Incidental:** e.g., unintentional experiences (hearing or smelling nature during commutes) ○ **Intentional:** e.g., gardening or recreational park visits	• Personal history, attitudes, and early experiences with nature shape individuals' awareness and receptivity toward natural environments. • Regular interactions with green spaces encourage healthier lifestyles, boost social interactions, and support sustainable development goals.	• **Motivational Factors:** There is limited research on why certain individuals or groups choose not to engage with green spaces. • **Barrier Analysis:** Further studies should examine cultural, social, and environmental barriers that hinder UGS usage. • **Engagement Strategies:** More work is needed to develop approaches that increase awareness and	n= 6	[32,65,73,84,85,91]

		• Temporal aspects (short-term to life-course exposure) • Interpersonal versus intrapersonal interactions • Factors influencing motivation and willingness to engage with urban green spaces	• Vegetation not only provides cooling and shade but also enhances the overall outdoor experience. • The quality and duration of nature contact (ranging from minutes to years) are critical for fostering resilience across biological, psychological, and social dimensions. • Regional preferences vary, with some cities favoring vibrant, water-inclusive landscapes and others valuing quiet, serene environments. • Disinterest in UGS is often linked to personal, cultural, or accessibility factors, contributing to a decline in direct nature contact (the “extinction of experience”).	motivation for engaging with green spaces, including investigations into nature connectedness.		
	Experience	Multiple Senses, and Subjective Psychology • Engagement of multiple senses (sight, sound, smell, touch) in the experience of green spaces • Consideration of how these sensory inputs contribute to overall psychological perception	• Holistic sensory engagement in green spaces enhances both psychological and physiological well-being. • While visual, auditory, and tactile stimuli generally have positive impacts, unpleasant odors can negatively influence perceptions. • Natural sounds (e.g., rustling leaves, bird songs) can significantly reduce stress and improve satisfaction, sometimes even more than visual stimuli. • Combining multiple sensory inputs creates a more immersive experience that amplifies stress reduction and mood enhancement.	• **Integrated Effects:** There is a need for more research on the combined impact of multisensory stimulation. • **Smellscapes:** Further studies should explore the role of olfactory experiences and the potential for artificial sensory enhancements (e.g., designed soundscapes or scent installations).	n= 6	15,16,73,84,86,96
UGS Benefits	Positive effect	**Environmental Regulatory Roles:** Urban heat island mitigation, noise reduction, air pollution control, water and food management, pollination, habitat maintenance	• **Urban Heat Island Mitigation:** Green spaces help lower heat-related mortality by improving urban thermal conditions. Their effectiveness varies with vegetation volume, spatial configuration, and type. • **Noise Reduction:** Green barriers and other natural elements can physically reduce traffic noise (by 5–10 dB) and help alleviate stress associated with noise exposure. • **Air Pollution:** Urban trees and vegetation remove significant quantities of air pollutants (e.g., PM2.5, PM10, NO_2, O_3), resulting in healthcare cost savings and reduced mortality.	• **Policy Monitoring:** More policy-oriented monitoring is needed to quantify the benefits of different green space types. • **Comparative Analysis:** Additional studies should determine which types and amounts of green space are most effective at mitigating noise, air pollution, water management issues, and supporting habitat connectivity. • **Detailed Mechanisms:** More research is necessary to clarify the relationships between specific green space configurations and their environmental regulatory functions.	n= 24	13–16,18,32,62,64,65,68–70,73,77,80,82,89,90,97–102

		• **Water Management:** Decentralized green infrastructure (e.g., "Sponge City" designs) effectively manages stormwater, reduces urban flooding, and improves water quality. • **Biodiversity and Habitat Maintenance:** Connected green spaces support ecological networks, enhance landscape connectivity, and help maintain habitats necessary for species movement.			
Positive effect	Public Health Impact • **Physical Health:** Effects on respiratory, reproductive, and physiological health; influence on physical activity levels • **Mental Health:** Impacts on cognitive functions and psychological well-being • **Social Health:** Influences on social perceptions, community cohesion, and social connectivity	• Physical Health: ○ Exposure to greenness is linked with higher birth weights and lower risk of low birth weight. ○ Attractive and well-maintained parks encourage physical activity, which improves sleep quality, reduces negative emotions, and enhances cardiovascular health. ○ Overall, green space exposure correlates with reduced risks of heart disease, COPD, diabetes, strokes, and supports improved physiological indicators (e.g., reduced heart rate, better blood pressure). • Mental Health: ○ Regular exposure to natural environments boosts cognitive performance, reduces stress (e.g., lower cortisol levels), and improves mood. ○ Activities such as nature walks can reduce rumination and increase productivity. • Social Health: ○ Accessible green spaces foster community identity, promote social interactions, reduce isolation, and enhance feelings of safety. ○ They contribute to both hedonic (happiness) and eudaimonic (life satisfaction) well-being.	• **Longitudinal Data:** Further research is required to fully elucidate the long-term public health benefits associated with various types of green space exposure. • **Immunology Health:** There is a need for more immunological health	n= 29	13–16,18,32,37,62,64,65,68,72–81,83,84,86,88,90,94,98,103
Positive effect	Cultural Impact • Contributions to city attractiveness and competitiveness	• Quality green spaces enhance a city's visual and functional appeal, contributing to lower crime rates and improved perceptions of safety.	• **Financial Dimensions:** More research is needed on the financial aspects of green space planning. • **Attractiveness Metrics:** There is limited investigation into which specific types of green space most effectively boost city attractiveness.	n= 3	70,82,104

		• Influence on crime rates, aesthetic appeal, walkability, and property values • Role in job creation and broader social and cultural benefits	• Attractive parks boost walkability and can drive up residential property values, thereby enhancing overall urban competitiveness. • Green spaces also support local economies by creating jobs and fostering vibrant community interactions.			
	Negative effect	• **Safety Issues:** Fear of crime, inadequate maintenance, poor lighting, and lack of surveillance • **Financial Aspects:** Potential for gentrification, rising property values, and displacement of low-income residents • **Health Challenges:** Risks such as allergic reactions, vector-borne diseases, sun overexposure, injuries, and dust-related respiratory issues • **Environmental Challenges:** Possibility of contributing to air pollution, facilitating invasive species spread, and generating ecosystem disservices (e.g., methane emissions)	• **Safety:** Poorly maintained, overgrown, or dark areas can heighten fear of crime—especially among women, teenagers, and ethnic minorities. Both physical and social factors (like loitering) can contribute to these perceptions. • **Financial:** While enhancing green spaces can uplift neighbourhoods, such improvements may inadvertently lead to gentrification and the displacement of vulnerable populations. • **Health & Environmental:** Although green spaces offer many benefits, they may also pose certain risks (e.g., allergies, vector-borne diseases) and contribute to environmental disservices.	• **Trade-off Analysis:** More research is needed to explore the long-term socio-environmental trade-offs of green space developments, balancing benefits with potential negative effects like eco-anxiety.	n= 9	14–16,30,37,78,79,82,97
Environmental justice	**Health inequality and equity**	• Examination of how socioeconomic status (SES), gender, and ethnicity affect green space benefits • Focus on equitable distribution of green spaces and its impact on health disparities	• Green space exposure tends to yield stronger health benefits for socioeconomically disadvantaged groups, women, and certain ethnic minorities—a concept known as the "equigenic effect." • Despite these potential benefits, these groups often live in areas with lower-quality or fewer green spaces, which can exacerbate health disparities. • Ensuring equitable access to green spaces is critical for reducing existing health inequalities.	• **Long-Term Effects:** There is limited data on the long-term impacts of green space inequity across different demographic groups. • **Measurement Standards:** A lack of standardized tools to assess green space equity and its health outcomes. • **Preventing Green Gentrification:** More research is needed on strategies to prevent green gentrification and ensure that improvements in green infrastructure benefit all community members.	n= 17	14,15,60,61,64,69,70,73,75–77,100,103,105–108
UGS Conceptual Dimension and Pathways	**Framework**	Planetary health framework, ecosystem service, biophilic city	• **Planetary Health Literacy**: This concept highlights the essential knowledge and competencies individuals and societies need to access, understand, appraise, and apply information regarding the interconnectedness between human and planetary health. It	• **Lack of Multidisciplinary Integration**: Existing frameworks often remain fragmented, making cross-disciplinary collaboration between urban planning, environmental science, and public health challenging.	n=35	5,7,13–16,31,37,57,60,61,70–72,77,79,81,82,84,88,89,92,96,97,100,1

		promotes informed decision-making for sustainable, health-promoting actions across societal levels. • **Ecosystem Services**: Ecosystem services encompass the direct and indirect benefits provided by natural ecosystems, categorized into provisioning (e.g., food, water), regulating (e.g., climate control, air purification), cultural (e.g., recreational and aesthetic value), and supporting services (e.g., nutrient cycling and soil formation). • **Biophilic Cities**: Biophilic cities integrate nature into urban design to foster human-nature connections. This approach relies on biophilic principles such as abundant green spaces, water features, biodiversity, nature-based solutions, and community engagement to enhance urban resilience and residents' well-being. • **Urban Ecosystem Services in Planning**: Research on urban ecosystem services (UES) supports the development of resilient, high-quality urban landscapes. Incorporating UES into urban planning enhances biodiversity, mitigates climate change impacts, and promotes sustainable urban growth through passive and active nature exposure.	• **Limited Context-Specific Applications:** Many frameworks are developed with a general perspective but struggle with local implementation. Urban ecosystems vary significantly based on geography, climate, and socioeconomic factors, making the transferability of frameworks challenging. • **Weak Social Environment Link**: Current models focus heavily on ecological and health benefits but lack insights into the social dynamics of urban environments (third place)		02,104,107,109–115
Pathway	Three Pathways Linking Green Space to Health (not mutually exclusive): • **Mitigation:** Reduces exposure to environmental stressors like air pollution, noise, and heat. • **Instoration:** Encourages physical activity, social cohesion, and develops biopsychosocial resources (e.g., healthy gut microbiome, motor skills, self-esteem, social contacts). • **Restoration:** Facilitates recovery from cognitive fatigue and stress through mechanisms like attention restoration and physiological stress recovery.	Challenge to study them all together Built Environment Solutions: • Active: Mechanical systems (ventilation, radiant heating/cooling) increase energy use. Transitional glass-enclosed space, reducing heating energy by ~50%. • Passive: Design adaptations (insulation, ventilation) enhance efficiency.	• **Complex Interaction Dynamics**: The pathways of mitigation, instoration, and restoration operate through overlapping mechanisms, making it difficult to isolate their individual and combined effects. For instance, green spaces mitigate heat (mitigation) while simultaneously restoring mental well-being (restoration). • **Data Limitations**: Longitudinal data on instoration mechanisms—such as the role of social cohesion and microbiome diversity in health outcomes—remain limited, hindering comprehensive analyses of long-term impacts.	n=8	15,16,32,62–66

2.3. Discussion

Disconnected Frameworks. This research has revealed significant disconnections within the field of UGS. These disconnections are not discipline-specific but arise from the diverse focal points of research, where each cluster approaches UGS from distinct perspectives. This fragmentation persists even when studies address overlapping topics, as similar research questions are often explored through differing conceptual frameworks. Notably, the conceptual integration of the Planetary Health framework appears particularly disconnected from other research areas. Semantic inconsistencies exacerbate this issue, as concepts and terms are frequently used interchangeably, impeding cohesive understanding. For instance, Bratman et al.'s extension of the ecosystem services framework to include mental health outcomes closely aligns with the Planetary Health emphasis on the interdependence of environmental integrity and human well-being[84]. However, the authors do not explicitly link their work to the Planetary Health conceptual framework. This lack of terminological consistency hinders the integration of related conceptual frameworks and complicates efforts to build cohesive connections across studies. Therefore, inconsistent terminology complicates efforts to link these conceptual frameworks, making it challenging to forge cohesive connections across studies.

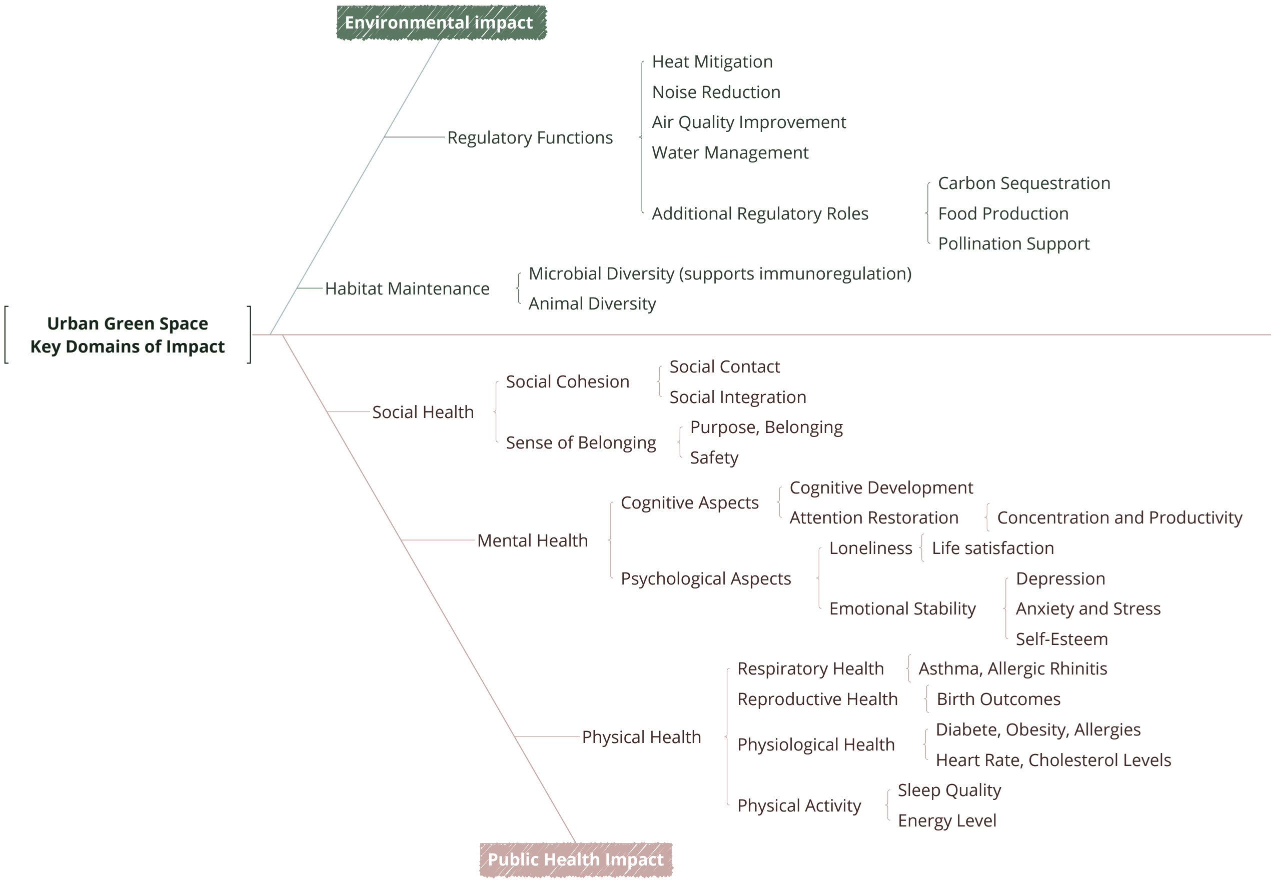
Toward a Shared Understanding. This issue extends to the definition of green space itself. While three papers in the corpus explicitly focus on defining green space, the majority do not provide clear or consistent definitions. This is corroborated by Matsler et al.[116] who conducted a three-part systematic review. They observed that the conceptualisation of the green space is different among urban planning, urban ecology and water management. 40% of their corpus did not define or gave an implicit definition. Such segmentation per topic rather than field is also one of the findings of the current research. Therefore, there is a necessity for further research to develop a comprehensive definitional framework. Such a framework could entail creating a 'definition notebook' that clarifies what constitutes UGS for various purposes. For instance, in the context of flood mitigation, green space could be defined by its capacity to absorb and retain water, whereas for mental health benefits, it might be characterized by its accessibility, biodiversity, and capacity to facilitate restorative experiences. Ismayilova et al. [117] have made initial progress in this direction by categorizing vegetation types based on land cover and defining the affordances of green spaces accordingly. For example, they suggest that parks are characterised by a "minimum patch size should be 0.5 ha, and a minimum of 45% of the area should be covered with high and/or low perennial vegetation, and/or low seasonal vegetation. Further characteristics are presence of footpaths and benches"[117p.52]. While this approach marks an important step towards standardization, it requires further refinement to align with the diverse impacts of UGS, particularly in relation to the seven identified benefit categories.

Pathways Between UGS and Health: A Missing Link. Similarly, mechanism of UGS (Mitigation, Instoration, Restoration) represent the core pathways through which urban green spaces influence human health, as highlighted across various theoretical frameworks. Yet, a significant gap persists, with only 8 out of 81 studies explicitly defining or operationalizing these pathways. This results in fragmented insights into the mechanisms underpinning the relationship between UGS and health outcomes. To advance the field, future research must establish clearer connections between empirical findings and theoretical models and systematic way of reporting.

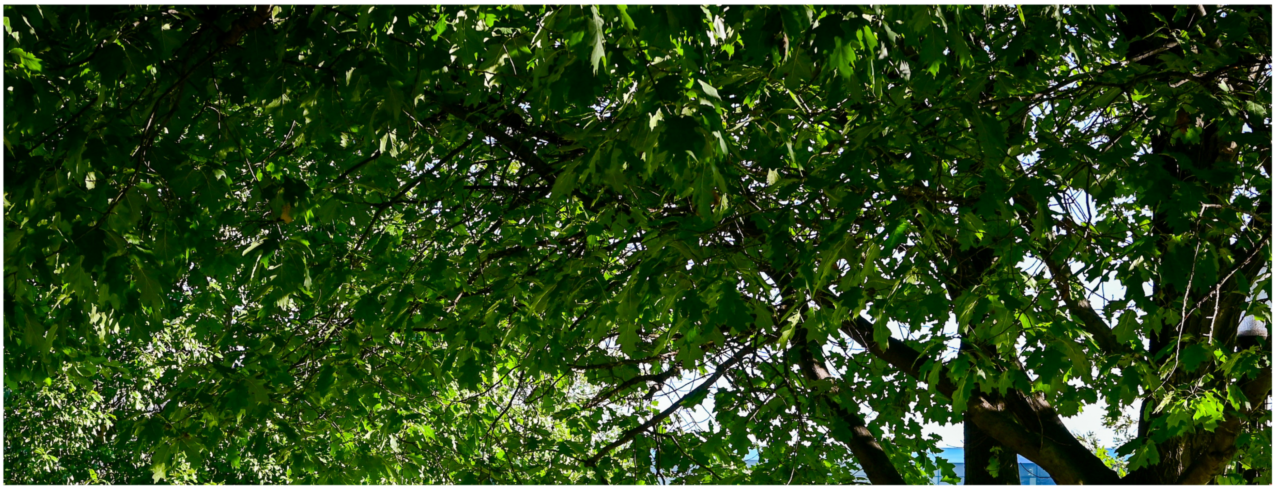
Affordances and the Human–Environment Dynamic. Furthermore, while many studies predominantly frame human health as an outcome of UGS exposure, this perspective risks oversimplifying the dynamic, bidirectional relationship between humans and their environments. Human activities significantly influence the availability, design, and usage patterns of green spaces, thereby shaping the settings and affordances that impact health outcomes. This reciprocal interaction is central to the concept of "Green Ergonomics," which refers to the "bi-directional interaction between natural and human structures to ensure the well-being and efficacy of human and social systems" [118p.1]. This approach emphasizes the importance of designing green infrastructure that optimally supports human health and social functionality [119]. Characteristics and type of green spaces are directly related to their affordances, defined as the features and attributes that influence how individuals perceive, use, and interact with these environments[120]. Affordances shape user experiences by determining what actions are possible within a space, such as walking, resting, or socializing. For example, accessible footpaths, seating areas, and diverse vegetation can encourage more active engagement and enhance perceived safety and comfort, while limited infrastructure may restrict usage and diminish perceived benefits. Commonly, the health benefits of urban green spaces have been closely linked to the duration and frequency of exposure[121]. However, the role of affordances in shaping these patterns of exposure is often underexplored. The type and characteristics of UGS directly affect how individuals perceive and utilize these environments, thereby influencing the duration of contact and the quality of the experience. Moreover, the concept of Salutogenic factors—those that promote health and well-being[122]—can be linked to the Biophilia Hypothesis, which suggests that humans have an innate affinity for nature[120]. Well-designed UGS that align with this natural inclination can enhance psychological restoration, reduce stress, and foster a deeper sense of connection to the environment. Therefore, understanding and designing for the affordances of green spaces is essential for maximizing their health benefits and seen UGS as a dynamic interaction between human and environment is crucial.

Remaining gaps. In conclusion to answer to the research question "*What are the key factors and conceptual dimensions identified in the literature that are essential for integrating environmental and health co-benefits into UGS planning?*", this review identifies five key interconnected dimensions through which UGS contribute to urban resilience and well-being: Regulatory Functions, Habitat Maintenance, Mental Health, Social Health, and Physical Health (Figure 5). However, important questions remain regarding the practical implementation and prioritization of these dimensions in urban planning and policy contexts. Specifically, it is unclear to what extent these health benefits are recognized, valued, and integrated into decision-making processes. To bridge this gap, stakeholder interviews are proposed as a critical next step. These will provide insights into how UGS are perceived to contribute to both environmental sustainability and public health, and, importantly, how such contributions are prioritized in policy practice. It will help clarify the criteria guiding policy decisions and reveal potential gaps between academic frameworks and real-world applications.

Figure 5. Five Interconnected Dimensions of UGS Contributions



PART 2



STAKEHOLDERS INTERVIEW

Q2: How do stakeholders identify, navigate, and prioritize trade-offs when designing and implementing UGS interventions?

3.1. Methodology

To deepen the understanding of UGS implementation and to ecologically validate the findings of the scoping review, semi-structured interviews were conducted with practitioners, researchers, and policymakers. These interviews provided qualitative insights into how stakeholders perceive and operationalize UGS within their respective contexts. Participants were selected from diverse governance levels (national, municipal, and neighbourhood) to ensure a comprehensive range of perspectives (table 4). Potential interviewees were identified through professional networks, primarily via official websites, and selected based on their expertise and relevance to the study. To protect confidentiality, participants are referred to by numeric identifiers (e.g., Interviewee[a], Interviewee[b]).

The interviews were intentionally not recorded to prioritize participant comfort and trust, particularly given the involvement of individuals from governmental institutions. This approach aimed to foster a more open and relaxed conversational environment, encouraging candid responses. The discussions were conducted in an informal, conversational style rather than adhering to a strict, formal interview structure, further promoting an atmosphere conducive to honest and reflective dialogue.

Table 4. Interview Participants

Level	Entity	Work Position	Interviewee
National level	Ministry of Infrastructure and Water management	Government Policy Officer	[a]
	PBL Netherlands Environmental Assessment Agency	Sustainability Researcher	[b]
Municipal level	Municipality of Enschede	Energy Policy Advisor	[c]
	Municipality of Enschede	Urban Landscape Architect	[d]
	Municipality of Hengelo	Urban Policy Advisor	[e]
Neighbourhood level	KennisPark	Urban Development Coordinator	[f]

3.2. Results

Priority Dimensions of UGS Implementation. The interviews revealed varying priorities regarding key dimensions in UGS implementation. Water management was primarily emphasized at the national level[a,b,c], while Heat management was a greater focus at the municipal level[d,e,f]. Resident health was not mentioned as a priority by any of the interviewees (Table 5).

Stakeholders Collaboration and communication between entities and departments was identified as a significant challenge. Participants noted that large projects typically involve multiple stakeholders and disciplines[d], each bringing distinct perspectives and visions, which complicates the process of reaching consensus. Additionally, limited land availability was highlighted as a constraint, with one interviewee emphasizing that effective collaboration is crucial to optimize the use of available space.

Monitoring efforts were consistently reported as insufficient, with time constraints and limited financial resources identified as key barriers to systematic and ongoing data collection[a,e,f]. The interviews also revealed significant variation in the tools and indicators used to assess progress and outcomes. Some participants mentioned using instruments such as Invest[b], the Buurtbarometer[e], the Brede Welvaart indicator (a well-being metric)[c], or the BREEAM certification[f]. Notably, two participants reported having no formal monitoring practices in place[e,f]. Meanwhile, more applied tools like StreetSmart and AutoDesk 3D[d] were used primarily for exploring and defining the spatial potential of NBS, rather than for monitoring their impacts.

Awareness was highlighted as a concern across all levels of governance. Various strategies have been employed to enhance public understanding of the benefits of urban green spaces, including promoting citizen participation in decision-making processes and implementing educational programs aimed at fostering environmental awareness[a]. Interviewees also reported that involving citizens can be challenging, depending on both the scale and the stage of the project[c,d]. Larger or more complex projects often pose greater difficulties for meaningful participation, while smaller-scale initiatives may allow for more direct engagement. Additionally, the timing of involvement matters. Citizen participation is generally more effective during early stages (e.g. co-creation or planning) whereas efforts limited to the final stages tend to focus on validation or awareness-raising, which offer less opportunity for genuine input. Despite these initiatives, challenges remain in effectively engaging diverse community groups and communicating the relevance of green spaces for public health and environmental resilience.

Table 5. Summary of Interviews insights

Factor	Interviewee [a]	Interviewee [b]	Interviewee [c]	Interviewee [d]	Interviewee [e]	Interviewee [f]
Research /Implementation Priorities	Water management (primary)- Heightened attention to heat at the municipal level	Ecological factors (e.g., data collection on environment and nature)	Water management (highest priority)- Heat mitigation (second priority)	Heat mitigation (trees provide more shade)- Water management- References WHO's 3-30-300 rule	Heat (cooling) (highest priority)- Water management, biodiversity (additional foci)	Heat mitigation, water management, and biodiversity
Stakeholders Collaboration	Department within the Ministry	N/A (focus on independent research; minimal stakeholder involvement)	Multiple municipal departments- Necessity of multi-stakeholder solutions due to limited land availability	Project-dependent: smaller projects handled in-house; larger ones involve traffic, water management, and landscape experts	Municipal colleagues in economics, traffic, health, water management, and transportation- Partnerships with green NGOs (IVN, KNNV, Groei en Bloei,Bijenvereniging, Natuur- en Milieuraad, Nivon)	Municipality of Enschede- University of Twente- Building owners
Tools Employed	N/A	InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs)	"Brede Welvaart" (happiness indicator)	StreetSmart- AutoDesk 3D	Buurtbarometer (neighbourhood-level scorecard for identifying green initiatives)	Not applicable (Insufficient time for data monitoring). BREEAM Certification
Approach to Citizen Involvement	Delegated to other departments (e.g., Behavioural Insight Team, Citizen Participation Department)	N/A (no direct citizen engagement)	Citizens are involved, but level and stage of participation depend on resource availability	Project-specific: ranges from co-design (active participation) to feedback(consultative)	Idea contribution: Residents can propose green projects/initiatives for their city or neighbourhood	N/A
Awareness Initiatives	Collaborates with teams running public campaigns and behavioural roadmaps for climate/event preparedness	N/A	A separate department focuses on motivating environmentally beneficial behaviour	Not extensively described	Social media: Showcases green projects and explains their rationale to increase public understanding and support	N/A
Additional Observations	Contextual differences: Municipal agendas are increasingly focused on heat, while national policy emphasizes water management	Produces reports for stakeholders and decision makers; serves as informational basis	Resource constraints (time, funding) limit fieldwork and monitoring, reducing long-term impact analysis	Implementation challenges: • Underground cables complicate infrastructure changes • Multiple stakeholder opinions • Parks vs. street greening trade-offs	Uses demonstration projects to highlight ecological and social benefits, thus fostering community support and broader acceptance	Monitoring gap: Shortage of time and resources hinders continuous data collection and long-term evaluation

3.3. Discussion

Stakeholder Engagement. The interviews highlighted the passion and commitment of all participants, who actively strive to contribute to better UGS design and the development of effective, context-sensitive solutions. Despite institutional or resource-related constraints, participants demonstrated a strong sense of responsibility and personal motivation to enhance the liveability and sustainability of urban environments. Their engagement reflects a shared recognition of the critical role that UGS play in addressing pressing urban challenges

Monitoring and data-driven decision making. A key barrier identified in the interviews to effective green planning is the absence of a shared monitoring framework. Currently, systematic monitoring remains limited, with inconsistent procedures creating significant challenges for clear and effective communication between departments and stakeholders. Without standardization, stakeholders struggle to establish common ground, leading to fragmented efforts and ineffective collaboration. Although the rise of smart cities promises enhanced data-driven governance, unresolved issues around data ownership, accessibility, and interoperability continue to limit their full potential[123]. Geographical Information Systems (GIS) present a promising solution by enabling the integration of spatial data (geographic contexts) with social and normative perspectives drawn from practical experiences[124]. Public Participatory GIS (PPGIS) further enhances this approach by incorporating subjective citizen perspectives, resulting in a more accurate reflection of local contexts and realities[125]. Nonetheless, the increased availability of open data and participatory initiatives demands improved data literacy and skills, which currently remain scarce among many stakeholders[126]. To address these issues, establishing a shared methodological framework for monitoring is critical. Such a framework would ensure comparability across datasets, streamline collaborative efforts, and foster inclusive, evidence-based planning. Departments would maintain the flexibility to conduct tailored monitoring as needed, but alignment around a common set of core indicators would enhance transparency, facilitate effective coordination, and promote consistency across governance levels.

Collaboration and co-creation. Closely linked to the challenges in monitoring is the issue of collaboration. The interviews reveal that while the ambition to work together exists, genuine collaboration remains difficult to achieve in practice. Sustainable solutions require more than communication alone; they demand transparency, mutual understanding, and meaningful co-creation across institutional boundaries[127]. While the concept of co-creation itself is not new, it takes on renewed importance when integrated into governance models that empower citizens as active participants[128]. This shift marks a departure from traditional centralized decision-making toward more inclusive, democratic, and responsive urban planning processes. The objective of collaborative dialogue is not merely to reach compromise, but to foster mutual learning by leveraging the complementary strengths, resources, and expertise of all stakeholders involved. Urban Living Labs (ULL) serve as practical environments to test and refine these collaborative approaches[129], allowing projects to be piloted at a neighbourhood scale before scaling them up to a city-wide implementation. Amsterdam stands out with several ULL initiatives that exemplify this model[130]. One notable example is the Living Lab Buiksloterham, a former industrial area that has been transformed into a circular, climate-adaptive neighborhood[131,132] This transformation includes experimental projects focused on decentralized energy systems, water reuse, and material circularity. Within this Living Lab, planners, researchers, residents, and entrepreneurs work together to co-create and evaluate sustainable urban solutions prior to broader application. By providing spaces for diverse stakeholders, from residents to policymakers, to engage in context-specific experimentation, these labs foster collaboration and support the development of more adaptive, inclusive, and resilient urban environments

Human-Environment Dynamics. Another critical finding relates to how priorities are set in UGS planning. Currently, flood mitigation and heat management emerge as the dominant priorities. These focus areas offer clear, measurable responses to urgent environmental risks and align with short political cycles and limited implementation timeframes. While this focus is understandable, it often comes at the expense of longer-term and less immediately visible benefits, particularly those related to public health and well-being. As also reflected in the scoping review, UGS are still primarily regarded as functional solutions for environmental management, rather than as multi-benefit systems that can simultaneously support human health. To achieve more sustainable and equitable outcomes, there is a need to adopt a more integrated perspective: one that recognizes the co-benefits of UGS for both environmental resilience and population health. However, shifting toward this holistic approach is challenging, given the persistence of siloed sectoral practices and the short-term logic of policymaking. Addressing these barriers requires a fundamental change in planning mindsets, encouraging stakeholders to reframe UGS not only as environmental infrastructure but also as vital public health assets.

In conclusion, to address the question, "*How do stakeholders identify, navigate, and prioritize trade-offs when designing and implementing UGS interventions?*" the interviews provided valuable insights into current practices, challenges, and potential pathways for enhancing UGS implementation through improved collaboration, standardized monitoring, and a more integrated approach to prioritizing environmental and health objectives.

PART 3

GENERAL DISCUSSION

RQ: What common conceptual ground can be identified across academic literature and stakeholders perspectives to support a shared understanding of environmental and health co-benefits of UGS?

4.1. Discussion

Establishing a Shared Understanding. The findings of this study highlight that UGS is a broad and multifaceted concept. Although the term is widely used, it is often treated as self-evident and therefore left undefined. This assumption overlooks the reality that researchers and stakeholders interpret UGS differently, depending on their disciplinary or professional backgrounds. Our scoping review highlights the urgent need for greater conceptual clarity and consistency in how UGS is defined and reported. To address this gap and support a more holistic understanding, we developed a protocol (Figure 6) that provides guidance on how to describe and communicate UGS. The protocol outlines its conceptual framing, the range of benefits it offers, and the mechanisms through which these benefits are realized. It is intended to serve as a shared reference point to foster clearer dialogue and cross-sector collaboration, particularly among professionals in urban planning, public health, and environmental management.

More specifically, we identified five key dimensions of UGS benefits: (1) regulatory functions and (2) habitat maintenance contributing to environmental outcomes, and (3) social, (4) mental, and (5) physical health supporting public health. However, insights from the interview phase revealed that, in practice, only one of these dimensions is consistently prioritized, namely benefices related to environmental regulation, such as heat mitigation and water management. This narrow focus suggests a missed opportunity. By adopting a shared language and framework for UGS, practitioners and decision-makers can more effectively recognize and explore the full spectrum of benefits, including those social and health-related dimensions that are currently underrepresented in practice.

Shifting Mindsets for Planetary Health. Fully unlocking the potential of UGS demands a fundamental shift in mindset: one that embraces a Planetary Health perspective. This shift is critical for moving beyond fragmented or narrowly functional views of nature, and toward a more integrated understanding of the interconnectedness between human health and the health of natural systems. However, as revealed in the interviews, this systems-level awareness remains relatively low among practitioners. Many acknowledged that adopting such a perspective is a gradual process that takes time. At present, their efforts tend to be reactive, moving from one pressing issue to another, most commonly heat stress and flooding, without addressing the broader feedback loops and root causes that Planetary Health seeks to illuminate. Adopting a Planetary Health mindset challenges conventional approaches to urban planning. It repositions UGS not merely as passive providers of ecosystem services, but as active, dynamic systems that both shape and are shaped by human decisions. This paradigm shift is already gaining traction in the Netherlands, particularly within the educational landscape. Leading institutions, including Utrecht University[133], Maastricht University[134], the University of Groningen[135], the University of Amsterdam [136], and the University of Twente[137] among other; have begun integrating Planetary Health into their research agendas and curricula. These programs treat green spaces as central infrastructures that deliver multiple co-benefits: enhancing environmental resilience, supporting mental and physical well-being, and advancing social equity. This educational evolution signals a growing recognition of the need to increase Planetary Health literacy among current and future decision-makers, practitioners, and citizens.

From Concept to Practice. Yet, embracing a Planetary Health perspective involves more than academic endorsement; it requires a systemic transformation in practice, particularly in how UGS are conceptualized, designed, and governed. Central to Planetary Health is the idea of systemic feedback loops, which emphasize how human activities impact ecological systems, and how these changes, in turn, influence human well-being [138]. Within this framework, UGS should be understood not as static patches of greenery, but as living, socio-ecological systems embedded in complex urban dynamics. Importantly, this transformation also calls for a shift toward citizen-centred approaches. Engaging local communities in the design, stewardship, and monitoring of green spaces is vital for ensuring that these areas are inclusive, context-sensitive, and resilient. By fostering co-creation and participatory governance, UGS can be shaped to reflect community values, strengthen social cohesion, and respond to evolving local needs. This participatory model also helps build trust and a sense of ownership, which are critical for the long-term success and adaptability of urban green initiatives.

Ultimately, operationalizing Planetary Health in urban environments requires the creation of governance structures that are collaborative, adaptive, and inclusive, capable of addressing current climate and health challenges while remaining flexible enough to respond to future uncertainties.

Planning for Resilience. Resilience, both as a guiding principle and as an operational goal, emerged as a recurrent theme across the theoretical literature reviewed in this study and also during the interviews. It captures the dynamic interactions between human systems and ecosystems, emphasizing the capacity to adapt to disturbances while maintaining core functions. Within the Planetary Health framework, this is closely linked to feedback loops, wherein human actions shape ecological systems, which in turn influence human well-being. Rather than aiming to eliminate hazards which is an increasingly unrealistic goal in the context of climate change and environmental degradation, urban resilience emphasizes adaptability and responsiveness[139]. UGS are instrumental in this regard. When strategically implemented, they can enhance ecosystem stability, support biodiversity, and offer adaptive capacity for communities. They also embody both resilience and transformability: the capacity to withstand stress and to reconfigure systems when current structures can no longer support ecological, social, or economic viability [140]. Crucially, resilience goes beyond surviving crises; it involves cultivating the conditions necessary for human well-being amid uncertainty. To support this, urban spaces must be designed to remain flexible, inclusive, and adaptive, enabling cities to effectively respond to the complex interplay of climate and health challenges.

4.2. Limitation

This study contributes a theoretical perspective to the evolving understanding of UGS by offering a solid foundation to build knowledge and facilitate more effective dialogue across disciplines and sectors. By synthesising conceptual dimensions, benefits, characteristics and mechanism of UGS and exploring how UGS is interpreted and applied in both literature and practice, the study provides a valuable basis for future research, policy development, and collaborative engagement.

Despite these contributions, several limitations should be acknowledged. First, the scope of the literature on UGS and well-being is vast and continuously expanding, making it impossible to review all available articles. While we conducted an in-depth analysis of 81 selected articles, a considerable number for a scoping review; it is possible that relevant studies were omitted, potentially limiting the breadth of perspectives included. Additionally, our use of the snowballing method for article selection may have introduced bias by reinforcing citations within similar academic circles or theoretical approaches. Nevertheless, this method allowed us to effectively trace conceptual linkages and observe patterns of knowledge clustering.

Another challenge concerned the identification and recruitment of appropriate participants for the interview phase. Locating experts with relevant knowledge and experience required significant outreach efforts. Although we succeeded in speaking with individuals whose expertise aligned with our research objectives, a potentially more impactful method could have involved organizing a focus group to stimulate broader discussion and interaction. However, this approach carries its own limitations, as participants may feel less comfortable sharing openly in the presence of other stakeholders.

Finally, the decision not to record interviews or produce verbatim transcriptions constitutes another methodological limitation. While this choice was made to promote a sense of trust and openness among participants, it may have impacted the richness and precision of the data collected. Relying solely on detailed notetaking risks the loss of subtle nuances, specific language, or non-verbal cues that could have further deepened our analysis.

4.3. Further research

There is a clear need for a more standardized and function-oriented definition of UGS. Rather than categorizing green spaces solely based on type of UGS (such as trees, grass, flowers, or shrubs), future research should focus on developing definitions grounded in the specific benefits or ecosystem services that UGS are intended to deliver. This would allow for more targeted planning and assessment, distinguishing, for instance, which types of green affordances (e.g. shaded tree canopies, open lawns, or biodiverse planting) are most effective in supporting mental health, social cohesion, climate regulation, or flood mitigation.

Moreover, the concept of co-benefits, where a single intervention addresses multiple challenges simultaneously, remains underexplored. Further research is needed to understand how UGS can be strategically planned to maximize synergies across sectors, particularly in addressing public health, climate adaptation, and environmental resilience. Investigating how green infrastructure can be designed to meet these overlapping objectives would significantly enhance its utility in urban policy and practice.

Finally, future studies should prioritize exploring societal values, perceptions, and attitudes toward UGS, as well as its economic valuation. Incorporating spatial tools such as GIS and 3D modelling presents a promising direction for capturing the multi-layered and context-specific type of UGS. These approaches can add crucial depth to the conceptualisation of UGS and support more inclusive, evidence-based decision-making.

PROTOCOL
URBAN GREEN SPACE

This protocol offers a structured approach to establish common ground for discussions and raise awareness about key considerations of urban green space.

CONCEPTUAL LEVEL 1

ECOSYSTEM SERVICE
Nature's contributions that support human survival and quality of life

PLANETARY HEATH
Human and environmental health interconnection

BIOPHILIA HYPOTHESIS
Humans' innate desire to connect with nature for psychological well-being

EXPECTED EFFECT 2

ENVIRONMENTAL IMPACT

- Air Quality Improvement
- Noise Reduction
- Heat Mitigation
- Water Management

co benefits

HEALTH IMPACT

- Mental Health
  Cognition, Loneliness, Emotional Stability...
- Physical Health
  Physical Activity, Diabetes, Obesity...
- Social Health:
  Social Cohesion, Sense of Belonging

MECHANISM USED 3

3 PATHWAYS AKNOWLEDGED:

MITIGATION	RESTORATION	INSTORATION
Reducing Harm Minimising exposure to environmental stressors like pollution, noise, and heat	**Restoring Capacities** Contributing to the restoration of mental and physical capacities	**Building Capacities** Encouraging behaviours and conditions that promote long-term well-being
Planting trees to create green corridors. (reduce air pollution, noise, and heat)	Facilitating attention restoration and aiding in psychophysiological stress recovery	Fostering physical activity or facilitating social cohesion within communities

4 DEFINING GREEN SPACE

SIZE
Total area of green space

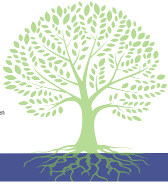
COMPOSITION
Type of vegetation, biodiversity, water feature.

CONFIGURATION
Spatial arrangement, connectivity, and morphology

ADDITIONAL FACTORS TO CONSIDER 5

ACCESSIBILITY
Ease of access and proximity for all users

EXPOSURE
Frequency and duration of interaction with green spaces



TYPE OF CONTACT
Direct (physical) or indirect (visual, auditory) experiences with nature

EXPERIENCE
Quality and perception of the interaction with green spaces

Conclusion

To address the central question "*What common conceptual ground can be identified across academic literature and stakeholder perspectives to support a shared understanding of environmental and health co-benefits of UGS?*", this research combined a comprehensive literature review with expert interviews from the UGS field. The findings reveal a pressing need for clearer, purpose-driven definitions of UGS, moving beyond physical typologies to consider the intended outcomes and functions, such as mental well-being, climate regulation, or biodiversity enhancement. At the same time, the interviews demonstrate a strong motivation among stakeholders to increase the use and integration of UGS in urban settings, recognizing its broad range of benefits. A recurring theme was the need for better monitoring and data collection to more accurately assess urban pressures and inform strategic, evidence-based planning. This practical insight aligns with broader academic trends, notably the emerging interest in the Planetary Health framework, which conceptually unites environmental sustainability and human health. The rise of educational programs and scholarly work on Planetary Health Literacy indicates a promising shift toward more holistic thinking among future planners and researchers. Together, these developments highlight the importance of fostering a shared conceptual foundation that enables interdisciplinary collaboration and meaningful stakeholder dialogue. Establishing common ground is essential for planning and implementing UGS in ways that enhance urban resilience while addressing both environmental and public health challenges equitably.

In conclusion, while urban planning remains an inherently complex task, this research contributes to simplifying and structuring that complexity by synthesizing diverse perspectives into a coherent framework. By promoting clearer conceptualization and encouraging shared understanding, the study lays the groundwork for more coordinated, inclusive, and forward-thinking approaches to UGS. Ultimately, advancing an integrated and actionable vision of UGS has the potential to simultaneously strengthen environmental resilience and improve human well-being, paving the way for healthier, more adaptive urban communities.

Declaration of generative AI and AI-assisted technologies in the writing process.

During the preparation of this work the author(s) used AI-based tools to improve readability and correct grammatical errors. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

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Annex 1 – Paper Corpus

Papers included in the scoping review

ID	Author	Year	Country (First Author)	Discipline	Study Design	Methodology	Aim of the Research
109	Albrecht et al.	2023	Germany	Environmental Science / Public Health	Quantitative- survey	Survey-based approach	Explore climate-specific health literacy among health professionals
80	Astell-Burt et al.	2022	Australia	Environmental Psychology	Systematic review	Literature review	Examine the relationship between green space and loneliness, offering theoretical/methodological guidance
141	Beery et al.	2023	Sweden	Environmental Psychology	Conceptual discussion	Literature-based approach	Expand understanding of human–nature disconnection
32	Beute et al.	2023	Netherlands	Environmental Psychology	Scoping review	Literature review	Investigate how different types/characteristics of green space impact mental health
142	Birks et al.	2022	France	Urban Planning	Quantitative- survey	Survey-based approach	Examine citizen participation in urban forests, focusing on a consultation process in the Rouen metropolitan area
110	Branny et al.	2022	Sweden	Digital Ecology	Literature review	Literature-based approach	Present a social-ecological-technological systems (SETS) approach for smarter greener cities
84	Bratman et al.	2019	United States	Environmental Science / Public Health	Conceptual discussion	Literature-based approach	Examine links between nature and mental health using an ecosystem service perspective
62	Browning, Li, et al.	2022	United States	Environmental Psychology	Quantitative- survey	Survey-based approach	Examine the link between childhood residential greenness and trait emotional intelligence in young adulthood (US sample)
63	Browning, Rigolon, et al.	2022	United States	Environmental Science / Public Health	Systematic review	Literature review	Examine how urbanicity moderates the association of greenspace with physical health
76	Campos-Uscanga et al.	2022	Mexico	Environmental Psychology	Quantitative- survey	Survey-based analysis	Examine running in natural spaces & its relationship with emotional intelligence, well-being, and physical activity
143	Cegielska et al.	2024	Poland	Environmental Science	Case study	Data-driven: GIS	Measure neighborhood sustainability by balancing anthropogenic pressure and ecological relevance

104	Cimburova et al.	2023	Norway	Environmental Science	Quantitative - modelling	Data-driven: GIS	Develop a GIS method for modeling visibility of urban trees for their valuation
69	Dong et al.	2024	Germany	Urban Planning	Case study	Data-driven: GIS	Propose an approach to plan green infrastructure prioritizing accessibility equity
144	Dorninger et al.	2023	Austria	Environmental Philosophy	Conceptual discussion	Literature-based approach	Understand destructive processes & explore regenerative potentials in social-ecological niche construction
91	Elbakidze et al.	2023	Sweden	Environmental Science	Quantitative- survey	Survey-based approach	Examine how people interact with urban greenspace in Eastern Europe
98	Elliott et al.	2023	United Kingdom	Environmental Psychology	Empirical study	Survey-based approach	Test serial mediation pathways linking nature contact with general health
111	Escobedo et al.	2019	United States	Environmental Science	Conceptual discussion	Literature-based approach	Examine relationships among urban forests, ecosystem services, GI, and nature-based solutions (NBS)
145	Gabrys	2020	United Kingdom	Digital Ecology / Governance	Conceptual discussion	Literature-based approach	Explore how “smart forests” and data practices may shape planetary governance
105	Gudi-Mindermann et al.	2023	Germany	Urban Planning / Public Health	Conceptual framework	Literature review	Integrate social environment + equity perspective into the exposome paradigm (Social Exposome)
60	Guzmán et al.	2021	United States	Planetary Health	Conceptual framework	Literature-based approach	Develop a guiding framework for planetary health education
78	Hashim et al.	2023	Malaysia	Environmental Science	Quantitative- survey	Survey-based approach	Identify benefits/challenges of valuing green space in a university environment
61	Howard et al.	2023	Canada	Environmental Science / Public Health	Conceptual discussion	Literature-based approach	Present social tipping interventions by the health community to address the climate emergency
85	Huai & Van de Voorde	2022	Belgium	Environmental Psychology	Quantitative - modelling	Data-driven: Natural Language Processing	Identify environmental features shaping positive/negative perceptions of urban parks using cross-cultural analysis
103	Hunter et al.	2019	United Kingdom	Environmental Science / Public Health	Meta-narrative review	Literature-based approach	Investigate environmental, health, social, and equity effects of urban green space interventions
89	J. Chen et al.	2023	Japan	Urban Planning	Quantitative - modelling	Statistical analysis	Examine how urban form + green space equity interacts in shrinking cities
77	J. Chen et al.	2024	Japan	Environmental Science / Public Health	Quantitative - modelling	Statistical analysis (modeling)	Estimate changes in inequality of green-exposure ecosystem services from a human health perspective

81	Jennings & Bamkole	2019	United States	Environmental Science / Public Health	Conceptual framework	Literature-based approach	Explore the relationship between social cohesion and urban green space for health promotion
7	Jochem et al.	2023	Germany	Planetary Health	Conceptual framework	Literature-based approach	Present a conceptual model of planetary health literacy
99	Kothencz et al.	2017	Hungary	Public Health	Quantitative- survey	Survey-based approach	Investigate perceived well-being from urban green space in a Hungarian city
94	Labib et al.	2020	United Kingdom	Environmental Science / Public Health	Systematic review	Literature-based approach	Investigate spatial dimensions linking urban green-blue spaces & human health
74	Lafrenz	2022	United States	Urban Planning / Public Health	Quantitative- survey	Survey-based approach	Propose an inclusive public health framework for designing multifunctional urban green spaces
100	Langemeyer & Connolly	2020	Spain	Governance	Conceptual discussion	Literature-based approach	Weave justice concepts into urban ecosystem services research and practice
146	Lee et al.	2023	Singapore	Environmental Psychology	Quantitative - modelling	Data-driven: GIS	Show how green space accessibility buffered declines in mental health during COVID-19
15	Markevych et al.	2017	Germany	Environmental Science / Public Health	Conceptual discussion	Literature-based approach	Provide theoretical and methodological guidance on pathways linking greenspace to health
125	Maurer et al.	2023	Denmark	Environmental Psychology	Case study	Data-driven: GIS	Examine just nature-based solutions using digital participatory mapping in a marginalized neighborhood
112	McLean et al.	2023	Australia	Planetary Health	Experimental study	Educational design	Show how medical students can become advocates on the UN SDGs for planetary and human health
70	Meerow & Newell	2017	United States	Urban Planning	Case study	Data-driven: GIS	Plan for multifunctional green infrastructure to build resilience in shrinking cities (Detroit)
16	Milliken et al.	2023	United Kingdom	Environmental Science / Public Health	Conceptual discussion	Literature-based approach	Explore the relationship between biophilic cities and health
71	Mobarak et al.	2022	Saudi Arabia	Urban Planning	Quantitative - modelling	Data-driven: GIS	Assess green infrastructures in Al Baha Region (Saudi Arabia) using GIS & MCDM
5	Myers	2017	United States	Planetary Health	Conceptual discussion	Literature-based approach	Emphasize planetary health challenges and the need to protect human health on a rapidly changing planet
14	Nielsen & Bronwen Player	2009	United Kingdom	Public Health	Literature review	Literature-based approach	Review impacts and effectiveness of urban green space interventions on health (WHO Europe)

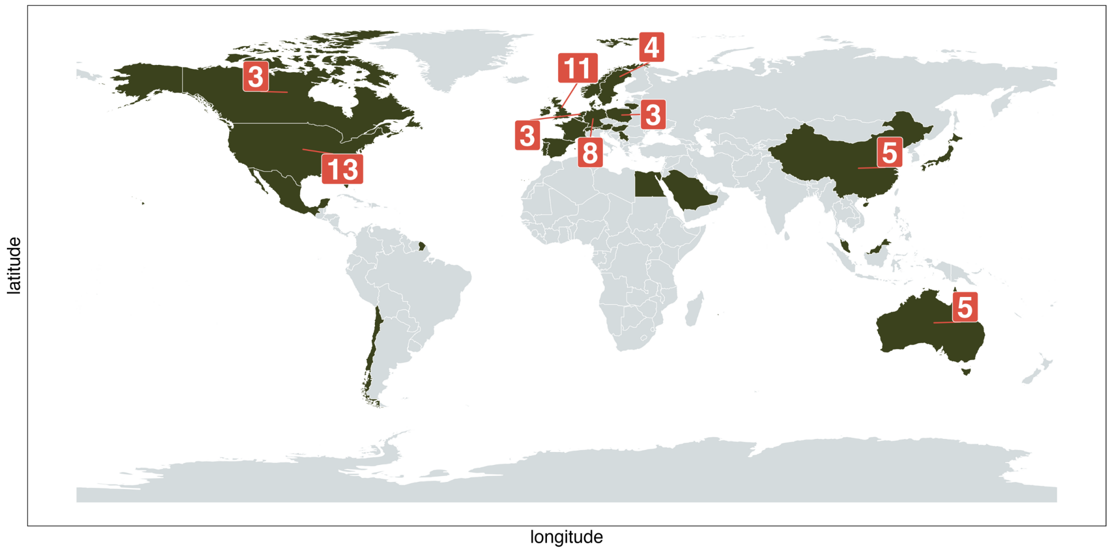
90	Nigg et al.	2022	Switzerland	Environmental Psychology	Quantitative- survey	Statistical analysis	Assess how geospatial + conceptual configuration of natural environment impacts children's health/behavior
96	Nitoslawski et al.	2019	Canada	Digital Ecology	Literature review	Literature-based approach	Review trends and technologies to create "smarter ecosystems" in cities via smart urban forestry
106	Nygaard	2024	Australia	Urban Planning / Public Health	Empirical study	Statistical analysis	Explore relationship between green infrastructure and socioeconomic dynamics in London's low-income neighborhoods
113	Oberndorfer et al.	2007	Canada	Urban Ecology	Conceptual discussion	Literature-based approach	Examine green roofs as urban ecosystems, focusing on structures, functions, and services
83	Olszewska-Guizzo et al.	2022	Singapore	Environmental Psychology	Experimental study	Quantitative - psychometric and neuroscience tools	Identify urban green space features linked to positive emotions, mindfulness, and relaxation
147	Pandics et al.	2023	Hungary	Environmental Science / Public Health	Conceptual discussion	Literature-based approach	Explore exposome & environmental drivers (pollution, occupational exposures) leading to unhealthy aging
114	Pauleit et al.	2022	Germany	Digital Ecology	Conceptual discussion	Literature-based approach	Discuss the concept of "smart urban forestry" and potential future directions
101	Pereira Barboza et al.	2021	Spain	Public Health	Case study	Data-driven: GIS	Assess the effect of green space on mortality in European cities
97	Pereira et al.	2023	Lithuania	Environmental Science / Public Health	Conceptual discussion	Literature-based approach	Discuss nature-based solutions, ecosystem services/disservices, and well-being in urban environments
107	Pineda-Pinto et al.	2022	Ireland	Urban Ecology / Planning	Quantitative - modelling	Multi-method	Present a framework to identify ecological injustice hotspots for targeted nature-based solutions
72	Pinto et al.	2022	Portugal	Environmental Science / Public Health	Systematic review	Literature review	Examine ecosystem services & well-being dimensions related to urban green spaces
57	Quitmann et al.	2023	Germany	Environmental Science / Public Health	Scoping review	Literature review	Develop a conceptual framework for climate-sensitive health counselling
92	Rall et al.	2019	Germany	Urban Planning	Case study	Data-driven: GIS	Show the added value of PPGIS for urban green infrastructure planning
82	Raymond et al.	2017	Sweden	Environmental Science	Conceptual framework	Literature review	Provide a framework for assessing co-benefits of nature-based solutions in urban areas

108	Redman	2023	United States	Governance	Conceptual discussion	Literature-based approach	Argue for rebalancing commercial/public interests by defining & managing conflicts of interest
37	Remme et al.	2021	Netherlands	Environmental Science / Public Health	Conceptual review	Literature-based approach	Discuss how urban nature, physical activity, and health intersect from an ecosystem services viewpoint
88	Reyes-Riveros et al.	2021	Chile	Environmental Science / Public Health	Systematic review	Literature review	Link public urban green spaces to human well-being
115	Russo & Cirella	2019	United Kingdom	Urban Planning	Conceptual discussion	Literature-based approach	Discuss the concept of “Edible Urbanism 5.0” as a future-oriented approach
148	Russo & Escobedo	2022	United Kingdom	Urban Planning	Conceptual discussion	Literature-based approach	Introduce new approaches in urban planning & design (Smart Urban Forests, Edible Cities)
13	Shao et al.	2023	China	Environmental Science	Systematic review	Literature review	Analyze the structure and evolution of urban ecosystem services research
149	Sheikh et al.	2023	Australia	Digital Ecology / Governance	Conceptual review	Literature-based approach	Propose a more-than-human approach to “smart urban governance”
64	Sillman et al.	2022	United States	Environmental Psychology	Systematic review	Literature review	Determine whether sex/gender modifies the association between green space and physical health
93	Simović et al.	2023	Serbia	Environmental Psychology	Case study	Survey-based analysis	Investigate mechanisms by which urban green areas influence residents’ health in Belgrade
30	Sreetheran & van den Bosch	2014	Denmark	Environmental Psychology	Systematic review	Literature review	Investigate socio-ecological aspects contributing to fear of crime in urban green spaces
102	Stępniewska	2021	Poland	Environmental Science	Empirical study	Survey-based approach	Compare capacity of urban parks for regulating/cultural ecosystem services vs. social perception
95	Tarek & Ouf	2021	Egypt	Digital Ecology / Governance	Conceptual review	Literature-based approach	Investigate how nature & technology can enhance resilience in biophilic smart cities
31	Taylor & Hochuli	2017	Australia	Environmental Science	Conceptual review	Literature review	Clarify multiple uses and disciplinary understandings of “greenspace”
150	Tironi & Rivera Lisboa	2023	Chile	Digital Ecology / Governance	Case study	Interview	Examine the role of AI in new forms of environmental governance in the Chilean State
151	Turnbull et al.	2023	United Kingdom	Digital Ecology / Governance	Conceptual discussion	Literature-based approach	Examine digital ecologies, materialities, and governance in environmental contexts

75	Twohig-Bennett & Jones	2018	United Kingdom	Public Health	Systematic review	Literature review	Evaluate evidence on the health benefits of greenspace exposure
79	Tzoulas et al.	2007	United Kingdom	Environmental Science / Public Health	Literature review	Literature review	Promote ecosystem and human health in urban areas using green infrastructure
86	van Rompay et al.	2023	Netherlands	Environmental Psychology	Experimental study	Environmental manipulations (VR)	Examine how spacious nature affects self-connectedness (“Lose yourself”)
68	Wang & Tassinary	2024	United States	Urban Planning / Public Health	Quantitative - modelling	Statistical analysis (spatial auto-regression)	Investigate how greenspace morphology relates to non-communicable disease prevalence, mediated by pollution & physical activity
65	White et al.	2023	Austria	Environmental Psychology	Conceptual framework	Literature-based approach	Propose an integrative theoretical framework (nature-based biopsychosocial resilience) connecting nature & health
152	Wielicka-Gańczarczyk & Jonek-Kowalska	2023	Poland	Digital Ecology / Governance	Quantitative- survey	Survey-based approach	Explore local authorities’ involvement in residents’ health protection under smart city concept
66	Xi et al.	2022	China	Urban planning / Engineering	Case study	Statistical analysis	Propose green-glass-space-based design to drive sustainable city development
153	Yang & Wang	2017	United States	Urban planning / Engineering	Case study	Statistical analysis	Plan for a sustainable desert city, focusing on potential water-buffering capacity of urban green infrastructure
18	Yang et al.	2021	China	Environmental Science / Public Health	Umbrella review	Literature review	Summarize evidence on greenspace and human health
87	Yao et al.	2024	China	Environmental Psychology	Experimental study	Environmental manipulations	Quantify threshold effects of greenspace exposure on physiological health
73	Zhang et al.	2023	China	Urban Planning	Quantitative - modelling	Data-driven: Deep Learning Method	Integrate online reviews of multisensory perception to plan sustainable urban green-blue spaces

Annex 2. Overview of the Corpus Characteristics

Figure 1. Geographic Distribu1on of First Authors in the Reviewed Studies



Caption: *Numbers represent the count of papers for countries with more than three papers. All coloured countries are included in the corpus.*

Figure 2. Annual Publicaton of Included Studies (2008–2023)

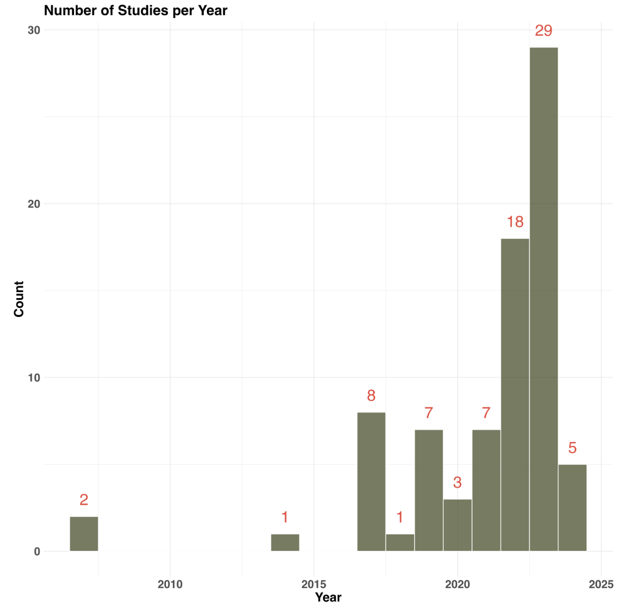


Figure 3. Distributon of Studies by Research Design

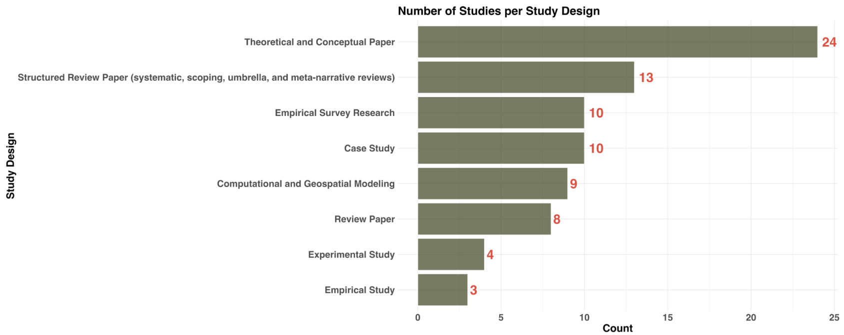
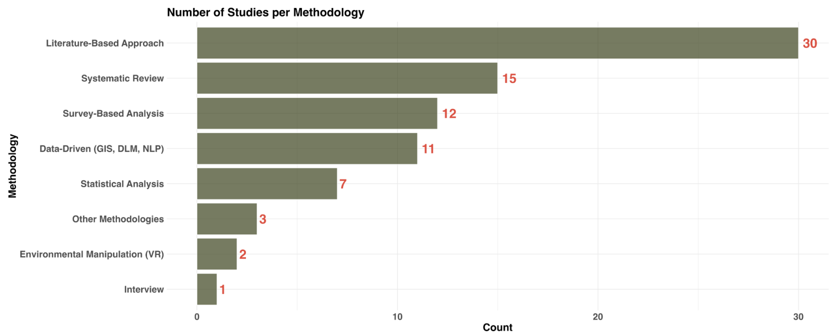


Figure 4. Distributon of Studies by Methodological Approach



Annex 3. Bibliometric clustering: Citation and Co-Link

id	document	citations	links
1	shao (2023)	2	3
2	guzman (2021)	91	3
3	raymond (2017)	584	6
4	maurer (2023)	4	5
5	maruthaveeran (2014)	246	6
6	remme (2021)	107	12
7	tironi (2023)	2	1
8	mobarak (2022)	8	2
9	wang (2024)	11	2
10	browning (2022a)	10	7
11	birks (2022)	3	1
12	quitmann (2023)	11	2
13	albrecht (2023)	0	2
14	taylor (2017)	419	7
15	lafrenz (2022)	6	3
16	beery (2023)	35	2
17	sillman (2022)	56	10
18	pinto (2022)	61	8
19	russo (2019)	31	1
20	hunter (2019)	245	7
21	chen (2024)	6	5
22	markevych (2017)	1395	16
23	pandics (2023)	17	0
24	olszewska-guizzo (2022)	14	1
25	russo (2022)	4	3
26	xi (2022)	18	0
27	nygaard (2024)	3	1
28	cegielska (2024)	1	1
29	oberndorfer (2007)	850	2
30	astell-burt (2022)	64	3
31	pereira barboza (2021)	124	1
32	yang (2021)	138	5
33	beute (2023)	18	5
34	gudi-mindermann (2023)	13	0
35	wielicka-ganczarczyk (2023)	2	0
36	howard (2023)	22	2

id	document	citations	links
37	reyes-riveros (2021)	206	6
38	van rompay (2023)	2	1
39	cimburova (2023)	2	2
40	mclean (2023)	2	2
41	bratman (2019)	878	16
42	elliott (2023)	11	6
43	white (2023)	15	4
44	pereira (2023)	19	4
45	jochem (2023)	11	3
46	myers (2017)	123	0
47	pineda-pinto (2022)	8	2
48	yang (2017)	49	2
49	tzoulas (2007)	1706	8
50	yao (2024)	14	1
51	redman (2023)	4	1
52	campos-uscanga (2022)	2	2
53	gabrys (2020)	64	4
54	nitoslawski (2019)	120	3
55	branny (2022)	30	5
56	dorninger (2024)	7	0
57	labib (2020)	258	8
58	meerow (2017)	537	3
59	zhang (2023)	6	3
60	rall (2019)	102	4
61	stepniewska (2021)	14	0
62	nigg (2022)	4	4
63	twohig-bennett (2018)	869	9
64	jennings (2019)	412	5
65	chen (2023)	27	3
66	simovic (2023)	2	4
67	elbakidze (2023)	6	4
68	escobedo (2019)	252	4
69	langemeyer (2020)	116	5
70	browning (2022b)	94	7
71	huai (2022)	62	4

Annex 5. Bibliometric clustering: Cluster Themes

Detailed table of themes' clusters

Cluster (color)	Theme	Name	Title	Topic
1 (Red)	Human-nature relationships and perceptions of GS	beery (2023)	Disconnection from nature: Expanding our understanding of human-nature relations	Connection with nature
		elbakidze (2023)	Understanding people's interactions with urban greenspace: Case studies in Eastern Europe	People's interactions with GS
		huai (2022)	Which environmental features contribute to positive and negative perceptions of urban parks? A cross-cultural comparison using online reviews and Natural Language Processing methods	Perception of green space
		labib (2020)	Spatial dimensions of the influence of urban green-blue spaces on human health: A systematic review	Perception and health impacts of green space
		maruthaveeran (2014)	A socio-ecological exploration of fear of crime in urban green spaces - A systematic review	Safety perceptions of green space
		mobarak (2022)	Assessing Green Infrastructures Using GIS and the Multi-Criteria Decision-Making Method: The Case of the Al Baha Region (Saudi Arabia)	Spatial planning and GIS for green infrastructure
		pereira (2023)	Nature-based solutions, ecosystem services, disservices, and impacts on well-being in urban environments	Co-benefit of GS
		pinto (2022)	Ecosystem services and well-being dimensions related to urban green spaces-A systematic review	Co-benefit of GS
		raymond (2017)	A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas	Education and awareness of co-benefits
		reyes-riveros (2021)	Linking public urban green spaces and human well-being: A systematic review	Perception and well-being impact of GS
		simovic (2023)	Underlying Mechanisms of Urban Green Areas' Influence on Residents' Health-A Case Study from Belgrade, Serbia	Co-benefit of green space - characteristic of GS
		zhang (2023)	Sustainable Urban Green Blue Space (UGBS) and Public Participation: Integrating Multisensory Landscape Perception from Online Reviews	Perception and engagement with GS

2 (Green)	Health impacts of green spaces and pathways	browning (2022a)	Association between residential greenness during childhood and trait emotional intelligence during young adulthood: A retrospective life course analysis in the United States	Impact of GS - emotional intelligence (pathway mentioned)
		campos-uscanga (2022)	Running in Natural Spaces: Gender Analysis of Its Relationship with Emotional Intelligence, Psychological Well-Being, and Physical Activity	Impact of GS - emotional intelligence
		elliott (2023)	Nature contact and general health: Testing multiple serial mediation pathways with data from adults in 18 countries	General health and mediation pathways
		markevych (2017)	Exploring pathways linking greenspace to health: Theoretical and methodological guidance	General health and mediation pathways
		pereira barboza (2021)	Green space and mortality in European cities: a health impact assessment study	Mortality and GS exposure
		sillman (2022)	Do sex and gender modify the association between green space and physical health? A systematic review	Physical health and pathway
		white (2023)	Nature-based biopsychosocial resilience: An integrative theoretical framework for research on nature and health	Impact of green space - resilience (pathway mentioned)
		yang (2021)	Greenspace and human health: An umbrella review	General health and pathway
3 (Blue)	Social impact of GS	astell-burt (2022)	Green space and loneliness: A systematic review with theoretical and methodological guidance for future research	Population health impact and pathway
		beute (2023)	How do different types and characteristics of green space impact mental health? A scoping review	Mental health impact and pathway
		chen (2023)	Toward green equity: An extensive study on urban form and green space equity for shrinking cities	Social inequality and green space access
		chen (2024)	Estimating changes in inequality of ecosystem services provided by green exposure: From a human health perspective	Ecosystem services and inequality
		hunter (2019)	Environmental, health, wellbeing, social and equity effects of urban green space interventions: A meta-narrative evidence synthesis	Social effects and equity in GS
		jennings (2019)	The Relationship between Social Cohesion and Urban Green Space: An Avenue for Health Promotion	Social cohesion and GS
		lafrenz (2022)	Designing Multifunctional Urban Green Spaces: An Inclusive Public Health Framework	Social cohesion and inclusive design
		twohig-bennett (2018)	The health benefits of the great outdoors: A systematic review and meta- analysis of greenspace exposure and health outcomes	Population health impact
4 (Yellow)		albrecht (2023)	Climate-specific health literacy in health professionals: an exploratory study	Climate-specific health literacy
		guzman (2021)	A framework to guide planetary health education	Planetary health education

	Planetary Health skills and literacy	howard (2023)	Learning to treat the climate emergency together: social tipping interventions by the health community	Climate emergency response skills
		jochem (2023)	Planetary health literacy: A conceptual model	Planetary health literacy
		mclean (2023)	Medical students as advocates for a healthy planet and healthy people: Designing an assessment that prepares learners to take action on the United Nations Sustainable Development Goals	Planetary health skills for advocacy
		quitmann (2023)	Climate-sensitive health counselling: a scoping review and conceptual framework	Climate-sensitive health communication
		redman (2023)	Rebalancing commercial and public interests in prioritizing biomedical, social and environmental aspects of health through defining and managing conflicts of interest	Stakeholder communication in planetary health
5 (Purple)	Characteristic and geospatial configuration	bratman (2019)	Nature and mental health: An ecosystem service perspective	Characteristic of GS (+mental health)
		cimburova (2023)	Making trees visible: A GIS method and tool for modelling visibility in the valuation of urban trees	GIS and visibility of GS
		nigg (2022)	The geospatial and conceptual configuration of the natural environment impacts the association with health outcomes and behavior in children and adolescents	Geospatial configuration and health
		remme (2021)	An ecosystem service perspective on urban nature, physical activity, and health	Spatial dimension and health benefits of GS
		van rompay (2023)	Lose yourself: Spacious nature and the connected self	Characteristic of GS (+mental health)
		wang (2024)	Association between greenspace morphology and prevalence of non-communicable diseases mediated by air pollution and physical activity	GS characteristic and health outcomes (morphology)
6 (Orange)	Smart cities, smart governance	branny (2022)	Smarter greener cities through a social-ecological-technological systems approach	Smart green city development
		gabrys (2020)	Smart forests and data practices: From the Internet of Trees to planetary governance	Smart governance and data practices
		nitoslawski (2019)	Smarter ecosystems for smarter cities? A review of trends, technologies, and turning points for smart urban forestry	Trends and technology in smart urban forestry
		nygaard (2024)	Green infrastructure and socioeconomic dynamics in London low-income neighbourhoods: A 120-year perspective	Green infrastructure governance and socioeconomic dynamics
		tironi (2023)	Artificial intelligence in the new forms of environmental governance in the Chilean State: Towards an eco-algorithmic governance	AI in environmental governance

7 (Light Blue)	Equity and fair GS planning	langemeyer (2020)	Weaving notions of justice into urban ecosystem services research and practice	Equity, fairness, and justice in GS
		maurer (2023)	A social-ecological-technological system approach to just nature-based solutions: A case of digital participatory mapping of meaningful places in a marginalized neighborhood in Copenhagen, Denmark	Inclusive GS planning (PPGIS)
		meerow (2017)	Spatial planning for multifunctional green infrastructure: Growing resilience in Detroit	Resilience-focused GS planning
		pineda-pinto (2022)	Planning Ecologically Just Cities: A Framework to Assess Ecological Injustice Hotspots for Targeted Urban Design and Planning of Nature-Based Solutions	Ecological justice and urban planning
		rall (2019)	The added value of public participation GIS (PPGIS) for urban green infrastructure planning	Social value and PPGIS planning
8 (Brown)	Urban forest and edible cities	birks (2022)	Citizen Participation in Urban Forests: Analysis of a Consultation Process in the Metropolitan Area of Rouen Normandy	Citizen participation in urban forests
		escobedo (2019)	Urban forests, ecosystem services, green infrastructure and nature-based solutions: Nexus or evolving metaphors	Urban forest and ecosystem services
		russo (2019)	Edible urbanism 5.0	Concepts of edible cities
		russo (2022)	From Smart Urban Forests to Edible Cities: New Approaches in Urban Planning and Design	Integrating urban forests with edible city planning
9 (Pink)	Green infrastructure	oberndorfer (2007)	Green roofs as urban ecosystems:: Ecological structures, functions, and services	Green roof infrastructure
		shao (2023)	A Bibliometric Analysis of Urban Ecosystem Services: Structure, Evolution, and Prospects	Structure and evolution of green infrastructure
		tzoulas (2007)	Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review	Ecosystem and human health benefits of green infrastructure
		yang (2017)	Planning for a sustainable desert city: The potential water buffering capacity of urban green infrastructure	Sustainable planning of green infrastructure in arid regions
10 (Light red)	Defining GS	cegielska (2024)	Green Neighbourhood Sustainability Index - A measure of the balance between anthropogenic pressure and ecological relevance	Defining GS - sustainability index
		olszewska-guizzo (2022)	Features of urban green spaces associated with positive emotions, mindfulness and relaxation	Feature of GS
		taylor (2017)	Defining greenspace: Multiple uses across multiple disciplines	Definition and multi-disciplinary uses of green space
11 (Light green)	Importance of green space	browning (2022b)	Where greenspace matters most: A systematic review of urbanicity, greenspace, and physical health	Physical health benefits and urbanicity

		yao (2024)	Quantifying threshold effects of physiological health benefits in greenspace exposure	Physiological health benefits and exposure levels
12 (Grey)	Long environmental exposure	dorninger (2024)	Social-ecological niche construction for sustainability: understanding destructive processes and exploring regenerative potentials	Sustainability and regenerative potentials
13 (Grey)	Long environmental exposure	pandics (2023)	Exposome and unhealthy aging: environmental drivers from air pollution to occupational exposures	Environmental exposures and aging
14 (Grey)	Exposome	gudi-mindermann (2023)	Integrating the social environment with an equity perspective into the exposome paradigm: A new conceptual framework of the Social Exposome	Social Exposome and equity in environmental exposures
15 (Grey)	Governance	wielicka-ganczarczyk (2023)	Involvement of Local Authorities in the Protection of Residents' Health in the Light of the Smart City Concept on the Example of Polish Cities	Smart city governance and health protection
16 (Grey)	Solution	xi (2022)	Green glass space based design for the driven of sustainable cities: A case study	Sustainable city design with green spaces
17 (Grey)	Regulating and cultural ecosystem services	stepniewska (2021)	The capacity of urban parks for providing regulating and cultural ecosystem services versus their social perception	Social perception and ecosystem services of urban parks
18 (Grey)	Planetary health overview	myers (2017)	Planetary health: protecting human health on a rapidly changing planet	Overview of planetary health and human health protection

Annex 5. Co-occurrence clustering

Detailed table of terms per clusters

Dark blue	Dark green	Light green	Yellow
Challenge	Assessment	Action	Community
Co-benefit	Justice	Connection	Disconnection
Conceptual framework	Intervention	Loneliness	Online review
Crime	Air pollution	NDVI (Normalized Difference Vegetation Index)	Climate specific health literacy
Ecosystem	Nature based solution	Issue	Individual
Fear	Association	Number	Climate-Sensitive Health Counseling
Framework	Opportunity	Nature	Case study
Greenspace exposure	Food security	Importance	Disease
Implementation	Solution	Planet	Need
Life	Concept	Green area	Resident health
Management	Park	Emotional intelligence	Frequency
Meta-analysis	Life	Lack	Prevalence
Metaphor	Understanding	Resilience	Involvement
Policymaker	Health outcome	Region	Health professional
Smart forest	Respondent	Man	Social exposome
Social cohesion urban green space	Natural environment	Urban planning	Integration
Technology	Environment	Natural space	Planetary health literacy
Term	City	Green glass space	Urban green space solution
Urban green infrastructure	Value	Distribution	Resident
Urban green space	Human	Child	Work
Urban green space intervention	Systematic review	Year	
Way	Urban forest	Series	
	Forest	Strong association	
		Climate change	
		Conceptual model	
		Environmental feature	
		Knowledge	
		Park perception	
		Participant	
		Perception	
		Planetary health	
		Public urban green space	
		Trait emotional intelligence	
		Urban park	
		Woman	