Urban Forestry & Urban Greening 97 (2024) 128372

Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

journal homepage: www.elsevier.com/locate/ufug

Review article

Global disparities in wellbeing from green infrastructure cooling services: A systematic review

Rui Han[a,*,1], Robert A. Marchant[a,2], Jessica P.R. Thorn[b,c,3]

[a] Department of Environment and Geography, University of York, YO10 5NG, UK
[b] School of Geography and Sustainable Development, University of St Andrews, KY16 9AL, UK
[c] Department of Environmental Sciences, University of Namibia, 13301, Namibia

ARTICLE INFO

Keywords:
Nature-based solutions
Environmental inequity
Sustainable Development Goals
Urbanisation
Hierarchical archetypal analysis

ABSTRACT

The escalation of urbanisation contributes significantly to climate change and exacerbates environmental, health and social disparities, especially affecting impoverished and vulnerable communities in the urban periphery. However, few studies contrast the global disparities in multiple wellbeing from inequitable green infrastructure (GI) and cooling perspectives. Through a combination of systematic literature review and hierarchical archetypal analysis, this study examines 95 out of 3864 initial articles focusing on the interplay between inequitable GI and disparate cooling services, and their emphasis on both subjective and objective wellbeing. Our findings highlight an increasing interest on this topic since 2009, with a notable surge post-2015 focused on the application of nature-based solutions for urban cooling and associated inequity. The literature review reveals 43 wellbeing thematic categories based on four dimensions, of which we identify characteristics: (1) the most affected vulnerable individuals often based on financial status, population density, and access to public facilities; (2) geographic areas where wellbeing effects are most pronounced, linked to building attributes and high-density impervious surfaces; (3) health implications highlighting physical ailments; and (4) perceptions of GI emphasising residents' GI demand. Afterwards, hierarchical analysis generated clustered archetypes that Archetype I and III mostly filled in North American, Archetypes II in Asia, and IV across Europe, Asia, and North America, to underscore substantial variances and similarities in wellbeing categories across continents. These archetypes characterise global pathways to enhancing cooling for wellbeing, including Archetype I of integrating GI in urban planning, Archetype II of retrofitting infrastructure to improve GI interaction, Archetype III of connecting disadvantaged groups with heat management, and Archetype IV of fostering public involvement in decision-making processes. The study's findings provide insights to narrow ecological injustices arising from GI and research direction for further in theoretical, technological, and practical investigations to optimize cooling and wellbeing.

1. Introduction

According to United Nations Human Settlements Programme UN-Habitat (2015), over one billion people globally, especially in the Majority world, are living in inadequate conditions such as informal settlements (Thorn et al., 2021a) and these create significant challenges for implementing the new urban agenda (United Nations UN, 2017) and achieving the Sustainable Development Goals (United Nations UN, 2015). Urban green infrastructure (GI) is increasingly recognized as a vital nature-based solution to enhance climate resilience and maximise human wellbeing in urban and peri-urban areas, particularly against the backdrop of escalating urbanisation and climate change (Giombini, Thorn, 2022; Zhao et al., 2016). The past decade has seen a shift in focus from merely integrating GI into urban landscapes to prioritising 'environmental equability', which emphasizes the equitable distribution of GI benefits across socio-demographic boundaries (Robert, 2000; Amaral et al., 2021; Pineda-Pinto et al., 2021). However, the understanding of how GI provide varied services, particularly in mitigating the Urban

* Correspondence to: Department of Environment and Geography, University of York, Wentworth way, Yok YO10 5NG, United Kingdom.
E-mail address: rh1935@york.ac.uk (R. Han).
[1] https://orcid.org/0000-0002-5503-2398
[2] https://orcid.org/0000-0001-5013-4056
[3] https://orcid.org/0000-0003-2108-2554

https://doi.org/10.1016/j.ufug.2024.128372
Received 22 January 2024; Received in revised form 12 April 2024; Accepted 18 May 2024
Available online 23 May 2024
1618-8667/

Heat Island effect (UHI) and its unequal outcomes on humanity wellbeing between continents, remains limited. This gap hinders our ability to envisage a more equitable future for urban welfare amidst global rising inequities.

GI's inequitable distribution is closely intertwined with human wellbeing, necessitating the protection of vulnerable populations' rights and the equitable sharing of nature's benefits (Mayne et al., 2016). Existing research on GI and human wellbeing primarily focuses on at least five dimensions. First, it characterises how access to natural urban spaces enhances residents' wellbeing in basic-needs (Fedele et al., 2021), security (Li et al., 2015), and healthy, for instance, reducing cardiorespiratory mortality (Moraisa et al., 2021), epidemics and chronic diseases in children (Dietz, 1998) and adults (Freedman et al., 2007), and through spiritual benefits, relaxation, education, recreation, and interaction (World Health Organization WHO, 2001; Klemm et al., 2015). Second, studies detail the significant disparities in wellbeing among social groups due to unequal greenspace access, particularly between ethnic minorities or marginalised communities and more affluent groups (Nesbitt et al., 2019). Third, research explores wellbeing through the lens of the (mis)match between residents' demand for natural resources and the supply of ecosystem services (Soto et al., 2018), especially in cities where dense transport networks fragment greenspaces (McConnachie, Shackleton, 2010). Fourth, studies investigate human preferences for ecosystem service values, monitoring perceptions of satisfaction and emotional states (Arnberger et al., 2017; Chen et al., 2020). Finally, research demonstrate how human welfare can be obtained based on GI services (Tuhkanen et al., 2022; Cinderby et al., 2021).

Despite these insights, gaps remain. Firstly, much research has evidenced the benefits of GI services for single or multiple aspects of wellbeing (Tzoulas et al., 2007; Reyes-Riveros et al., 2021). For the interlinkages between multiple wellbeing and GI's services, a global joint effect highlights them to evidence how people interact with nature; how nature system is valued by human; and how our dependence on cultural services supports human needs (Millennium Ecosystem Assessment MEA, 2005; Huynh et al., 2022). However, these studies on the multiple components of wellbeing with GI's services insufficiently consider the temperature cooling service. Existing research on the GI's cooling service to human wellbeing often relies on single wellbeing component, such as, the cooling benefits of green roofs to the marginalised communities (Venter et al., 2021), the shading role of natural urban elements for the elderly (Arnberger et al., 2017), and greenspace heat reduction in relation to temperature-related health impacts (Vargo et al., 2016). These studies on single issue of 'who' has access to nature (Kolosna, Spurlock, 2019) or 'which benefits' are being enhanced (Cinderby et al., 2021) at local and city scales (Nelson et al., 2021), rarely scale up the insights to encompass multiple angles through both subjective and objective lenses, systematically examining how, which, where, and for whom wellbeing has been impacted.

Secondly, how GI impact cooling service on wellbeing is place-based. This place-based pattern occurs because of the varying effectiveness in (1) the UHI intensity and (2) GI's cooling capacity. The UHI increases global average temperature by 6.4 ± 2.3 °C (mean $\pm$ SD), of which the degree of heating varies between latitudes and cities (Phelan et al., 2015). For instance, Phelan et al. (2015) estimated short-term temperature deviations in the excess of 7∘C for dense urban areas (i.e. Tokyo, Shanghai) and less than 4 ∘C for sparse cities (i.e. Sydney, Athens). Bastin et al. (2019) projected a shift in average temperature of the major cities for the future that cities in the tropical regions will experience smaller changes relative to the regions in higher latitudes. The estimate of the extent to which the GI cools urban environment varies considering the global social-biophysical disparity. For example, Chen et al. (2022) documented a contrasting difference of vegetation exposure level that the Majority world cities experience one third of level in Global North cities. United Nations Environment Programme UNEP (2021) showed a global gap in the cooling adaptation needs and actions, especially true in low-income countries where the expected costs are five to ten times as high as the current flows of public fundings. In this case, someone developed scenarios about the global graduate in temperature rising along the urbanization intensity, others simulated the temperature cooling extent based on nature-based solutions (Girardin et al., 2021). However, few studies narrate the outcomes of GI inequitable cooling effects on residents' wellbeing at global scale, particularly lacking the contrast of their disparities between latitudes or continent.

In response to this knowledge gap, the study draws on a systematic literature review of the inequitable GI cooling services to capture their multiple focuses on the wellbeing, aiming to generate a global disparity in wellbeing categories based on archetypes analysis to understand their differences and similarities across continents. We focus our analysis around three key questions: (1) How do global publications on the inequitable GI with UHI cooling effects vary over time and space? (2) What thematic categories of wellbeing can be detected from these publications? (3) How do these wellbeing thematic categories interlink across continents?

1.1. Human wellbeing dimensions from a GI cooling service perspective

A narrow body of literature has explored GI cooling service impact on human wellbeing grounded in the capability approach (Sen, 1999), which is evidenced as one of the most effective ways conceptualising the wellbeing impacts of nature both on theoretical and practical grounds (Fig. 1) (Sangha et al., 2018; Chaigneau et al., 2019). First, goods and services are of interest to wellbeing as their characteristic enable people to obtain certain functions (Robeyns, 2005), of which GI for UHI mitigation effect is our focus, entered as the capability inputs. The aesthetic value, opportunities for recreation, relief from stress and anxiety, offered by GI relaxing residents, especially for urban dwellers, are entered as the capability inputs as well. Second, the above goods and services can be conceptualised as influencing people's capabilities. Capability does not deduce a certain level of wellbeing from the availability of goods and services, rather, it refers to opportunities entailing their capabilities to derive those benefits (Sangha et al., 2018). Third, the specific conditions in which the person makes goods and services become "converted" wellbeing have to be considered, such as a set of 'conversion factors' in terms of personal, social, and environmental contexts (Polishchuk & Rauschmayer, 2012). For example, the shade and health of GI offering for residents become 'converted' wellbeing via factors such as individual background, religious beliefs, activity preference, and social contact. This means the real human wellbeing effects from GI are diverse and cannot be concluded on a general level as people 'converted' services from GI biases on individuals, such as people with/without a migration background, and different sets of social and environmental conversion factors (Hicks & Cinner, 2014).

Based on Fig. 1, our analytical approach is summarised as: several personal, social, and environmental 'conversion factors' are instrumental for converting services into wellbeing. These contextual factors (only the parts of 'who' and 'where' factors explored in this study) shape people's ability to gain access to goods and ecosystems, of which GI and cooling-associated services are our focus. Contextual factors also shape people's values, which in turn are reflected in the: (a) perceptions about services, (b) the mechanisms through monetary, attendance, or experience that people mobilize in order to convert services into capabilities, and (c) the choices they make about which capabilities to pursue in order to satisfy their needs. Besides, the achieved functioning matters that determine individual circumstance in the circle. These taxonomies underscore our four 'cooling-wellbeing' constituents in terms of how, which, where, and for whom wellbeing is affected to structure synthesis of the literature documenting the tangible and intangible connections spanning subjective and objective wellbeing lens (Alatartseva & Barysheva, 2015; D'Acci, 2011) (Fig. 1 and Table 1). We do not intend these as a theoretical framework for 'wellbeing-cooling' theory, the creation of which is beyond our scope, but rather a framework with which to

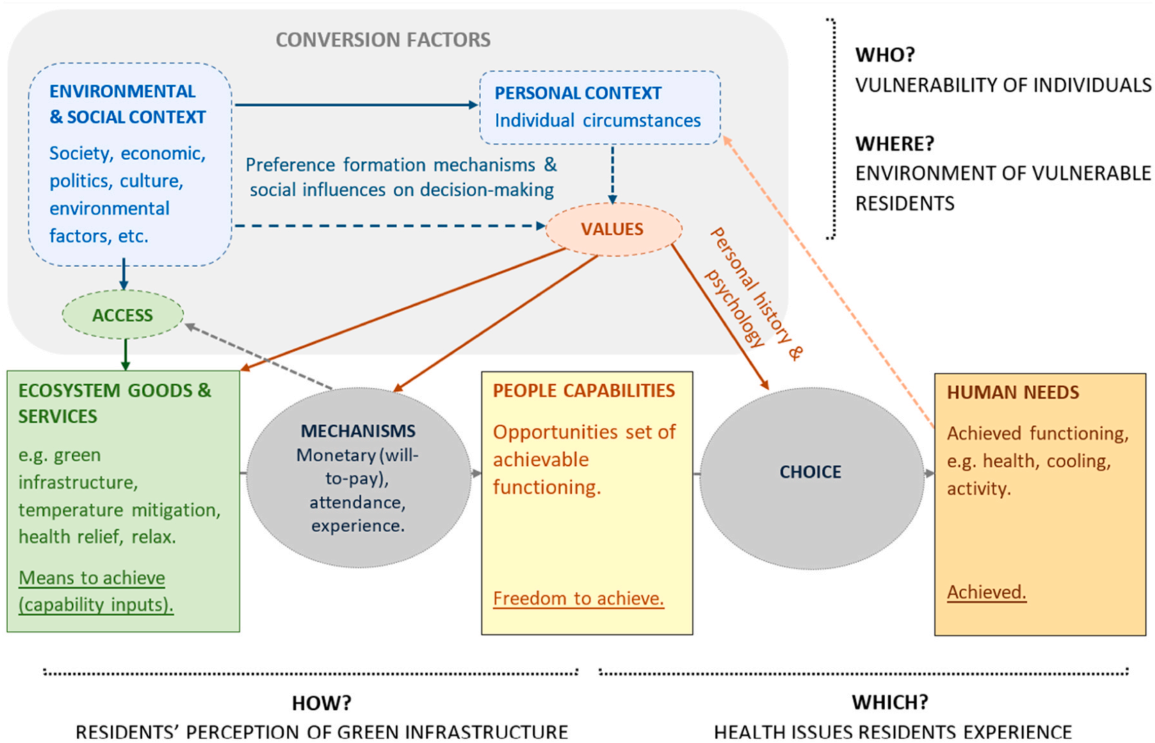

Fig. 1. Conceptual connection between GI's cooling services and human wellbeing through capability approach analytic lens (Polishchuk and Rauschmayer, 2012; Chaigneau et al., 2019).

organize the literature.

2. Methodology

2.1. Systematic review screen

The systematic review followed the approach established by the Centre for Collaboration of Environmental Evidence (Pullin et al., 2013), using the following six key steps (Fig. 2):

- Step 1: Establish search parameters and define scope and keywords.
- Step 2: Initial information mining through online sources.
- Step 3: Removing duplicate articles.
- Step 4: Screening titles, abstracts and full texts as to whether articles meet the inclusion criteria.
- Step 5: Randolph free kappa analysing for reviewers' agreement.
- Step 6: Creating the article database after critical appraisal for quality based on five criteria.

2.1.1. Scope and keywords

To determine the most comprehensive search criteria, we tested 37 strings of alternative search terms in Web of Science Core Collection TM (Table 1 in Appendix A). We then built a test library of 30 references to confirm that the search strings captured the most relevant literature (Table 2 in Appendix A), balancing specificity and sensitivity. After testing, the final search string using Boolean logic and wildcards was chosen, as follows: ((((TS=("ecosystem services" OR " ecosystem services value" OR "wetland*" OR "green infrastructure*" OR " green-spaces" OR "green gallery" OR "green patch" OR "permeable surface*" OR "ecological infrastructure" OR "natural infrastructure" OR "parks" OR "nature-based solution*" OR "vegetation" OR "trees" OR "green roof*" OR "ecological habitat" OR "open space" OR "green wall"* OR "ecological corridor" OR "grass" OR "gardens" OR "habitat enhancement" OR "shrub" OR "greenbelt" OR "verge*")) AND TS=("peri-urban" OR "peri urban" "suburb" OR "urbaniz*" OR "urban*" OR "informal settlement" OR "slum" OR "building area" OR "city" OR "town" OR "formal settlement" OR "household poor group" OR "built environment" OR "household*")) AND TS=("environmental inequality" OR "equity" OR "access" OR "environmental justice" OR "social equity" OR "equality" OR "environmental injustice" OR "race" OR "racial" OR "class" OR "ethno-racial" OR "community disparity" OR "uneven" OR "unjust" OR "just*" OR "inequality" OR "social distribution" OR "climate justice" OR "fairness" OR "justice" OR "procedure" OR "social vulnerability" OR "spatial equity" OR "right*" OR "benefit" OR "status")) AND TS=("urban heat island*" OR "temperature*" OR "heat stress" OR "thermal stress" OR "thermal warm*" OR "earth surface" OR "land surface" OR "heat wave" OR "hot*")).

2.1.2. Bibliographic sources

We accessed three bibliographic databases, Google Scholar (with the first 200 results), and fourteen grey literature databases (Table 2). These search sources were selected because they provide extensive coverage of the relevant journals and allow complex keyword strings for the literature search. Grey literature databases containing non-governmental organisations, public and research institutions and databases helped expand studies to individual research papers, reports, and conference proceedings. As a result, an initial pool of 3864 studies were found with no restriction on publication year (Fig. 2). Searches were conducted between 30th November 2021 and 18th January 2022.

2.1.3. Removing duplicates and screening for inclusion criteria

After removing duplicates, we screened for eligibility at title, abstract, and the full text stages. We referenced the method in Thorn et al. (2020) to apply our judgement as to whether articles met the inclusion criteria. The geographic scope of the analysis was global without time limitation. Studies were included in the review if they do following: empirical cases research lensing on natural elements (i.e., parks, gardens, forests) and GI temperature regulation services in social, social-ecological, or non-natural systems (e.g., urban-rural, (in)formal

Table 1
Four dimensions of inequitable GI and cooling effect on residents' wellbeing (cooling-wellbeing framework) applied in this study.

Wellbeing dimensions	Cooling-wellbeing dimensions	Examples of wellbeing-cooling categories	Description	Examples of references
Objective (material resources and social-demographic attributes)	Who? Vulnerability of individuals	Income, race, age, gender, education, education, occupation, migration, public facilities, settlements, property, commute, vulnerable index	GI is suited near (dis)advantaged individuals in terms of demographic and socio-economic characteristics.	Li et al., 2015; Sanchez & Reames, 2019; Wang et al., 2019
	Where? Environment of vulnerable residents	Building attributions (i.e. high-dense, low-open), impervious surface rate	Distribution of GI varies across community settings in terms of building height and density, resulting in different impacts on residents who live in different communities/streets/blocks.	Perini & Magliocco, 2014
		Topography (i.e. elevation), morphology (i.e. community size, sky view factor), climate types (i.e. tropical)	Greenspaces cooling capacity and impact on residents are relatively discrepant between settlements with different landscape, morphology, topography, and climate zones.	Vailshery et al., 2013, Lin et al., 2012
		Greenery policy, urban extend direction	Urbanization influences greenspace evolution direction, planning policy, and green space access resulting in different wellbeing outcomes.	Nguyen, et al., 2020; Koprowska et al., 2020
		Traffic flows	Daily thermal exposure and greenspace access is unusual for communities with more traffic flows or transport options of individuals' movements from their homes to parks.	Wang & Qiu, 2018
		Nature dependency level	The wellbeing for community where people depend the most on natural resources for their basic needs is pronounced once nearby nature sources being changed.	Fedele et al., 2021
Subjective (internal experience and perception by self-judgement)	How? Residents' perception of GI	GI perception, preference, and demand	Individual circumcentre drives personal perception, preferences, and demand profiles on GI , resulting in wellbeing differences.	Arnberger et al., 2017; Venter et al., 2021
		Perception of greenspaces on business change	Greenspace establishment and mainstream influence communities economic/business.	Cinderby & Bagwell, 2018
		Will to attend	Residents' GI visiting level affects psychological and physical health.	Saw et al., 2015
		Willingness to pay	Willingness to pay for using a park influences greenspace attendance and experience, resulting in wellbeing differences.	Chen et al., 2020
	Which? Health issues residents experience	Anxiety, stress, emotion, suicide, criminal	Impact of unequable GI on residents' psychological health.	Potgieter et al., 2019
		Satisfaction, happiness, pleasure	Status of satisfaction, happiness, pleasure for adults or children could be influenced when interacting with natures.	Saw et al., 2015
		Brain activity	Effect of interacting with greenspace on people' brain functioning.	Neale et al., 2020
		Physical diseases, risks, and mortality	Risks of obesity, chronic, epidemic, and heat-related diseases and mortality are influenced by natures.	Freitas et al., 2021

region) including diverse climates (e.g., semi-arid, desert, arid, tropical); and present their interlinks with stakeholders in terms of social-demographic characteristics, physical and psychological experience, thoughts, and judgement (Table 3 in Appendix A). Articles were excluded if they were not written in English due to the linguistic capability of the review team, or the full texts were not open access. We did not include studies that target conceptual theory or methodological improvements. For example, 304 articles were excluded at the full-text screening stage with 96 articles not written in English and 208 studies that did not meet the inclusion criteria (Fig. 2, Table 4 in Appendix A).

2.1.4. *Validation*

We ran a Randolph free kappa analysis to assess agreement in screening between three reviewers who are experienced in geography and ecology research. A total of 25% of all articles at title, abstract, and full contents level were screened. The kappa result indicated 0.91 level of agreement, which falls above the normal agreement range of 0.6–0.7 (Randolph, 2008). This result indicates that there was sufficient agreement across reviewers.

2.1.5. *Quality assessment*

Following screening, the full texts for remaining papers were retrieved and assessed as to whether they were of quality for inclusion, based on a critical appraisal where five quantitative quality criteria: (1) data collection methods are thoroughly explained, clear, replicable; (2) sample size is well explained and representative of population; (3) qualitative or quantitative analytical methods are thoroughly explained, clear, replicable; key terms are well defined; (4) results and conclusion is logically derived and supported by presented evidence; (5) limitations and implications of study are well considered and explained in discussions (Thorn et al., 2020, Gutiérrez Rodríguez et al., 2016). A quality assessment score of 0–5 – based on the sum of scores for each quality criterion (yes=1, no=0). Only studies with total scores of 3–5 were considered eligible for further data extraction. Finally, a total of 95 studies were included in this review (Table 1 in Appendix B) for further analysis (Fig. 3)

2.2. *Identifying wellbeing thematic categories*

Scanning the remaining 95 articles, we used inductive, iterative coding to record the diverse wellbeing variables. The procedure of scanning and capturing was repeated three times by reviewers to guarantee verifiability and consistency. A total of 315 individual wellbeing variables were detected (Table 2 in Appendix B). These variables dominate 43 wellbeing thematic categories (Table 3 in Appendix B), emphasising subjective and objective practices with four 'wellbeing-cooling' dimensions in terms of how, where, which and for whom wellbeing has been influenced (Fig. 1 & Table 1). Subsequently, the frequency of wellbeing thematic coverages and their temporal and spatial trends were mapped by the function of heatmap in R Studio

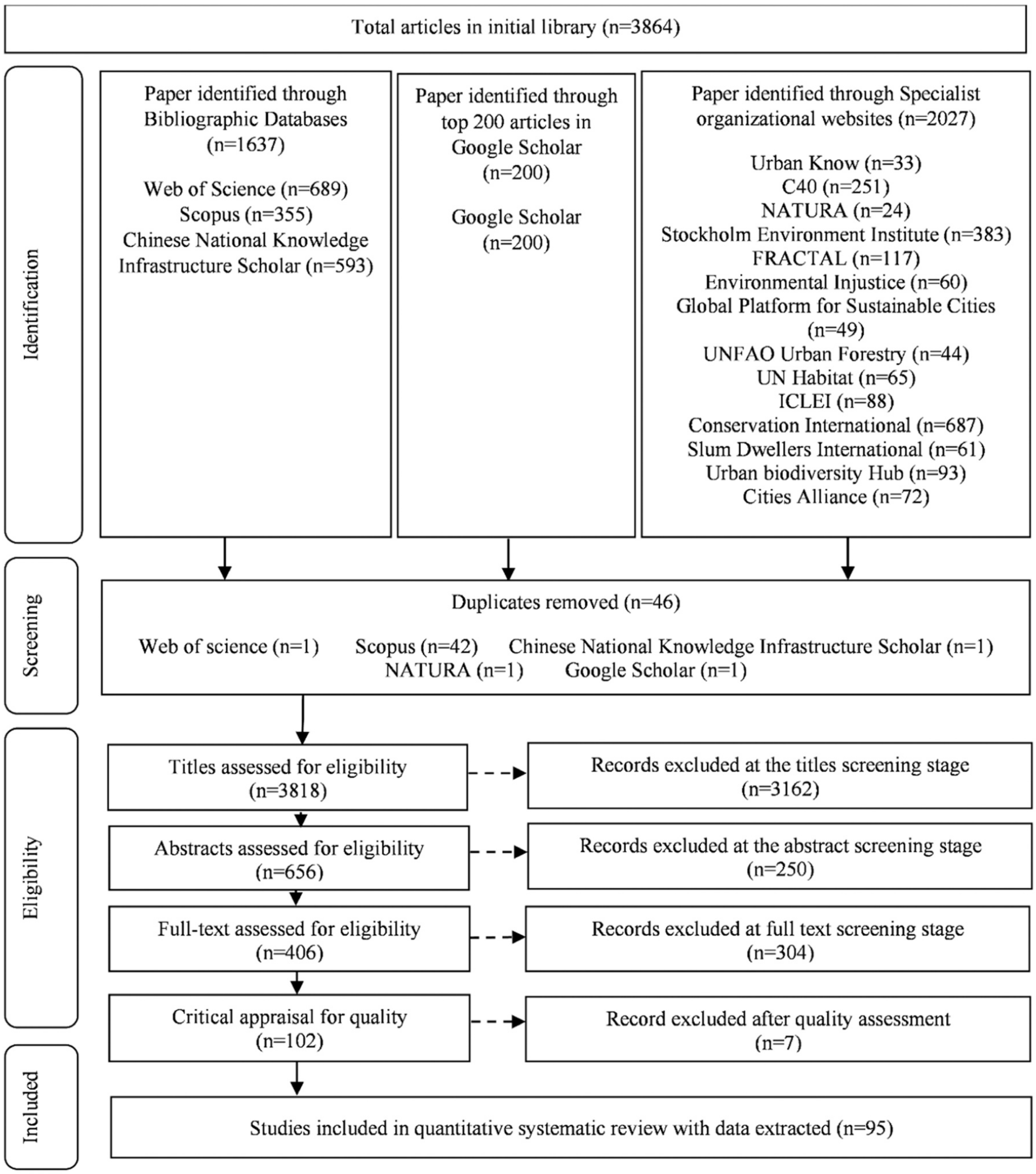

Fig. 2. PRISMA diagram of the reviewed papers identified in the steps through the systematic literature review process following Moher et al. 2009.

(version 4.1.2) (R Development Core Team, 2019).

2.3. Generating hierarchical archetypes

Following Thorn et al. (2021b) and Hunt et al. (2012), a hierarchical archetypal analysis was performed based on the NbClust package in RStudio (R Development Core Team, 2019), aiming to generate archetypes in which global disparity in multiple wellbeing can be detected. Archetypal hierarchical analysis is a common iterative clustering and machine learning algorithm, aiming to build a tree diagram that places most similar objects on branches close together (Charrad et al., 2014). In our study, the archetypal hierarchical analysis employed 43 thematic categories of wellbeing to aggregate a tree diagram that places the most similar articles closer. The method of Ward (1963) was used to identify the numbers of clusters/archetypes in this tree, which has been considered as one of the most outstanding methods when creating a small number of homogeneous clusters with data across multiple countries or cities (Punj and Stewart, 1983). Afterwards, a heatmap visualized the tree diagram with the number of archetypes using the pheatmap function in RStudio as Appendix C (Hummerl et al., 2017).

2.4. Presenting archetypes heterogeneity

The value of each wellbeing thematic category within archetype was standardised into a fixed scale of 0–1 (Eq.1) based on their frequency to present archetype heterogeneity:

$$Y = (X \quad - Min)/(Max - Min) \tag{1}$$

where Y is the value after standardisation, and X is the frequency of each wellbeing category before normalisation. The *Min* and *Max* are the maximum and minimum frequency of the samples, respectively. Results

Table 2
Databases searched in the systematic review (website links were updated on the 21 March 2023).

Sources	Engine or institution	Website
Bibliographic databases	Web of Science core collection	https://www.webofscience.com/wos/woscc/basic-search
	Scopus	https://www.scopus.com/search/form.uri?display=basic#basic
	Chinese National Knowledge Infrastructure Scholar	https://oversea.cnki.net/index/
Google scholar	Google Scholar	https://scholar.google.com/
Grey literature databases	Urban Know	https://www.urban-know.com/
	C40	https://www.c40.org/
	NATURA	https://natura-net.org/
	Stockholm Environment Institute	https://www.sei.org/
	FRACTAL	https://www.fractal.org.za/
	Environmental Injustice Foundation	https://ejfoundation.org/
	Global Platform for sustainable Cities	https://www.thegpsc.org/
	UN FAO Urban Forest	https://www.fao.org/forestry/urbanforestry/en/
	UN Habitat	https://unhabitat.org/
	Local Government for Sustainability	https://iclei.org/
	Conservation International	https://www.conservation.org/
	Slum Dwellers International	https://sdinet.org/
	Urban biodiversity Hub	https://www.ubhub.org/
	City Alliance	https://www.citiesalliance.org/

Table 3
List continents and countries in the systematic review.

Continents	Country and number of studies	Total studies
Asia	China (22), India (4), Israel (2), Iran (1), Singapore (1), Bangladesh (1)	31 (33%)
Northe America	United States (24), Canada (2)	26 (30%)
Europe	United Kingdom (9), Norway (2), Italy (2), Germany (2), Netherlands (2), Austria (1), Czech (1), Spain (1), France (1), Poland (1), Portugal (1), Sweden (1)	24 (25%)
Latin America and Caribbean	Brazil (1), Chile (1)	2 (2%)
Africa	South Africa (3), Kenya (1), Tanzania (1), Somalia (1)	6 (6%)
Oceania	None	0 (0%)
Studies conducted across multiple countries	Global (2), Thailand and Kenya (2), Korea and Japan (1), United Kingdom, Sweden, Estonia, Kenya and Thailand (1)	6 (6%)
Total		95

were presented by the radial function graphic by the metafor package in RStudio (Viechtbauer, 2010).

2.5. Analysing the difference between archetypes

A paired sample T-test of k independent samples was conducted by the IBM SPSS Statistics version 28.0, aiming to understand the degree of differences and overlap between archetypes (Wang et al., 2021a). The first step was to determine the general difference across 43 wellbeing thematic categories through T-test of k independent samples to confirm which categories are significant ($p<0.05$). Secondly, a T-test of any two independent samples (paired archetypes) was conducted based on the categories that have been identified as significant in the first step, clarifying the overlap level between archetypes through the 95% confidence. A higher number of differences implies a lower degree of overlap between archetypes.

3. Results

3.1. Temporal and geographic scope of published papers

The earliest studies originate from 2009, with an exponential growth in the number of studies published with initially one study in 2009 and 27 studies by 2021. The overwhelming majority (96.8%) of studies were published since 2013, and the number of publications increased since 2015 (Fig. 4). Studies have been conducted over 30 countries, spanning five continents (Table 3). Asia has received the most attention (n=31, 33%), followed by North America (n=26, 30%), and Europe (n=24, 25%). There remain significant gaps in knowledge in Africa, Oceania, Latin America and Caribbean, with studies published in four countries in Africa (n=6, 6%), two countries in Latin America and Caribbean (n=2, 2%), and none in Oceania. Most studies (94%) have been conducted at the national or subnational scale, while 6% have spanned multiple countries.

3.2. Human wellbeing thematic categories

Results show a trend of increased interest in this topic with time (2009–2022). The frequency in dimension of 'who' (n=196, 62%) expanded since 2013; the same year as the dimension of 'where' (n=50, 16%), but two years earlier than when interest grew in 2015 on the dimension of 'what health implications residents have' (n=44, 14%) and 'how residents perceive GI' (n=28, 9%). Dimension of 'who' is the most common focus, based on the outcome of the Nonparametric-Test, and the dimension of 'how residents perceive GI' is of least commonly studied ($p<0.01$). Among them, the most cited wellbeing categories for four dimensions are financial status (n=31, 10%), building attributes (n=24, 8%), physical disease (n=15, 5%), and GI demand (n=8, 3%), respectively.

3.3. Emergent archetypes

A wide range of thematic categories of wellbeing was valued in the global literature, though their frequencies varied. Hierarchical analysis

Table 4
The difference of wellbeing categories across the four archetypes.

Categories	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
Sig.	<.001*	.229	<.001*	.001*	<.001*	<.001*	.030*	.884	.415	.005*	.762
Categories	A12	A13	A14	A15	A16	A17	B1	B2	B3	B4	B5
Sig.	.333	.631	.638	.005*	.019*	.937	<.001*	.048*	.573	.631	.023*
Categories	B6	B7	B8	B9	C1	C2	C3	C4	C5	C6	C7
Sig.	.013*	.195	.937	.937	.182	.449	.449	.535	.828	.839	.839
Categories	C8	C9	D1	D2	D3	D4	D5	D6	D7	D8	
Sig.	.839	.937	.450	.885	.631	.839	.839	.839	<.001*	.937	

Note: * represents a significant difference at a level less than 0.05.

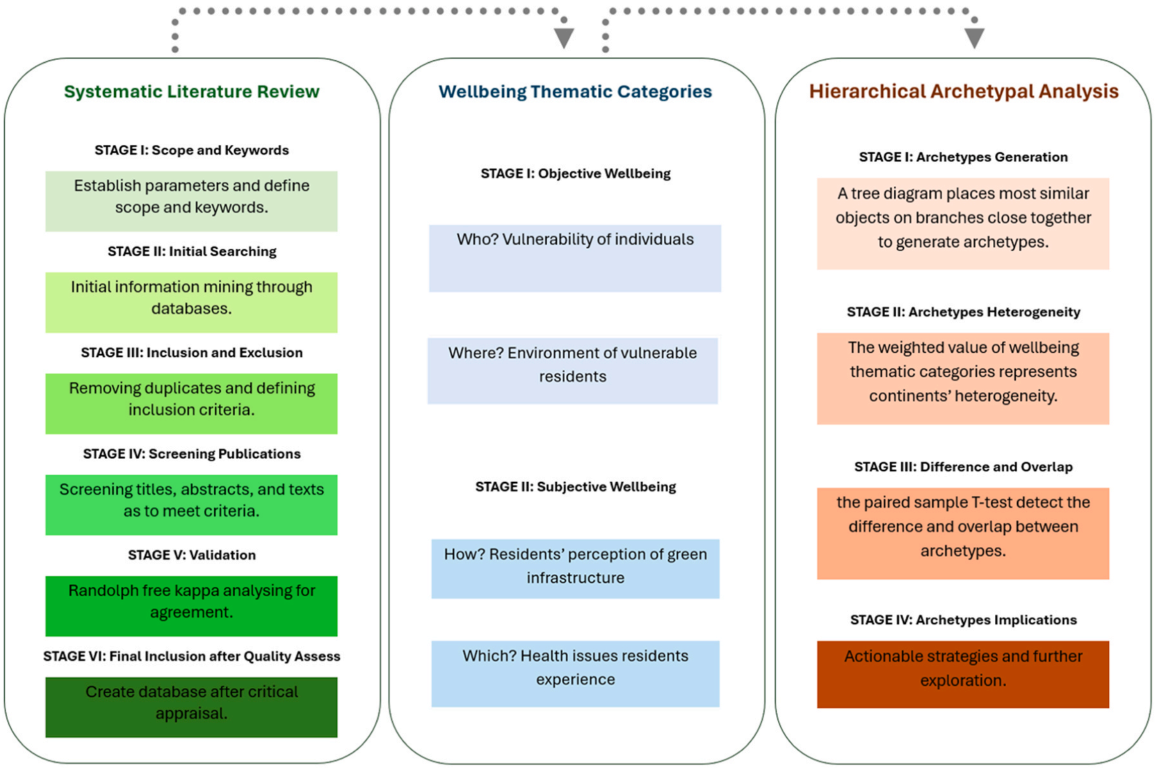

Fig. 3. Methodological outline of this study.

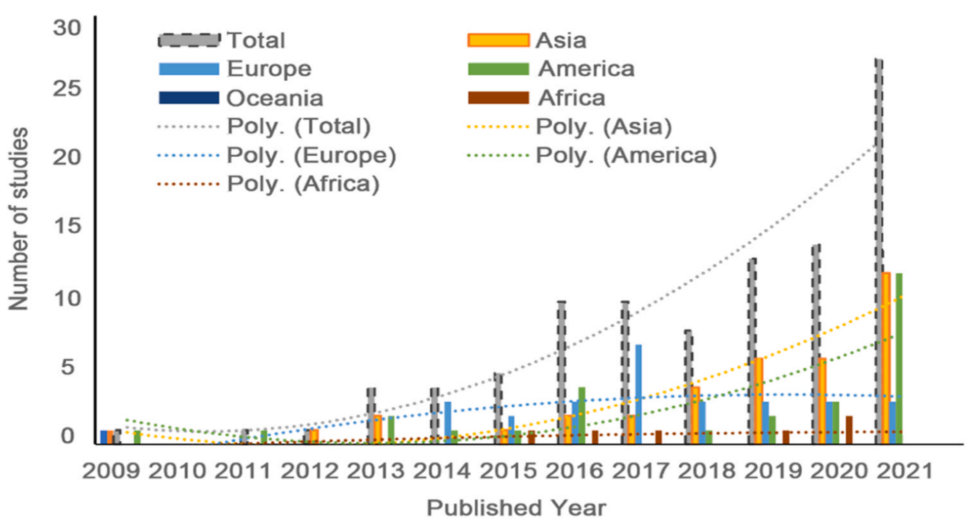

Fig. 4. Year and continent of the 95 studies with an exponential growth trend as shown by the polynomial regressions.

demonstrated their distance as Fig. 6 that four optimal clusters were determined with the first archetype dominated by the wellbeing thematic category of building attributes; the second by access to public facilities; the third by financial status; and the fourth by physical disease risk and GI demand (Fig. 7a).

3.4. Geographic distribution of archetypes

In terms of the geographic distribution, Archetype I (50%) and Archetype III (56%) mainly fell within North America; Archetype II majorly (80%) within Asia; and Archetype IV randomly across Asia (38%), Europe (33%), and North America (20%). However, blind plots existed in archetypes for Africa and Latin America and Caribbean (Fig. 7b).

3.5. Heterogeneity and overlap across archetypes

A T-test for k independent samples revealed general differences in fourteen wellbeing thematic categories ($p<0.05$) (Table 4). More specifically, a T-test for two independent samples comparing six pairs of archetypes (I-II, I-III, I-IV, II-III, II-IV, III-IV) highlighted in Table 5 shows that access to public facilities category difference is most pronounced among the four archetypes, with noticeable pairwise differences in five out of six pairs. Conversely, the categories of age, occupation, property right, and impervious surface rate show consistency in at least one pair (pairwise differences in one out of six pairs).

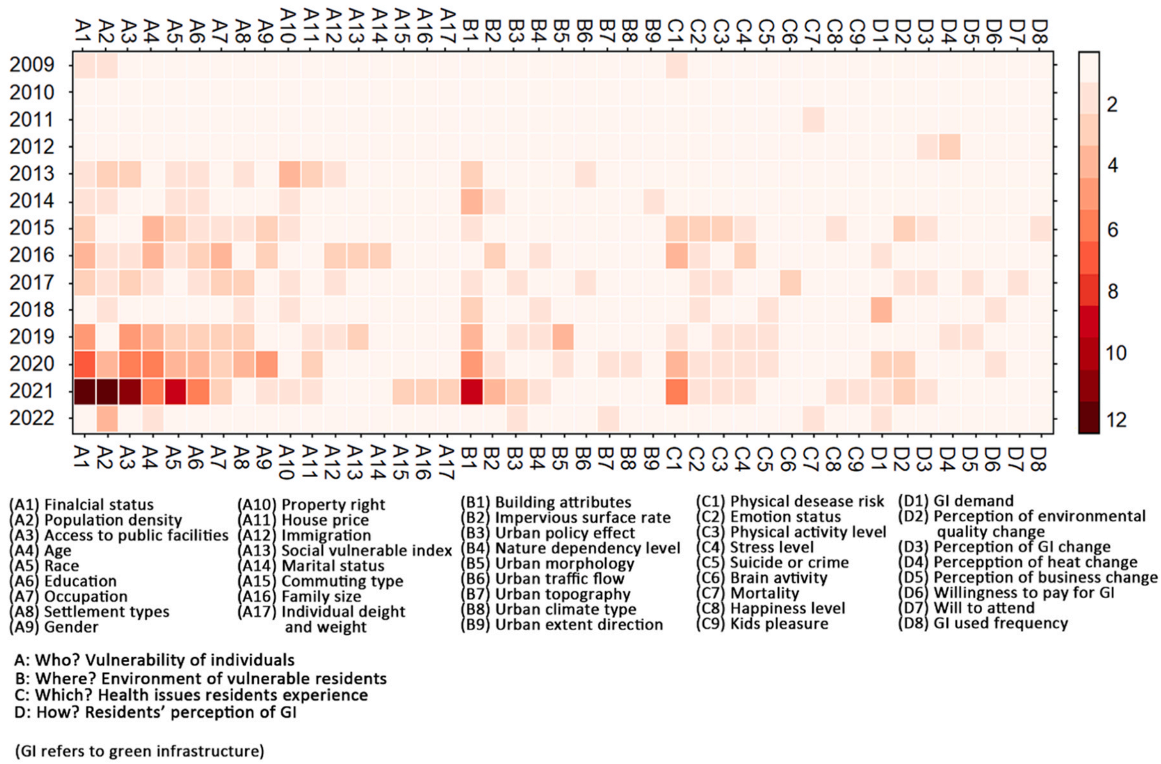

Fig. 5. Rank frequency of wellbeing categories.

The degree of overlap between archetypes can be gauged by the difference across the 14 significantly different wellbeing categories ($p<0.05$). There are 42 samples when considering the wellbeing of any one archetype compared to the other three (e.g., the three paired archetypes of I-II, I-III, and I-IV times 14 wellbeing categories whose difference was confirmed before). A higher number of differences implies a lower degree of overlap. Thus, Archetype I shows the most overlap with others (15 out of 42 pairs exhibit significant differences), while Archetypes III and IV exhibit the least overlap (18 out of 42 pairs demonstrate significant differences) (Table 5).

4. Discussion

Our assessment is structured around several key areas. Initially, we provided fresh insights covering four 'cooling-wellbeing' dimensions: vulnerability of individuals, residents' living locations, health issues faced by residents, and perceptions of GI. This approach allows us to investigate who, where, which, and how aspects of wellbeing are impacted by unequal cooling services, and to examine the thematic coverage and temporal scope of studies across these dimensions. Subsequently, human wellbeing archetypes using hierarchical analysis explored global disparities in 'cooling-wellbeing' to identify similarities and differences across continents. Lastly, we assess the implications of these archetypes and the field research in the future.

4.1. Scope of wellbeing thematic coverage and temporal variation

4.1.1. Evolution of GI studies: Aligning human wellbeing with ecosystem services and urban sustainability goals

Since 2009, there has been a notable increase in studies focusing on GI inequity and cooling services. This trend aligns with a growing interest in ecosystem services, as evidenced by key international assessments and agreements. For instance, the Millennium Ecosystem Services report in 2005 highlighted the benefits humans derive from ecosystems (Millennium Ecosystem Assessment MEA, 2005). In 2010, the Nagoya Protocol under the United Nations Environment Programme outlined effective strategies for benefit-sharing related to genetic resources, a key objective of the Convention of Biological Diversity (United Nations Environment Programme UNEP, 2010). Additionally, the establishment of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services in 2010 significantly enhanced work on biodiversity and ecosystem service matters and the policy-science interface (Díaz et al., 2019).

The surge in GI inequity and cool studies, particularly from 2015 onwards, coincides with major global initiatives for sustainable urban development, such as the launch of the Sustainable Development Goals (United Nations UN, 2015), the Paris Agreement (United Nations Framework Convention on Climate Change UNFCCC, 2015), and the New Urban Agenda (United Nations UN, 2017). This period marks a shift in research focus towards human wellbeing, particularly in urban and peri-urban settings. A two-year lag observed between the studies on subjective wellbeing (emphasising 'who' and 'where') since 2013, and those on objective wellbeing (focusing on 'which' and 'how') since 2015, suggests a progression from objective to subjective aspects of wellbeing in research. Initially, studies concentrated on objectively identifying beneficiaries or losers of ecosystem services, gradually shifting to subjective outcomes such as perceptions and health impacts. These trends indicate a burgeoning interest in human wellbeing, especially subjective wellbeing, which may dominate future research in this field.

4.1.2. Who? Vulnerability of individuals

Key themes emerging as critical for identifying vulnerable groups include financial status, population density, and age. These factors are often highlighted due to their availability in public databases like the World Bank. Besides, an inequitable distribution of GI, often situated near socially disadvantaged groups (Nelson et al., 2021), given that socially disadvantaged groups encompass a diverse array of influential actors depending on factors such as income, age, ethnicity, race, disability, education, occupation, historic injustices, and access to public

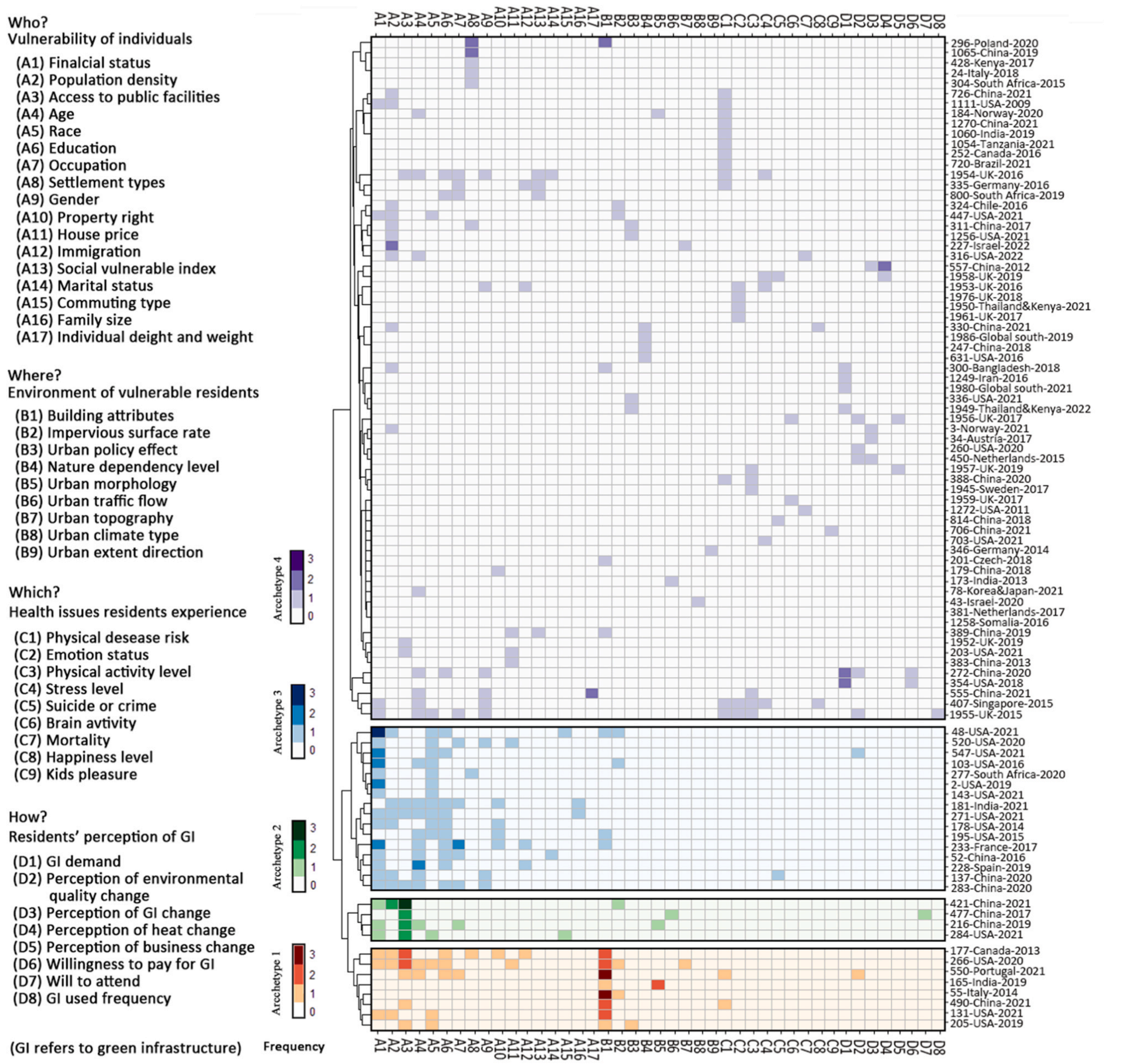

Fig. 6. Heatmap of four emergent clusters using hierarchical analysis.

services. Advantaged groups often control decisions related to the GI access, considering factors like the costs, planning and maintenance of trees, which can sometimes outweigh their benefits (Holt & Borsuk, 2020; Vogt et al., 2015; Conway, 2016). However, the impact is context specific. For example, some contrasting findings narrative that the vulnerable groups received more greenspace than socially advantaged population (Xiao et al., 2017); Vegetation coverage is linked to varying rates of cardiorespiratory mortality across social groups, peaking among the elderly (Moraisa et al., 2021); Heat exposure hotspots for the elderly differ between cities, as seen in Tokyo and Seoul (Park et al., 2021). Contrastingly, some studies focus on the paradox of GI's marginal value, observing that increased living costs due to GI improvements force residents in urban peripheries to relocate (Anguelovski et al., 2018; Haase et al., 2017). In response, Wolch et al. (2014) and Friedman et al. (2018) propose 'just green enough' strategies, advocating for smaller parks targeted at serving long-term residents while maintaining affordable housing and curbing speculative development. Thus, themes categorise of vulnerable groups in GI access prioritise projects to enhance their resilience against the UHI.

4.1.3. Where? Environment of vulnerable residents

Urban expansion affects residents' GI access, creating new vulnerable areas for thermal environments. For instance, Shanghai's rapid urbanisation and expansion, characterised by increased transportation networks has cut off residents' access to greenspace (Fan et al., 2017). At a micro-scale, impervious surfaces contribute to thermal pressure in different building environments. For instance, a study by Chatterjee et al. (2019) found temperature regulation differences in open low-rise, compact low-rise, and mid-rise residential areas, with temperature variances of 2.8–3.1 °C, 2.2–2.8 °C, and 2.8–2.9 °C, respectively. Whereas certain anticipated themes crucial for understanding urban evolution and characteristics, such as urban traffic flow (e.g., bus flows), city climate types (e.g., arid, tropical), and topography (e.g., elevation), have received minimal attention in the literature. Similarly, themes related to the level of urban nature dependency and the dominant effects of policy, have furthermore been largely neglected in studies.

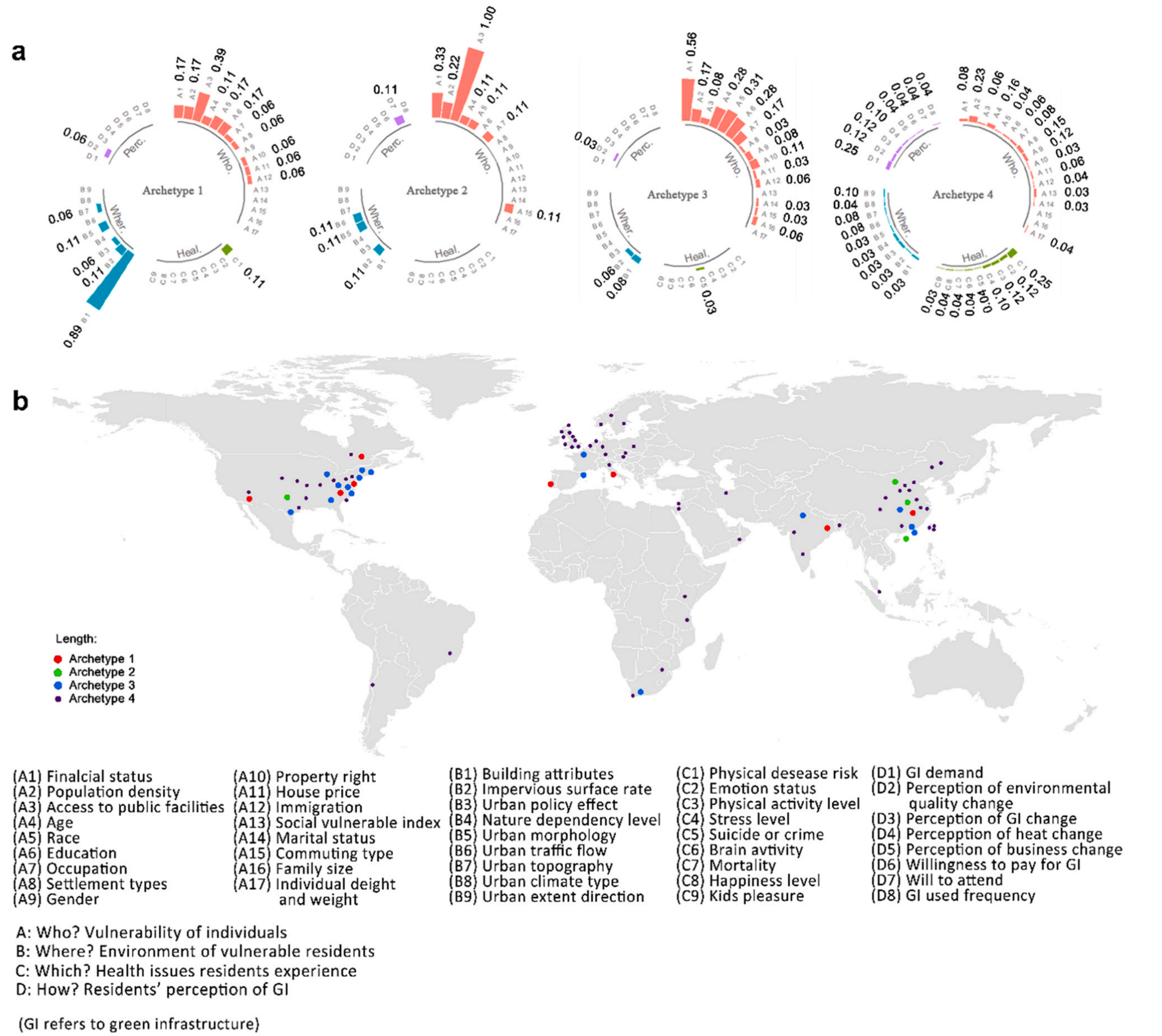

Fig. 7. Mapping global pattern of four archetypes: (a) the average value for each wellbeing thematic category under their archetype, and (b) the geographical distributions (one pot presents one article whose study area conducted in single city).

Table 5
The difference between the paired archetypes.

Pair	A1	A3	A4	A5	A6	A7	A10	A15	A16	B1	B2	B5	B6	D7
I-II	.187	**.034**	1.00	.596	.104	.530	.404	**.005**	1.00	**.001**	1.00	.266	**.005**	**.001**
I-III	**.004**	**.005**	.070	**.042**	.125	.167	.238	.317	**.045**	**.001**	.272	.094	1.00	1.00
I-IV	.069	**.001**	.400	**.017**	**.019**	.592	.229	1.00	1.00	**.001**	**.025**	.086	.782	1.00
II-III	.422	**.001**	.160	.061	**.003**	.701	.067	**.020**	.121	.399	.395	**.012**	**.002**	**.001**
II-IV	**.004**	**.001**	.541	.267	.817	.256	.906	**.001**	1.00	.762	.103	**.010**	**.002**	**.001**
III-IV	**.001**	.192	**.001**	**.001**	**.001**	**.004**	**.001**	.120	**.002**	.256	.193	.763	.710	1.00

Note: bold represents a significant difference at a level of $p<0.05$.

4.1.4. Which? Health issues residents experience

The most frequently cited health theme is the risk of physical diseases. This review has been evidenced in heat-caused ambulance calls (Graham et al., 2016), the Chikungunya epidemic (Freitas et al., 2021), cardiorespiratory mortality (Moraisa et al., 2021), and series chronic diseases. Studies have also explored psychological health aspects, including emotional status, stress levels, suicide rates, crime, mortality, happiness, and children's pleasure for interaction with nature (Fig. 5). However, two significant knowledge gaps persist. Firstly, there is a lack of exploration into the direction of causality. While some studies have examined the spatial scale of GI inequity with socio-demographic boundaries (Nesbitt et al., 2019), and others have assessed the impact of GI on health outcomes (Milošević et al., 2017), they rarely perform cross-sectional analyses to infer causality between these factors. Secondly, the breadth of relationships between GI engagement and human health remains underexplored. How the different types (e.g., trees vs.

grassland), qualities (e.g., abundance) and belonging (e.g., public vs. private) of greenspaces influence residents' access and preferences, resulting in different health outcomes, has not been thoroughly investigated.

4.1.5. How? Residents' perception of GI

This group has garnered the least attention, primarily due to the complexities and uncertainties in measuring residents' perceptions (Fedele et al., 2021; Naidoo et al., 2019). Key themes within this group include GI demand, perceptions of changes in environmental quality and GI quantity. These themes indicate a growing trend in developing scientific methods for measuring perception. Some trials have been started, for instance, a study in Guangzhou, utilized questionnaires to gauge consumer demand for GI cooling services, revealing a mismatch between demand and supply (Chen et al., 2020). Inversely, the themes on perception of heat change, business change, will-to-pay, and attendance frequency have seldom been investigated but they are interlinked and important. For instance, will-to-pay drives investment in park landscapes, features, and equipment, ultimately influencing visitation frequency. In this case, how to develop feasible, plausible, and applicable methodologies to quantify people's perception and how this influences the environment and economy, not only to pay, is a valuable tool to identify strategies for improving GI implementation and maintenance (Soto et al., 2018; Bokaie et al., 2016).

4.2. Understanding global disparities in wellbeing based on archetypes

Hierarchical findings reveal sets of wellbeing categories consistently appeared across different archetypes. These consistent appearance of wellbeing categories underscores archetypes similarities. Here, we defined sets of wellbeing categories consistently appeared in different archetypes as the term 'bundle' that has been applied in many cases of synergies and trade-off analysis (Zoderer et al., 2019, Wang et al., 2021a), for example, cultural services are often bundled with regulation services across different urban parks in Rotterdam (Derkzen et al., 2015). In our study, the wellbeing categories of financial status, access to public facilities, age, race, occupation, and impervious surface rate – are noticeably bundled ($p<0.05$) across four archetypes spanning multiple continents. This bundle represents a diverse array of influential actors influencing GI access is universal concerns.

Even through, other issues diverge regionally based on continents' biophysical and socioeconomic contexts (Table 4 & Table 5). Firstly, in developing countries, urban priorities addressing poverty, infrastructure adequacy, housing affordability, informal settlement upgrading, youth unemployment, and secondary city development. In Archetype II, predominantly found in Asia, the wellbeing categories in combination of public facilities, population, and finance underscores the growing conflicts arising from rapid urbanisation, inadequate infrastructure, and increasing populations across the most urbanizing cities in Asia (Valente de Macedo et al., 2021). Plenty projects (e.g., Chinese Sponge City Program) are ongoing integration of green and blue infrastructure for infrastructure updating and ecological restoration in urbanising countries in Asia (Jia et al., 2017). Asia with averaged temperature at 29.13°C almost double than Northern Europe at 15.92°C (Choi et al., 2022) requires more preparations for a dynamic and unpredictable future while transitioning to more sustainable, just, green, resilient, and healthy futures.

Conversely, in Archetypes I and III, predominant in North America, the dominant wellbeing categories are - for example, finance, age, race, education, and building attribution - highlighting the social-economical conflicts of urban priorities include managing cultural diversity, modernising ageing infrastructure, addressing shrinking cities, and catering to an ageing population amidst entrenched gentrifications in developed countries. These archetypes emphasise the importance of including diverse voices into decision making for equitable wellbeing rather than gentrifications.

Archetype IV is characterised by a balance of synergies in different wellbeing categories across Asia, Europe, and North America. This is consistent with the results in Zhang et al. (2020) that the studies in ecosystem services and individual health found across the multiple continents but most pounced in Europe, North America, and Asia where the territories are highly densely populated (Pappalardo et al., 2023). In particularly Archetype IV includes 'health' implications and individual 'perception', supporting the opinion that the globe spontaneously starts to act on individual perception. It also emphasises the necessity of "bottom-to-top" management to engage public participation into sustainable policies (O'Brien et al., 2016, de Jesus Crespo & Fulford, 2018).

The wellbeing gaps persist in most countries in Oceania, Africa, and Latin America and the Caribbean. This pattern is aligning with previous studies (Brink et al., 2016; Valente de Macedo et al., 2021), for example, the least studies in greenspace and health from 1950s to 2010s were in the continents of Sub-Saharan Africa and the Latin America and Caribbean (Zhang et al., 2020). Sub-Saharan Africa, in particular, faces the highest multidimensional poverty rates (29%, 11 times higher than the Latin America and Caribbean), and poverty is on the rise in close to one-third of the countries (United Nations Human Settlements Programme UN-Habitat, 2022), challenging in achieving the Sustainable Development Goals by 2030 and the Africa Agenda by 2063. Therefore, within the Decade of Action (2020–2030), substantial efforts on cooling service and multiple wellbeing in terms of instigation, investments, and plantation are comprehensively imperative to address socio-economic structures and ensure policy coherence.

Previous studies exploring wellbeing (Western & Tomaszewski, 2016; Tomyn et al., 2013), or focusing on single wellbeing linkages with multiple greenspace services (Pitman et al., 2015) are reported from Oceanian, while the links between urban GI and different components of human wellbeing are emerging but still rare (Reyes-Riveros et al., 2021). Our study found no published papers from Oceania because it considered the multiple wellbeing components with the single GI service simultaneously. However, new research is emerging quickly, for instance, Patton & Pojani (2022) focusing on multiple wellbeing with unequitable GI cooling effects was found in Oceania when we repeated our search in 2024. The relatively few studies reported from Oceania probably relate to diverse contexts, such as a focus on national nature-based solutions plans, and a comparatively historically lower population in 1950 that continued through to 2009–2020 (0.33% of global population) compared with other continents (United Nations Human Settlements Programme UN-Habitat, 2022). Research on nature-based solutions has surged post-2015 when the Paris Agreement was launched, and particularly from 2015 to 2021 as revised Paris Agreement climate pledges (nationally determined contributions) that involved nature-based solutions into their urban climate mitigation. However, this momentum is rare from Oceania and absent in Australia (Seddon, 2022), where the slight urban heat island extremes are located (Mentaschi et al., 2022).

4.3. Implications for wellbeing management based on archetypes

This study offers practical implications by analysing wellbeing categories and their associated bundles. The dominant wellbeing categories for each archetype characteristics their effective pathways to manage GI for UHI and wellbeing:

Archetype I: Maintaining GI into urban planning

Archetype I emphasises building attributes, for example, the density and height of buildings influences urban outdoor thermal comfort (Perini & Magliocco, 2014), that reveals effective and space-saving cooling strategies of retrofitting urban structures by integrating GI (Perini & Magliocco, 2014; Lino & Tony, 2019). For example, Chatterjee et al. (2019) shows green pavements, green roofs and green walls can reduce diurnal air temperature at the neighbourhood scale by 0.7 °C, 0.8 °C and 1.1°C. This is because vegetation reduces thermal radiation by reflecting and absorbing incoming short-wave solar radiation (Brown &

Gillespie, 1995), the temperature of the leaves and the surrounding air decreases when vegetation transpires (Lai et al., 2019) sheltering areas under the crowns (Milošević et al., 2017). Vegetation changes wind speed through increasing the roughness of the building surfaces (Oke et al., 2017). Additionally, the magnitude of cooling capacity varying across different urban settings should be consider, for instance, average cooling capacity for urban areas reaching 4.52 °C in Changchun, China (Ren et al., 2013), and 6.82 °C in Nagoya, Japan (Cao et al., 2010), whereas another based on 89 studies suggests cities cooling of 1.5–3.5 °C in Netherlands, Sweden, Portugal, and Israel (Saaroni et al., 2018) and elsewhere of 24 studies covering tropical climates indicating smaller cooling of 0.94 °C (Bowler et al., 2010).

Archetype II: Retrofitting public facilities for GI interaction

Archetype II, dominated by access to public facilities, suggests enhancing GI access through such as improving transportation networks allowing residents easy access to nature. For example, Wang & Qiu (2018) indicates that people who have convenient transportation services are highly likely to go to parks. Even though residents mostly prefer parks near their homes (Poppe et al., 2022), others further away could be attractive if transportation is accessible (Saif et al., 2019). Liu et al. (2017) goes on to highlight the importance of investment in grants to establish parks and transportation (i.e., metro systems) easier access.

Archetype III: Linking disadvantaged groups to heat management

Archetype III implicates us linking diverse demographic groups (by age, race, education, and occupation) to heat management, with special attention to areas of high thermal stress. For example, the Public Health England (2018) mentioned several special groups at higher risk of heat-related illness, older citizens (>75 years) being among the most vulnerable. Sanchez & Reames (2019) working in Detroit revealed green roofs were found mostly in the affluent part of the city, where the population is predominantly white. Mitchell et al., 2021 in North Carolina examined disease risks that were relatively higher within higher population communities with the lesser greenspace, lower education, and lower income. Therefroe, emerging suggestions emphasize where people do not have enough space or budget, e.g., live in informal settlements without yard and gardens, could be priority in the projects of installing green roofs/walls for houses that can raise surface albedo, increase evapotranspiration, reduce heat risks, and have cost savings.

Archetype IV: Engaging participants health and perception into decision-making

Archetype IV, one the one hand, concerning disease risk, underlines the importance of integrating health considerations into cooling strategies, particularly as climate change manifests in more frequent, intense, and long-lasting extreme weather events in cities. For instance, more approaches involving not only traditionally spatially explicit land surface temperature reduction but mainstreaming temperature, greenspace, and health reports into evaluations together are needed. This aligns with the Health in All Policies (HiAP) ideas advocated by the World Health Organization and Europe Union (Leppo & Ollila, 2013). On the other hand, participant perception is also a key theme in Archetype IV, underscoring the need for catering public preferences in urban greenspace design. For example, Arnberger et al. (2017) conducted a visual discrete choice experiment with 193 elderly people to analyse their perceptions and preferences for greenspaces during hot days. They found most people preferred greener elements, if they provide more shade, cooler, and easier accessible at neighbour scale. Fedele et al. (2021) employed more than five million household interviews in 85 countries and showed that 1.2 billion people across tropical countries are highly dependent on nature for their basic life and cooling needs. This approach also necessitates maintaining trust and transparency between government and civil society, avoiding corruption and shocks across vertical and horizontal scales.

4.4. Insights for the further investigation in theory, technology, and implementation

Our systematic literature review offers several practices ranging from theory and technology to implementation for further research in this field.

Theory: Our assessment provides fresh insights in the inequitable GI cooling effects. It also investigates the multiple components of wellbeing through the subjective and objective emphasis around four key cooling-wellbeing aspects in terms of how, which, where, and for whom wellbeing has been impacted. This framework can serve as a benchmark foundation of a wide range of future research.

Technology: The hierarchical analysis and bundle method in this study provide a way to the multiple components of wellbeing assessment. This methodology can be used to fill in data gaps, using reasonable assumptions when no other information is available for instance. For example, our study shows residents who have lower income often with less greenspace, have a higher likelihood of heat-related health issues (Meacham et al., 2022).

Implementation: Firstly, the types, qualities, and access to greenspaces vary in their proximity to people. Therefore, integrating spatially explicit greenspace data and demographic attributes (e.g., boundaries of informal settlements) into databases could prove beneficial. Secondly, although there are existing publications linking health with heat or greenspace, comprehensive systems that narratively integrate greenery, heat, and health to establish the direction of causality and map resilient or risk zones for analysing future scenarios are rare (Venter et al., 2020). Thirdly, traditional methods such as questionnaires and interviews for assessing residents' perceptions are challenging to implement on a large scale due to the consumption of time and resources. The application of media data, such as Volunteered Geographic Information, facilitates access to large volumes of data and public participation, which we believe plays a crucial role in future analyses. Fourthly, wellbeing analysis identifies the gap between the perceived services of greenspaces and the actual supply of these services. By comparing people's perceived wellbeing with the design intentions of parks, researchers can understand why certain services may not be adequately translated into wellbeing (Dou et al., 2020; Arslan & Kaymaz, 2020), aiming to prevent recurrence of such issues (Larson et al., 2016). Fifthly, people's exposure to environments beyond their homes is a daily occurrence. The human mobility database is a direction for future real-time wellbeing assessments. Finally, our study demonstrated the individual contexts with the unequal cooling effects, while community wellbeing—such as social contact, cohesion, and culture—deserve further attention (Atkinson et al., 2017).

4.5. Limitations

Our study faces several limitations. Firstly, it focuses exclusively on English reports, leaving other languages unexplored. Secondly, the scope of search keywords is constrained by search engine limitations, potentially introducing biases in the number of studies identified. Thirdly, the literature reviewed consists solely of empirical case studies, excluding conceptual theories, methodological notes, and literature reviews. Despite these limitations, our results are robust. We employed a broad range of search terms across various search engines to capture as much relevant material as possible, minimising the risk of omitting important information. The validation process, conducted at the title, abstract, and full-text levels by experienced reviewers, ensured the inclusion of high-quality literature. Additionally, a validation test using final search strings in the Web of Science™ Core Collection, without language restrictions, showed a 96.9% overlap with our English-limited results, strongly supporting the efficacy and comprehensiveness of our approach.

5. Conclusions

This research evaluates the interaction between GI equity with disparate cooling services and wellbeing. Utilising a systematic review, we analysed 95 global studies, identifying the temporal trends and global distribution of work in this space, in terms of wellbeing thermotical categories to understand the effectiveness of GI inequity and their impact on wellbeing, considering factors like locations and target population. We identified wellbeing archetypes, each offering insights into global similarities and differences. These archetypes unveil four sustainable and resilient strategies for enhancing wellbeing through GI functions. The study's findings in our study can assist in the design and planning of diverse nature-based cooling solutions, narrowing ecological injustice, and highlight research cold-pot areas to direct further investigation in theoretical (cooling-wellbeing framework), technological (bundle approach), and practical insights (e.g., human and greenspace database, greenery-heat-health system, Volunteered Geographic Information application, gaps of perceived wellbeing with parks design intentions, human mobility, community wellbeing) to foster more effective, inclusive governance to unpin sustainable development in expanding urban areas.

CRediT authorship contribution statement

Rui Han: Conceptualization, Methodology, Software, Formal analysis, Data Curation, Writing - Original Draft, Writing - Review & Editing; **Robert Marchant:** Methodology, Validation, Writing - Review & Editing, Supervision; **Jessica Thorn:** Conceptualization, Methodology, Writing - Review & Editing, Validation, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This research was supported by funding from China Scholarship Council-University of York Scholarship (202106390012). This research was also supported with the financial assistance of the European Union (Grant no. DCI-PANAF/2020/420-028), through the African Research Initiative for Scientific Excellence (ARISE), pilot programme. ARISE is implemented by the African Academy of Sciences with support from the European Commission and the African Union Commission. We thank the anonymous reviewers whose comments and suggestions helped improve and clarify this manuscript.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ufug.2024.128372.

References

Alatartseva, E., Barysheva, G., 2015. Well-being: subjective and objective aspects. Procedia Soc. Behav. Sci. 166, 36–42.
Amaral, M.H., Benites-Lazaro, L.L., Antonio de Almeida Sinisgalli, P., Prates da Fonseca Alves, H., Giatti, L.L., 2021. Environmental injustices on green and blue infrastructure: urban nexus in a macrometropolitan territory. J. Clean. Prod. 289, 125829.
Anguelovski, I., Connolly, J.J., Masip, L., Pearsall, H., 2018. Assessing green gentrification in historically disenfranchised neighbourhoods: a longitudinal and spatial analysis of Barcelona. Urban Geogr. 39 (3), 458–491.
Arnberger, A., Allex, B., Eder, R., Ebenberger, M., Wanka, A., Kolland, F., Wallner, P., Hutter, H.P., 2017. Elderly resident's uses of and preferences for urban greenspaces during heat periods. Urban For. Urban Green. 21, 102–115.
Arslan, E.S., Kaymaz, I., 2020. Visitor perception of recreational ecosystem services and their role in landscape management of Golcuk Nature Park, Turkey. Int. J. Sustain. Dev. World Ecol. 27, 202–213.
Atkinson, S., Bagnall, A.M., Corcoran, R., South, Curtis1, S., di Martino, S., Pilkington, G., 2017. What is Community Wellbeing? Conceptual review. https://whatworkswellbeing.org/resources/what-is-community-wellbeing-conceptual-review/.
Bastin, J.-F., Clark, E., Elliott, T., Hart, S., van den Hoogen, J., Hordijk, I., Ma, H.Z., Majumder, S., Manoli, G., Maschler, J., Mo, L., Routh, D., Yu, K., Zohner, C.M., Crowther, T.W., 2019. Understanding climate change from a global analysis of city analogues. PLoS ONE 14 (7), e0217592.
Bokaie, M., Zarkesh, M.K., Arasteh, P.D., Hosseini, A., 2016. Assessment of urban heat island based on the relationship between land surface temperature and land use/land cover in Tehran. Sustain. Cities Soc. 23, 94–104.
Bowler, D.E., Buyung-Ali, L., Knight, T.M., Pullin, A.S., 2010. Urban greening to cool towns and cities: A systematic review of the empirical evidence. Landsc. Urban Plan. 97, 147–155.
Brown, R.D., Gillespie, T.J., 1995. Microclimatic landscape design: creating thermal comfort and energy efficiency. Int. J. Climatol. 17 (2), 225–226.
Brink, E., Aalders, T., Adam, D., Feller, R., Henselek, Y., Hoffmann, A., Ibe, K., Matthey-Doret, A., Meyer, M., Negrut, N.L., Rau, A.L., 2016. Cascades of green: a review of ecosystem-based adaptation in urban areas. Glob. Environ. Change 36, 111–123.
Cao, X., Onishi, A., Chen, J., Imura, H., 2010. Quantifying the cool island intensity of urban parks using ASTER and IKONOS data. Landsc. Urban Plan. 96, 224–231.
Chaigneau, Tomas, Brown, Katrina, Coulthard, Sarah, Daw, Tim M., Szaboova, Lucy, 2019. Money, use and experience: Identifying the mechanisms through which ecosystem services contribute to wellbeing in coastal Kenya and Mozambique. Ecosyst. Serv. 38, 100957.
Charrad, M., Ghazzali, N., Boiteau, V., Niknafs, A., 2014. NbClust: An R package for determining the relevant number of clusters in a dataset. J. Stat. Softw. 61 (6), 1–36.
Chatterjee, S., Khan, A., Dinda, A., Mithun, S., Khatun, R., Akbari, H., Kusaka, H., Mitra, C., Bhatti, S.S., Doan, Q.V., Wang, Y., 2019. Simulating micro-scale thermal interactions in different building environments for mitigating urban heat islands. Sci. Total Environ. 663, 610–631.
Chen, S., Wang, Y., Ni, Z., Zhang, X., Xia, B., 2020. Benefits of the ecosystem services provided by urban GIs: Differences between perception and measurements. Urban For. Urban Green. 54, 126774.
Chen, B., Wu, S., Song, Y., Webster, C., Xu, B., Gong, P., 2022. Contrasting inequality in human exposure to greenspace between cities of Global North and Global South. Nat. Commun. 13, 4636.
Choi, Hm, Lee, W., Roye, D., Heo, S., Urban, A., Entezari, A., Vicedo-Cabrera, Am, Zanobetti, A., Gasparrini, A., Analitis, A., Tobias, A., Armstrong, B., Forsberg, B., Íñiguez, C., Åström, C., Indermitte, E., Lavigne, E., Mayvaneh, F., Acquaotta, F., Sera, F., Orru, H., Kim, H., Kyselý, J., Madueira, J., Schwartz, J., Jaakkola, J.J.K., Katsouyanni, K., Diaz, M.H., Ragettli, M.S., Pascal, M., Ryti, N., Scovronick, N., Osorio, S., Tong, S., Seposo, X., Guo, Y.L., Guo, Y., Bell, M.L., 2022. Effect modification of greenness on the association between heat and mortality: A multi-city multi-country study. EBioMedicine 84, 104251.
Cinderby, S., Archer, D., Mehta, V.K., Neale, C., Opiyo, R., Pateman, C.M.M.R., Adelina, C., Tuhkanen, H., 2021. Assessing inequalities in wellbeing at a neighbourhood scale in low-middle-income-country secondary cities and their implications for long-term livability. Front. Sociol. 6, 729453.
Cinderby, S., Bagwell, S., 2018. Exploring the co-benefits of urban GI improvements for businesses and workers' wellbeing. Area 50 (1), 126–135.
Conway, T.M., 2016. Tending their urban forest: Residents' motivations for tree planting and removal. Urban For. Urban Green. 17, 23–32.
D'Acci, L., 2011. Measuring well-being and progress. Soc. Indic. Res. 104 (1), 47–65. https://doi.org/10.1007/s11205-010-9717-1.
Derkzen, M.L., van Teeffelen, A.J.A., Verburg, P.H., 2015. Review: quantifying urban ecosystem services based on high-resolution data of urban green space: an assessment for Rotterdam, the Netherlands. J. Appl. Ecol. 52, 1020–1032.
de Jesus Crespo, R., Fulford, R., 2018. Eco-Health linkages: assessing the role of ecosystem goods and services on human health using causal criteria analysis. Int. J. Environ. Res. Public Health 63, 81–92.
Díaz, S., Settele, J., Brondízio, E.S., Ngo, H.T., Guèze, M., Agard, J., Arneth, A., Balvanera, P., Brauman, K.A., Butchart, S.H.M., Chan, K.M.A., Garibaldi, L.A., Ichii, K., Liu, J., Subramanian, S.M., Midgley, G.F., Miloslavich, P., Molnár, Z., Obura, D., Pfaff, A., Polasky, S., Purvis, A., Razzaque, J., Reyers, B., Roy Chowdhury, R., Shin, Y.J., Visseren-Hamakers, I.J., Willis, K.J., Zayas, C.N., 2019. IPBES 2019: Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, 56. IPBES secretariat, Bonn, Germany. https://doi.org/10.5281/zenodo.3553579.
Dietz, W.H., 1998. Health consequences of obesity in youth: Childhood predictors of adult disease. Pediatrics 101 (Suppl. 2), 518–525.
Dou, Y., Yu, X., Bakker, M., De Groot, R., Carsjens, G.J., Duan, H., et al., 2020. Analysis of the relationship between cross-cultural perceptions of landscapes and cultural ecosystem services in Genheyuan region, Northeast China. Ecosyst. Serv. 43, 101112.
Fan, P., Xu, L., Yue, W., Chen, J., 2017. Accessibility of public urban green space in an urban periphery: the case of Shanghai. Landsc. Urban Plan. 165, 177–192.
Fedele, G., Donatti, C.I., Bornacelly, I., Hole, D.G., 2021. Nature-dependent people: Mapping human direct use of nature for basic needs across the tropics. Glob. Environ. Change 71, 102368.

Friedman, R.S., Law, E.A., Bennett, N.J., Ives, C.D., Thorn, J.P.R., Wilson, K.A., 2018. How just and just how? A systematic review of social equity in conservation research. Environ. Res. Lett. 13, 053001.
Freedman, D.S., Mei, Z., Srinivasan, S.R., Berenson, G.S., Dietz, W.H., 2007. Cardiovascular risk factors and excess adiposity among overweight children and adolescents: The Bogalusa Heart Study. J. Pediatr. 150 (1), 12–17.
Freitas, L.P., Schmidt, A.M., Cossich, W., Cruz, O.G., Carvalho, M.S., 2021. Spatio-temporal modelling of the first Chikungunya epidemic in an intra-urban setting: The role of socioeconomic status, environment and temperature. PLoS Negl. Trop. Dis. 15 (6), e0009537.
Giombini, V., Thorn, J.P.R., 2022. 2021. Urban greenspaces in a post-apartheid city: challenges and opportunities for nature-based solutions. Hum. -Nat. Interact.: Explor. Nat. 'S. Values Across Landsc. 207–219. https://doi.org/10.1007/978-3-031-01980-7_17.
Girardin, C.A.J., Jenkins, S., Seddon, N., Allen, M., Lewis, S.L., Wheeler, C.E., Griscom, B. W., Malhi, Y., 2021. Nature-based solutions can help cool the planet - if we act now. Nature 593 (7858), 191–194.
Gutiérrez Rodríguez, L., Hogarth, N.J., Zhou, W., Xie, C., Zhang, K., Putzel, L., 2016. China's conversion of cropland to forest program: a systematic review of the environmental and socioeconomic effects. Environ. Evid. 5, 21.
Graham, D.A., Vanos, J.K., Kenny, N.A., Brown, R.D., 2016. The relationship between neighbourhood tree canopy cover and heat-related ambulance calls during extreme heat events in Toronto, Canada. Urban For. Urban Green. 20, 180–186.
Haase, D., Kabisch, S., Haase, A., Andersson, E., Banzhaf, E., Baro, F., 2017. Greening cities-to be socially inclusive? About the alleged paradox of society and ecology in cities. Habitat Int. 64, 41–48.
Hicks, C.C., Cinner, J.E., 2014. Social, institutional, and knowledge mechanisms mediate diverse ecosystem service benefits from coral reefs. PNAS 111, 17791–17796.
Holt, J.R., Borsuk, M.E., 2020. Using Zillow data to value greenspace amenities at the neighbourhood scale. Urban For. Urban Green. 56, 126794.
Hummerl, M., Edelman, D., Kopp-Schneider, A., 2017. CluMix: clustering and visualization of mixed-type data. R. Package 2017. ⟨https://www.rdocumentation.org/packages/CluMix/versions/2.3.1⟩.
Hunt, D.V.L., Lombardi, D.R., Atkinson, S., Barber, A.R.G., Barnes, M., Boyko, C.T., Brown, J., Bryson, J., Butler, D., Caputo, S., Caserio, M., Coles, R., Cooper, R.F.D., Farmani, R., Gaterell, M., Hale, J., Hales, C., Hewitt, C.N., Jankovic, L., Jefferson, I., Leach, J., MacKenzie, A.R., Memon, F.A., Sadler, J.P., Weingaertner, C., Whyatt, J. D., Rogers, C.D.F., 2012. Scenario archetypes: Converging rather than diverging themes. Sustainability 4 (4), 740–772.
Huynh, L.T.M., Gasparatos, A., Su, J., Lam, R.D., Grant, E.I., Fukushi, K., 2022. Linking the nonmaterial dimensions of human-nature relations and human well-being through cultural ecosystem services. Sci. Adv. 8 eabn8042.
Jia, H., Wang, Z., Zhen, X., Clar, M., Shaw, L.Y., 2017. China's sponge city construction: a discussion on technical approaches. Front. Environ. Sci. Eng. 11 (4), 18.
Klemm, W., Heusinkveld, B.G., Lenzholzer, S., van Hove, B., 2015. Street greenery and its physical and psychological impact on thermal comfort. Landsc. Urban Plan. 138, 87–98.
Kolosna, C., Spurlock, D., 2019. Uniting geospatial assessment of neighbourhood urban tree canopy with plan and ordinance evaluation for environmental justice. Urban For. Urban Green. 40, 215–223.
Koprowska, K., Łaszkiewicz, E., Kronenberg, J., 2020. Is urban sprawl linked to green space availability? Ecol. Indic. 108, 105723.
Lai, D., Liu, W., Gan, T., Liu, K., Chen, Q., 2019. A review of mitigating strategies to improve the thermal environment and thermal comfort in urban outdoor spaces. Sci. Total Environ. 661, 337–353.
Larson, L.R., Keith, S.J., Fernandez, M., Hallo, J.C., Shafer, C.S., Jennings, V., 2016. Ecosystem services and urban greenways: What's the public's perspective? Ecosyst. Serv. 22, 111–116.
Leppo, K., Ollila, E., 2013. Health in All Policies: Seizing Opportunities, implementing policies. Ministry of Social Affairs and Health, Finland: Helsinki.
Li, X.J., Zhang, C., Lia, W.D., Kuzovkina, A.Y.L., Weiner, D., 2015. Who lives in greener neighborhoods? The distribution of street greenery and its association with residents' socio-economic conditions in Hartford, Connecticut, USA. Urban For. Urban Green. 14, 751–759.
Lin, T.P., Tsai, K.T., Hwang, R.L., Matzarakis, A., 2012. Quantification of the effect of thermal indices and sky view factor on park attendance. Landsc. Urban Plan. 107 (2), 137–146.
Liu, W.P., Dong, C.L., Chen, W.J., 2017. Mapping and quantifying spatial and temporal dynamics and bundles of travel flows of residents visiting urban parks. Sustainability 9, 1296.
Lino, S., Tony, G.R., 2019. Cooling Detroit: A socio-spatial analysis of equity in green roofs as an urban heat island mitigation strategy. Urban For. Urban Green. 2019 (44), 126331.
Mayne, R., Fawcett, T., Hyams, K., 2016. Climate justice and energy: applying international principles to UK residential energy policy. Local Environ. 22 (4), 393–409.
Meacham, M., Norström, A.V., Peterson, G.D., Andersson, E., Bennett, E.L., Biggs, R., Crouzat, E., Cord, A.F., Enfors, E., Felipe-Lucia, M.F., Fischer, J., Hamann, M., Hanspach, J., Hicks, C., Jacobs, S., Lavorel, S., Locatelli, B., Martín-López, B., Plieninger, T., Queiroz, C., 2022. Advancing research on ecosystem service bundles for comparative assessments and synthesis. Ecosyst. People 18 (1), 99–111.
McConnachie, M.M., Shackleton, C.M., 2010. Public greenspace inequality in small towns in South Africa. Habitat Int. 34 (2), 244–248.
Mentaschi, L., Duveiller, G., Zulian, G., Corbane, C., Pesaresi, M., Maes, J., Stocchino, A., Feyen, L., 2022. Global long-term mapping of surface temperature shows intensified intra-city urban heat island extremes. Glob. Environ. Chang. 72, 102441.
Millennium Ecosystem Assessment (MEA), 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington DC, US. ⟨http://www.millenniumassessment.org/en/Synthesis.aspx⟩.
Milošević, D.D., Bajšanski, I.V., Savić, S.M., 2017. Influence of changing trees locations on thermal comfort on street parking lot and footways. Urban For. Urban Green. 23, 113–124.
Mitchell, B.C., Chakraborty, J., Basu, P., 2021. Social inequities in urban heat and greenspace: analysing climate justice in Delhi, India. Int. J. Environ. Res. Public Health 18 (9), 4800.
Moher, D., A, the PRISMA Group, 2009. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. 6, e1000097.
Moraisa, L., Lopes, A., Nogueira, P., 2021. Human health outcomes at the neighbourhood scale implications: Elderly's heat-related cardiorespiratory mortality and its influencing factors. Sci. Total Environ. 760, 144036.
Naidoo, R., Gerkey, D., Hole, D., Pfaff, A., Ellis, A.M., Golden, C.D., Herrera, D., Johnson, K., Mulligan, M., Ricketts, H.K., Fisher, B., 2019. Evaluating the impacts of protected areas on human well-being across the developing world. Sci. Adv. 5, eaav3006.
Neale, C., Aspinall, P., Roe, J., Tilley, S., Mavros, P., Cinderby, S., Coyne, R., Thin, N., Thompson, Cw, 2020. The impact of walking in different urban environments on brain activity in older people. Cities Health 4 (1), 94–106.
Nelson, J.R., Grubesic, T.H., Miller, J.A., Chamberlain, A.W., 2021. The equity of tree distribution in the most ruthlessly hot city in the United States: Phoenix, Arizona. Urban For. Urban Green. 59, 127016.
Nesbitt, L., Meitner, M.J., Girling, C., Sheppard, S.R.J., Lu, Y., 2019. Who has access to urban vegetation? A spatial analysis of distributional green equity in 10 US cities. Landsc. Urban Plan. 181, 51–79.
Nguyen H., Vigil, S., Dang, N., 2020. Effects of environmental change and policy responses on natural resource access in Vietnam. https://www.sei.org/wp-content/uploads/2020/09/sei-report-nguyen-vietnam-sep-2020.pdf.
O'Brien, A., et al., 2016. How is ecosystem health defined and measured? A critical review of freshwater and estuarine studies. Ecol. Indic. 69, 722–729.
Oke, T.R., Mills, G., Christen, A., Voogt, J.A., 2017. Urban climates. Cambridge University Press, Cambridge, United Kingdom, 2017. https://doi.org/10.1017/9781139016476.
Park, C.Y., Thorne, J.H., Hashimoto, S., Lee, D.K., Takahashi, K., 2021. Differing spatial patterns of the urban heat exposure of elderly populations in two megacities identifies alternate adaptation strategies. Sci. Total Environ. 781, 146455.
Pappalardo, E.S., Zanetti, C., Todeschi, V., 2023. Mapping urban heat islands and heat-related risk during heat waves from a climate justice perspective: A case study in the municipality of Padua (Italy) for inclusive adaptation policies. Landscape Urban. Plan 238, 104831.
Patton, S., Pojani, D., 2022. Some like it hot? Unequal provision of tree shading in Australian subtropical suburbs. Aust. Plan. 58 (1-2), 1–10.
Perini, K., Magliocco, A., 2014. Effects of vegetation, urban density, building height, and atmospheric conditions on local temperatures and thermal comfort. Urban For. Urban Green. 13 (3), 495–506.
Phelan, P.E., Kaloush, K., Miner, M., Golden, J., Phelan, B., Silva, H., Taylor, R.A., 2015. Urban heat island: mechanisms, implications, and possible remedies. Annu. Rev. Environ. Resour. 40, 285–307.
Pineda-Pinto, M., Herreros-Cantis, P., McPhearson, T., Frantzeskaki, N., Wang, J., Zhou, W., 2021. Examining ecological justice within the social-ecological-technological system of New York City, USA. Landsc. Urban Plan. 215, 104228.
Pitman, S.D., Daniels, C.B., Ely, M.E., 2015. GI as life support: urban nature and climate change. Trans. R. Soc. South Aust. 139 (1), 97–112.
Poppe, L., Deforche, B., Van Cauwenberg, J., Brondeel, R., Mertens, L., de Weghe, N.V., Benoit, S., Veitch, J., Dyck, D.V., 2022. The association between the number of parks near home and levels of physical activity among community-dwelling older adults: A longitudinal study. Cities 130, 103931.
Polishchuk, Y., Rauschmayer, F., 2012. Beyond "benefits"? Looking at ecosystem services through the capability approach. Ecol. Econ. 81, 103–111.
Potgieter, L.J., Gaertner, M., O'Farrell, P.J., Richardson, D.M., 2019. Does vegetation structure influence criminal activity? Insights from Cape Town, South Africa. Front. Biogeogr. 11 (1), e42035.
Public Health England, 2018. Heatwave Plan for England. UK, 2019. https://assets.publishing.service.gov.uk/media/5a7c83bde5274a559005a655/dh_127235.pdf.
Pullin, A.S., Bangpan, M., Dalrymple, S., Dickson, K., Haddaway, N.R., Healey, J.R., Hauari, H., Hockley, N., Jones, J.P.G., Knight, T., Vigurs, C., Oliver, S., 2013. Human wellbeing impacts of terrestrial protected areas. Environ. Evid. 2 (19), 1–41.
Punj, G., Stewart, D.W., 1983. 'Cluster analysis in marketing research: Review and suggestions for application'. J. Mark. 20, 134–148.
R Development Core Team. 2019. R: A language and environment for statistical computing with R Foundation for Statistical Computing. Vienna, Austria, 2020. http://www.r-project.org/index.html.
Randolph, J. 2008. Online Kappa calculator [computer software]. http://justusrandolph.net/kappa/.
Reyes-Riveros, R., Altamirano, A., De, La, Barrera, F., Rozas-Vásquez, D., Vieli, L., Meli, P., 2021. Linking public urban green spaces and human well-being: A systematic review. Urban For. Urban Green. 61, 127105.
Ren, Z., He, X., Zheng, H., Zhang, D., Yu, X., Shen, G., Guo, R., 2013. Estimation of the relationship between urban park characteristics and park cool island intensity by remote sensing data and field measurement. Forests 4, 868–886.
Robeyns, I., 2005. The capability approach: a theoretical survey. J. Hum. Dev. 6 (1), 93–114.
Robert, B., 2000. Dumping in dixie: race, class and environmental quality. Westview press, New York, US. 2000. https://doi.org/10.4324/9780429495274.

Saaroni, H., Amorim, J.H., Hiemstra, J.A., Pearlmutter, D., 2018. Urban Green Infrastructure as a tool for urban heat mitigation: Survey of research methodologies and findings across different climatic regions. Urban Clim. 24, 94–110.
Saif, M.A., Zefreh, M.M., Torok, A., 2019. Public Transport Accessibility: A Literature Review. Period. Polytech. Transp. Eng. 47 (1), 36–43.
Sangha, K.K., Preece, L., Villarreal-Rosas, J., Kegamba, J.J., Paudyal, K., Warmenhoven, T., RamaKrishnan, P.S., 2018. An ecosystem services framework to evaluate indigenous and local peoples' connections with nature. Ecosyst. Serv. 31, 111–125.
Sanchez, L., Reames, T.G., 2019. Cooling Detroit: A socio-spatial analysis of equity in green roofs as an urban heat island mitigation strategy. Urban For. Urban Green. 44, 126331.
Saw, L.E., Lim, F.K.S., Carrasco, L.R., 2015. The relationship between natural park usage and happiness does not hold in a tropical city-state. PLoS ONE 10 (7), e0133781.
Seddon, 2022. Harnessing the potential of nature-based solutions for mitigating and adapting to climate change. Science 376, 1410–1416.
Sen, A., 1999. Commodities and Capabilities. OUP Catalogue. Oxford University Press.
Soto, J.R., Escobedo, F.J., Khachatryan, H., Adams, D.C., 2018. Consumer demand for urban forest ecosystem services and disservices: Examining trade-offs using choice experiments and best-worst scaling. Ecosyst. Serv. 29, 31–39.
Thorn, J.P.R., Biancardi, R., Aleua, A., Wijesinghec, M., Mdongwed, R.A., Marchantb, S., Shackleton, S., 2021a. Mainstreaming nature-based solutions for climate resilient infrastructure in peri-urban sub-Saharan Africa. Landsc. Urban Plan. 216, 104235.
Thorn, J.P.R., Klein, J.A., Steger, C., Hopping, K.A., Capitani, C., Tucker, C.M., Nolin, A. W., Reid, R.S., Seidl, R., Chitale, V.S., Marchant, R., 2020. A systematic review of participatory scenario planning to envision mountain social-ecological systems futures. Ecol. Sociol. 25 (3), 6.
Thorn, J.P.R., Julia, A.K., Cara, S.K., Hopping, A., Claudia, C., Tuckerg, T.R., Robert, A. M., 2021b. Scenario archetypes reveal risks and opportunities for global mountain futures. Glob. Environ. Change 69, 102291.
Tomyn, A.J., Norrish, J.M., Cummins, R.A., 2013. The subjective wellbeing of indigenous Australian adolescents: validating the personal wellbeing index-school children. Soc. Indic. Res. 110, 1013–1031.
Tuhkanen, H., Cinderby, S., Bruin, A.D., Wikman, A., Adelina, C., Archer, D., Muhoza, C., 2022. Health and wellbeing in cities - Cultural contributions from urban form in the Global South context. Wellbeing, Space Soc. 3, 100077.
Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kázmierczak, A., Niemela, J., James, P., 2007. Promoting ecosystem and human health in urban areas using GI: a literature review. Landsc. Urban Plan. 81, 167–178.
United Nations (UN), 2015. Sustainable Development Goals - global goals 2030. New York, US. 2015. https://sdgs.un.org/goals.
United Nations (UN), 2017. New Urban Agenda. UN Habitat III Secretariat. Quito, Ecuador. 2016. https://habitat3.org/wp-content/uploads/NUA-English.pdf.
United Nations Environment Programme (UNEP), 2010. Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity. Nagoya, Japan, 2010. https://www.cbd.int/abs/doc/protocol/nagoya-protocol-en.pdf.
United Nations Framework Convention on Climate Change (UNFCCC), 2015. Paris Agreement to the United Nations Framework Convention on Climate Change. Paris, France, 2015. https://unfccc.int/process-and-meetings/the-paris-agreement.
United Nations Human Settlements Programme (UN-Habitat), 2015. UN-Habitat Global Country Activities Report: 2015 - Increasing Synergy for Greater National Ownership. US, 2015. https://unhabitat.org/un-habitat-global-country-activities-report-2015-increasing-synergy-for-greater-national-ownership.
United Nations Human Settlements Programme (UN-Habitat), 2022. World cities reports 2022: Scenarios of Urban Futures. pp38-40. https://unhabitat.org/sites/default/files/2022/07/chapter_2_wcr_2022.pdf.
United Nations Environment Programme, 2021. Adaptation Gap Report 2021: The gathering storm – Adapting to climate change in a post-pandemic world. https://www.unep. org/resources/adaptation-gap-report-2021.
Vailshery, L.S., Jaganmohan, M., Nagendra, H., 2013. Effect of street trees on microclimate and air pollution in a tropical city. Urban For. Urban Green. 12 (3), 408–415.
Valente de Macedo, M.E.B., Antonio, A.J., Puppim deOliveir, Shih, W.U., 2021. Urban green and blue infrastructure: A critical analysis of research on developing countries. J. Clean. Prod. 313, 127898.
Vargo, J., Stone, B., Habeebc, D., Liu, P., Russell, A., 2016. The social and spatial distribution of temperature-related health impacts from urban heat island reduction policies. Environ. Sci. Policy 66, 366–374.
Venter, Z.S., Barton, N.D., Martinez-Izquierdo, L., Langemeye, J., Barǿ, F., McPhearson, T., 2021. Interactive spatial planning of urban GI – Retrofitting green roofs where ecosystem services are most needed in Oslo. Ecosyst. Serv. 50, 101314.
Venter, Z.S., Krog, N.H., Barton, D.N., 2020. Linking GI to urban heat and human health risk mitigation in Oslo, Norway. Sci. Total Environ. 709, 136193.
Viechtbauer, W., 2010. Conducting meta-analyses in R with the metafor package. J. Stat. Softw. 36 (3), 1–48 http://www.jstatsoft.org/v36/i03/.
Vogt, J., Hauer, H.J., Fischer, B.C., 2015. The costs of maintaining and not maintaining the urban forest: a review of the urban forestry and arboriculture literature. Arboric. Urban For. 41 (6).
Wang, H., Qiu, F., 2018. Spat. disparities Neighb. Public tree Cover.: Do Modes Transp. Matter? Urban For. Urban Green. 29, 58–67.
Wang, J., Kuffer, M., Sliuzas, R., Kohli, D., 2019. The exposure of slums to high temperature: Morphology-based local scale thermal patterns. Sci. Total Environ. 650, 1805–1817.
Wang, Z.F., Miao, Y., Xu, M., Zhu, Z., Qureshi, S., Chang, Q., 2021a. Revealing the differences of urban parks' services to human wellbeing based upon social media data. Urban For. Urban Green. 63, 127233.
Ward Jr., J.H., 1963. Hierarchical Grouping to Optimize an Objective Function. J. Am. Stat. Assoc. 58, 236–244. https://doi.org/10.1080/01621459.1963.10500845.
Western, M., Tomaszewski, W., 2016. Subjective wellbeing, objective wellbeing and inequality in Australia. PLoS ONE 11 (10), e0163345.
Wolch, J.R., Byrne, J., Newell, J.P., 2014. Urban greenspace, public health, and environmental justice: The challenge of making cities 'just green enough. Landsc. Urban Plan. 125, 234–244.
World Health Organization (WHO), 2001. Geneva macroeconomics and health: investing in health for economic development-report of the commission on macroeconomics and health. Commission on macroeconomics and health, digital design group, Newton, MA USA, 2001. https://apps.who.int/iris/handle/10665/42435.
Xiao, Y., Wang, Z., Li, Z., Tang, Z., 2017. An assessment of urban park access in Shanghai – Implications for the social equity in urban China.Landscape Urban. Plan 157, 383–393.
Zhao, S., Liu, S., Zhou, D., 2016. Prevalent vegetation growth enhancement in urban environments. Proc. Natl. Acad. Sci. USA 113 (22), 6313–6318.
Zoderer, B.M., Tasser, E., Carver, S., Tappeiner, U., 2019. Stakeholder perspectives on ecosystem service supply and ecosystem service demand bundles. Ecosyst. Serv. 37, 100938.
Zhang, j, Yu, J., Zhao, B., Sun, R., Vejre, H., 2020. Links between green space and public health: a bibliometric review of global research trends and future prospects from 1901 to 2019. Environ. Res. 15, 063001.