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The effects of neighbourhood green spaces on mental health of disadvantaged groups: a systematic review

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Mental disorders affect many different groups around the world, and disadvantaged groups are often more severely affected. Neighbourhood green spaces (GS) can improve mental health, especially in disadvantaged groups. Many countries address social inequality and inequity through GS interventions. However, current evidence shows inconsistencies, which may result from the study site, research design, socio-demographically diverse samples, inclusivity considerations, and the different metrics used to quantify GS exposure and mental health benefits. Few conceptual models explain how neighbourhood greenery can act as a structural intervention. We used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method and retrieved 5559 documents from eight databases to examine whether neighbourhood GS can modify mental health associations in disadvantaged groups. We found that neighbourhood GS had substantial protective effects on the mental health of disadvantaged groups. However, disadvantaged people are more influenced by GS quality than by other GS exposures, such as GS usage, distance, and accessibility. Improvements in subjective well-being were most pronounced in terms of mental health outcomes. Mechanistically, neighbourhood GS improves mental health mainly through increased social cohesion and, green visibility, and young people receive further benefits from physical activity (PA). These findings offer a comprehensive understanding of the associations and mechanisms between neighbourhood GS and the mental health of disadvantaged groups, addressing health equities that are induced by the unfair distribution of GS, and thus promoting health-oriented environmental planning and policies.

Introduction

Globally, approximately one in eight people suffer from mental disorders, which are the leading cause of years lived with disability (YLD), affecting one in every six YLD globally (World Health Organization 2022). Mental disorders affect people of all ages, cultures, and backgrounds, but the burden of health disorders is unevenly distributed within and among

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populations (Rogers 2004), especially among disadvantaged groups whose low socioeconomic status (SES) makes them more prone to mental illnesses due to poor living conditions, unemployment, and physio-psychological disparities. These situations increase the difficulty of obtaining high-quality mental health treatments (World Health Organization 2022). Although national authorities are attempting to reduce inequality, disadvantaged groups still face systemic and unavoidable health disparities relative to those with higher SES (Sugiyama et al. 2016). Green spaces (GS)are nature-based solutions for improving health and reducing health inequities (Wendelboe-Nelson et al. 2019), particularly for disadvantaged groups (Nawrath et al. 2021; Rigolon et al. 2021). Additionally, neighbourhood-focused activity engagement is considered a valuable strategy for achieving these goals (Rifkin et al. 2000; Team 2010; Wallerstein and Duran 2006); thus, the availability of neighbourhood GS is critical for promoting residents' health. Moreover, studies show that neighbourhood GSs have a more pronounced effect on mental than on physical health (Liu et al. 2019; Sugiyama et al. 2008), especially for low-income and poor urban or suburban populations (Maas et al. 2009; Mitchell and Popham 2008; Mitchell et al. 2015). GSs may enhance residents' mental health through several mechanistic pathways, including instoration (e.g., encouraging physical activity [PA] and promoting social cohesion), restoration, and mitigation (Lachowycz and Jones, 2013; Perrino et al. 2019; Wan et al. 2022). Therefore, previous studies have examined neighbourhood-based GS interventions as leverage to enhance health and reduce health disparities (Anzivino 2019; Astell-Burt et al. 2014; Canberra 2011; de Oliveira et al. 2013). Current evidence is inconsistent, however, potentially due to study site (Nawrath et al. 2021), research design (Wendelboe-Nelson et al. 2019), socio-demographically diverse samples (Rigolon et al. 2021), and various metrics used to quantify GS exposure and mental health benefits(Shuvo et al. 2020). The common practice of characterising vulnerable groups based on SES and race/ethnicity also may lack comprehensive inclusivity. Health disparities are systemic, as noted by Starfield (2001), and are intrinsically linked to systemic social disadvantage. Every group experiencing social disadvantage should have equal opportunities to achieve their optimal health status (Braveman et al. 2011). These factors make comprehensive assessments of the aspects of neighbourhood GS that affect the mental health of the broader vulnerable groups difficult. Thus, a systematic review is necessary to articulate predictable GS exposures, then examine the heterogeneity in the associations between GS and the mental health of broader disadvantaged groups across different study sites and sociodemographic contexts. This study is the first to explore the protective effects and impact pathways of neighbourhood GS on the mental health of disadvantaged groups using different metrics. Through a systematic review of quantitative research, this study discusses the following five questions:

1. Is there a discrepancy between the results of subjective and objective indicators?
2. Which types of green exposure metrics could predict the mental health of disadvantaged groups more efficiently and effectively?
3. Which aspect of mental health is more likely to be improved in the disadvantaged groups via the lens of green exposure?
4. Is the protective effect of greenery exposure consistent across vulnerable populations in different regions worldwide and in different specific environments?
5. What underlying pathways link green exposure to disadvantaged groups' mental health?

Methods

Search strategy. This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines(Moher et al. 2009). The literature search was conducted from 1 January 2012 to 26 February 2023 as studies prior to 2012 were concentrated specific developed countries and a small number of related topics. Eight frequently accessed databases—Web of Science, ProQuest, Medline, PsycINFO, CINAHL Plus, Cochrane Library, PubMed, and Embase— were used to search for relevant papers on disadvantaged neighbourhood GS. Table 1 presents the terms used to search the article titles, abstracts, and keywords. The definition of the target population includes terms that appear in relevant systematic reviews (Bonevski et al. 2014; Chenyang et al. 2022; Didsbury et al. 2016; O'Mara-Eves et al. 2015; Rigolon et al. 2021) while covering those who are economically, racially, physically, psychologically, or functionally disadvantaged or, disenfranchised people (Lambert 1990). Because some older adults and are not

Table 1 Search terms used for the systematic search.

Main keywords	Search terms
Target population	disadvantage OR disadvantaged OR socioeconomic status OR vulnerable OR disparities OR disparity OR equality OR equity OR gap OR gaps OR gradient OR gradients OR determinants OR inequalities OR inequality OR inequities OR inequity OR unequal OR poverty OR impoverished OR Low-income OR poor OR racially/ethnically minoritised OR health inequalities OR the disabled OR disabled OR handicapped OR reduced mobility OR hard-to-reach OR difficult-to-reach OR chronic OR chronically mentally ill OR disenfranchised OR deprived OR unprivileged OR unemployed OR Career exposure OR high school drop-outs OR criminal offenders OR prostitutes OR veteran OR juvenile delinquents OR gang members
Green exposure	community green space OR community greenspace OR community greenness OR community green OR community green infrastructure OR community green area OR community garden OR community land OR community parks OR residential green space OR residential greenspace OR residential greenness OR residential green OR residential green infrastructure OR residential green area OR residential garden OR residential land OR residential parks OR public housing green space OR public housing greenspace OR public housing greenness OR public housing green OR public housing green infrastructure OR public housing green area OR public housing garden OR public housing land OR neighborhood green space OR neighborhood greenspace OR neighborhood greenness OR neighborhood green OR neighborhood green infrastructure OR neighborhood green area OR neighborhood garden OR neighborhood land OR neighborhood parks
Mental health outcomes	mood disorder OR dysthymic disorder OR depressive disorder OR depression OR bipolar disorder OR cyclothymic disorder OR anxiety disorder OR anxiety OR panic disorder OR agoraphobia OR phobia OR obsessive-compulsive disorder OR posttraumatic stress OR stress, OR acute stress disorder OR somatisation disorder OR somatoform disorder OR hypochondriasis OR body dysmorphic disorder OR factitious disorder OR depersonalization disorder OR dissociative amnesia OR dissociative disorder OR mental health OR mental hygiene OR mental disorders OR emotional well-being OR psychological well-being OR social well-being OR well-being OR addiction OR internet addiction

Table 2 Eligibility criteria.

Criteria for the screening	1. Employing quantitative methods through observation or experimental design. 2. Mental health outcomes appeared as outcomes or mediator variables, and GS indicators appeared. 3. Disadvantaged populations appear as the primary object of study or are expressed as indicators that reflect disadvantaged populations (e.g., SES) as covariates (e.g., moderating variables) in the stratified analysis. 4. At least one objective or subjective (self-reported or perceived) indicator of mental health (anxiety or stress) is assessed. 5. At least one objective or subjective (e.g., self-reported or perceived) measure of greenspace availability or exposure (e.g., Normalised Difference Vegetation Index [NDVI], accessibility, etc.) is reported. 6. Analyse whether the magnitude or direction of the association between GS and mental health differs between vulnerable and non-vulnerable groups (e.g., sample split analysis or interaction tests). 7. It must be a peer-reviewed journal published in English.
Criteria for the excluding	1. Research using virtual environments, as our aim is to specifically understand the effects of natural exposure experienced in real-life settings. 2. The cause of exposure is institutionalised in a specific setting (e.g., hospital, prison, or school) or is a well-documented factor, since participants in these places experience green space exposure that does not reflect daily life. 3. Non-peer reviewed articles, commentaries, case reports and conference papers. 4. Studies which did not test associations and examined proxy measures of mental health or disadvantaged groups, such as sleep quality or family crowding.

included in these categories, we did not add them to the search groups for this study. Relevant systematic reviews on green exposure and mental health were also referenced (Astell-Burt et al. 2022; Núñez et al. 2022; Xu et al. 2022). To meet our research objectives, we specifically focused on residential areas and surrounding greenery rather than urban GS in general. Supplementary File 1 includes detailed explanations of the search strategy and inclusion criteria.

Eligibility criteria. The specific criteria for the screening were as follows (Table 2):

Selection process and data extraction. Figure 1 illustrates the process of searching for and selecting articles for this systematic. All articles retrieved from each database were processed using EndNote reference management. Two reviewers independently assessed the titles and abstracts based on the selection criteria (Z.X., K.L.); next, each reviewer (Z.X., K.L., J.Z., YX.L.) examined articles which required full-text assessments. Any disagreements or differences were resolved through discussion and consultation with a third reviewer (T.N., B.Z., JH.Z., JG.Z.). We extracted information from each selected article, including the year of publication, author, region, country, study design, study sample and size, data related to disadvantaged populations, exposure measures and assessments, outcome measures, and measures of association. We could not conduct a meta-analysis of each study's results due to heterogeneity in study designs, variable GS measurements, and mental health outcomes (Astell-Burt et al. 2022; Van den Berg et al. 2015).

Results

Study selection. Figure 1 shows the results of the systematic search based on PRISMA criteria. We retrieved 5559 documents from eight databases and removed 1550 duplicates. After checking titles and abstracts, full text was screened in 185 of the remaining 4009 documents. We excluded 144 studies, summarised in Supplementary File 2. A total of 41 studies met the inclusion criteria. (Supplementary File 3).

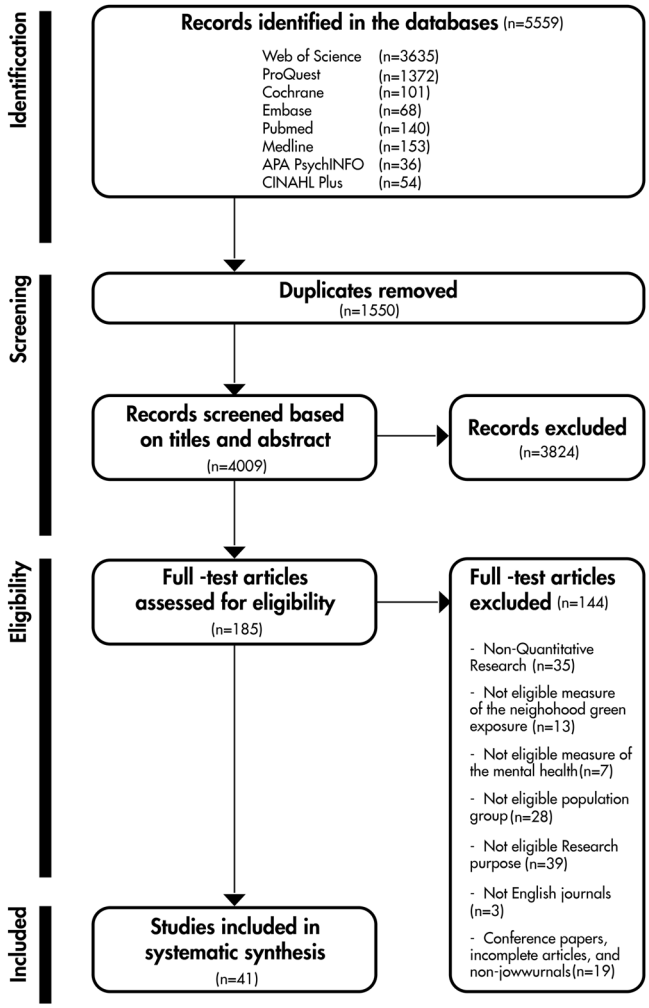

Fig. 1 Flowchart illustrating the systematic search process. This flowchart shows the process of collecting and gradually screening the literature used for analysis.

Study characteristics. The reviewed studies were concentrated in the European region ($n = 17$), with studies from the United Kingdom (UK) (Chalmin-Pui et al. 2021; Flouri et al. 2014; McEachan et al. 2016; McEachan et al. 2018; McElroy et al. 2021; Roberts et al. 2021; Roe et al. 2017; Roe et al. 2013; Sarkar et al. 2018; Thompson et al. 2016; Thompson et al. 2019; Thompson et al. 2012) ($n = 12$) dominating the group. The remaining studies were conducted in Spain (Subiza-Pérez et al. 2021; Triguero-Mas et al. 2015) ($n = 2$), Belgium (Mendoza et al. 2023) ($n = 1$), Norway (Mouratidis 2020) ($n = 1$), and Finland (Gonzales-Inca et al. 2022) ($n = 1$). In total, 10 studies were conducted in North

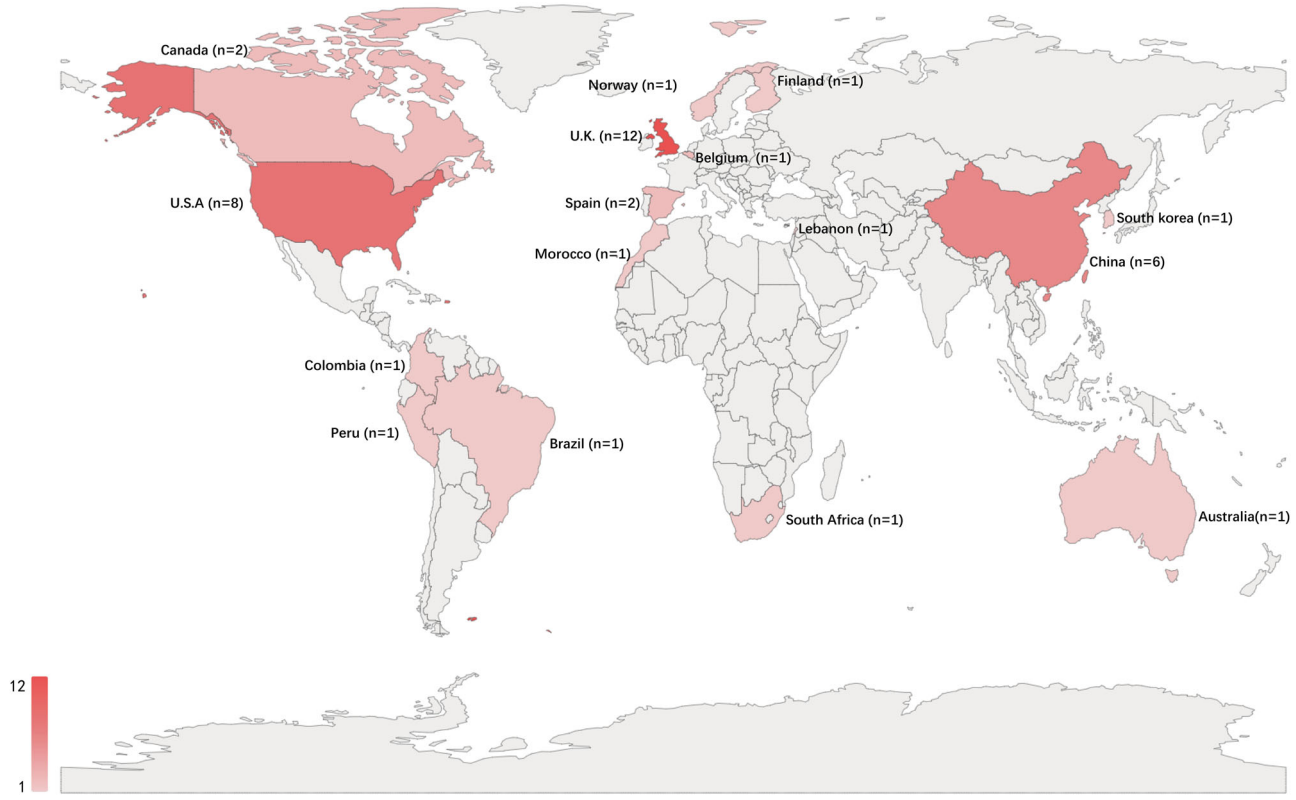

Fig. 2 Countries covered by the studies included in this synthesis. This figure expresses the geographical distribution of studies conducted on neighbourhood green spaces and mental health of vulnerable groups.

American, mostly in the United States (Ambrose et al. 2020; Brown et al. 2018; Kodali et al. 2023; Kondo et al. 2022; Lee et al. 2023; Mennis et al. 2021; Murphy et al. 2022; South et al. 2018) ($n = 8$), and Canada (Cottagiri et al. 2022; Crouse et al. 2021) ($n = 2$). The Asian ($n = 8$) region was dominated by studies from China (Ma et al. 2022; Wang et al. 2022; Wu et al. 2021; Xiao et al. 2021; Yang et al. 2020; Zhang et al. 2020) ($n = 6$), with studies conducted in South Korea (Won and Lee 2020) ($n = 1$), Lebanon (Talhouk et al. 2021) ($n = 1$), Australia (Sugiyama et al. 2016) ($n = 1$), South Africa (Tomita et al. 2017) ($n = 1$), Morocco (Afrad and Kawazoe 2020) ($n = 1$), Peru (Korn et al. 2018) ($n = 1$), Colombia (Hong et al. 2021) ($n = 1$), and Brazil (Barreto et al. 2019) ($n = 1$). (Fig. 2)

In all studies, definitions of neighbourhood GS included internal greenery, private and public gardens, vertical, parks, jungles, and vacant GS. Sample sizes ranged from 25 to 3,549,514 individuals. Approximately 20% of the studies ($n = 8$) included fewer than 200 participants, and the smallest sample size was obtained from an exploratory study that measured salivary cortisol levels in the UK ($n = 25$) (Thompson et al. 2012). A Census-based longitudinal study conducted in Belgium had the largest sample size ($n = 3,549,514$) (Mendoza et al. 2023). Most studies focused on adults ($n = 35$). Some focused on pregnant women (McEachan et al. 2016; Subiza-Pérez et al. 2021), older adults (Brown et al. 2018; Cottagiri et al. 2022), children (Flouri et al. 2014; McEachan et al. 2018), and adolescents (Mennis et al. 2021). The 41 studies included, one quasi-experimental study (Talhouk et al. 2021) and one randomised trial (RT) (South et al. 2018). The other 39 studies were observational, and all but nine were longitudinal. Epidemiological studies have not examined mental health across geographical units. Most studies used the logistic regression model for analysis ($n = 13$), followed by (generalised) linear regression ($n = 10$) and structural equation modelling (SEM) ($n = 3$) which examined their potential underlying mechanisms.

Green exposure and mental health measures. To facilitate the understanding of green exposure metrics and their correlation with mental health outcomes across all studies, we established metrics for generalised categories of both green exposure and mental health outcomes, relying on the characteristics table (Supplementary File 3). Chord diagrams were generated to clearly convey the relationships among all green exposure metrics, mental health outcomes, and their respective categories, as identified within the studies.

GS measures. Objective evaluation metrics were used in 74% of the studies ($n = 31$) and 20% used both subjective and objective metrics ($n = 8$). The objective metrics mainly consisted of availability (incorporating land use/land cover and satellite-derived vegetative metrics [e.g., NDVI and Landsat Enhanced Vegetation Index [EVI]), street greenery visibility (calculated using deep learning method to analyse street view maps), and accessibility (proximity to recreational GS). The subjective indicators, mainly consisted of—— perceived quality, perceived greenery visibility, perceived quantity, perceived distance/accessibility, GS usage (i.e., frequency and duration), horticultural activities, and ownership of private gardens or other forms of small-scale green exposure (Fig. 3). Most studies interchangeably selected one to three green exposure indicators, whereas Thompson et al. (2016), Thompson et al. (2019), Roe et al. (2017), and McEachan et al. (2018) used more diversified green exposure metrics, including not only land cover maps, NDVI, and other remote sensing-based measurement methods, but also paid more attention to human exposure Factors such as GS perception, GS satisfaction, and frequency of use were used to capture actual feelings about the GS.

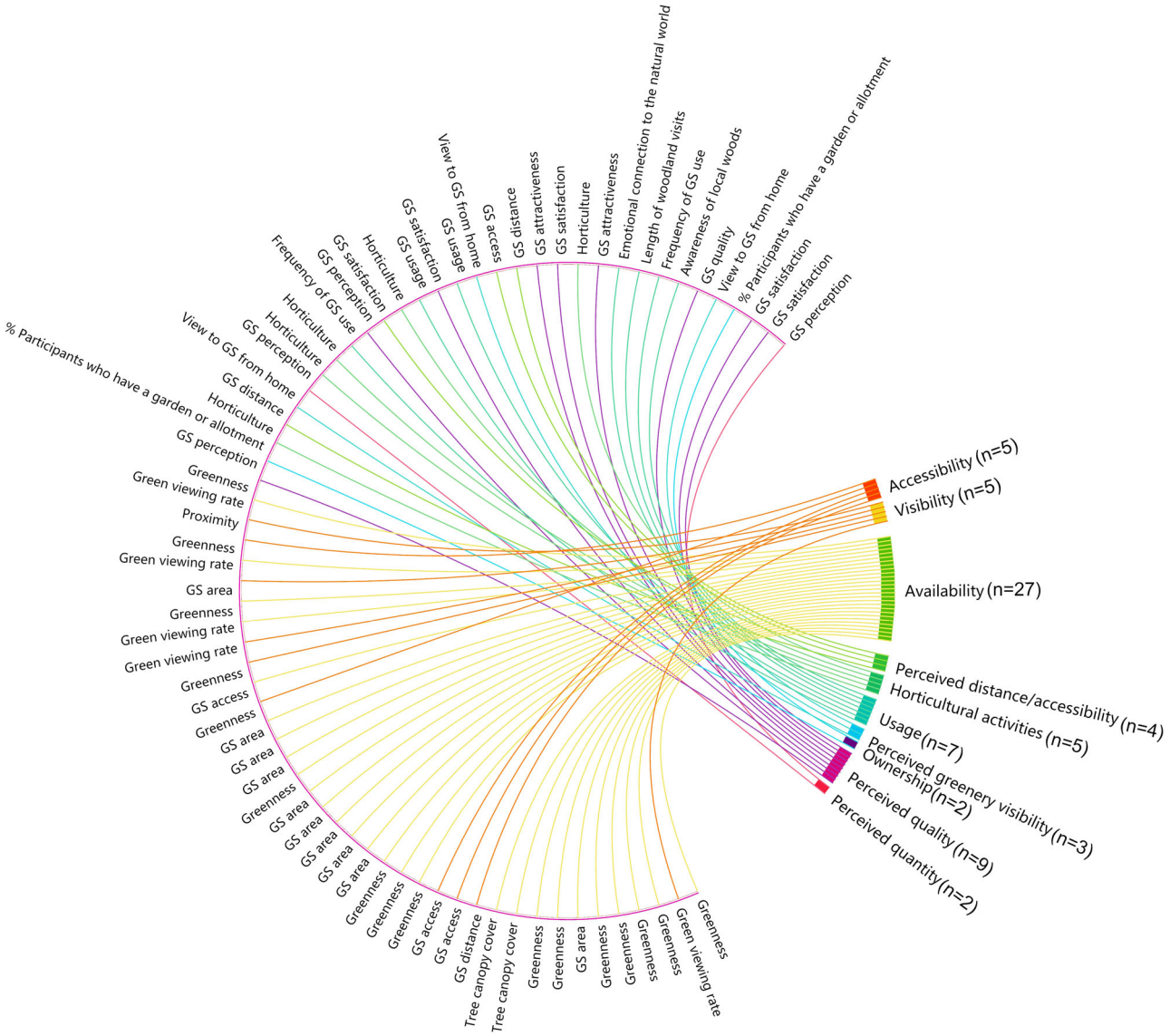

Fig. 3 Green space (GS) exposure metrics addressed in various studies. The chord diagram summarizes the variables used in all the studies involved to assess green space exposure.

Mental health measures. To measure mental health, most studies used a single self-reported subjective assessment measure ($n = 34$); three studies measured only objective indicators (Brown et al. 2018; Lee et al. 2023; Mendoza et al. 2023), and five used both subjective and objective methods (Chalmin-Pui et al. 2021; Cottagiri et al. 2022; Roe et al. 2013; Thompson et al. 2012; Triguero-Mas et al. 2015). Research on the measurement of mental health has been divided into three main categories of well-being, specific mental disorders, and overall mental distress (Fig. 4).

Measurement of disadvantaged groups. The definition of disadvantaged groups in the reviewed studies overwhelmingly (93%) included SES as an important factor; 35 studies considered only SES, and four focused on SES and race (McEachan et al. 2016; McEachan et al. 2018; Mennis et al. 2021; Roberts et al. 2021). Spinal cord injuries (Murphy et al. 2022) and refugee status (Talhouk et al. 2021) have also been studied as key metrics for disadvantaged groups. Disadvantaged groups investigated also included veterans (Lehmann et al. 2018), refugees (Eggert et al. 2015), indigenous people (Hatala et al. 2020), and people with disabilities (Pihl 2015). However, the sample size in these studies was small, and they were conducted qualitatively.

Associations between multiple GS exposures and mental health outcomes. Of the 41 studies, the majority (70%, $n = 29$) concluded that neighbourhood GS had a protective effect on the mental health of vulnerable populations, 17% ($n = 7$) did not find this effect, and 12% ($n = 5$) found a negative effect. (Table 3) Furthermore, 138 associations between metrics were extracted from 41 studies. Most studies used GS exposure metrics that were consistent with the corresponding mental health outcomes as expected, but in seven studies (17%) some green exposure indicators used were inconsistent with expected outcomes despite positive mental health outcomes (e.g., in one study with a positive mental health result, there was no contribution or a negative contribution of some GS metrics to mental health). Among the studies with positive final mental health outcomes, some mental health metrics/outcomes used in 10% ($n = 4$) of the studies produced unexpected results (e.g. only stress improved, rather than subjective well-being).

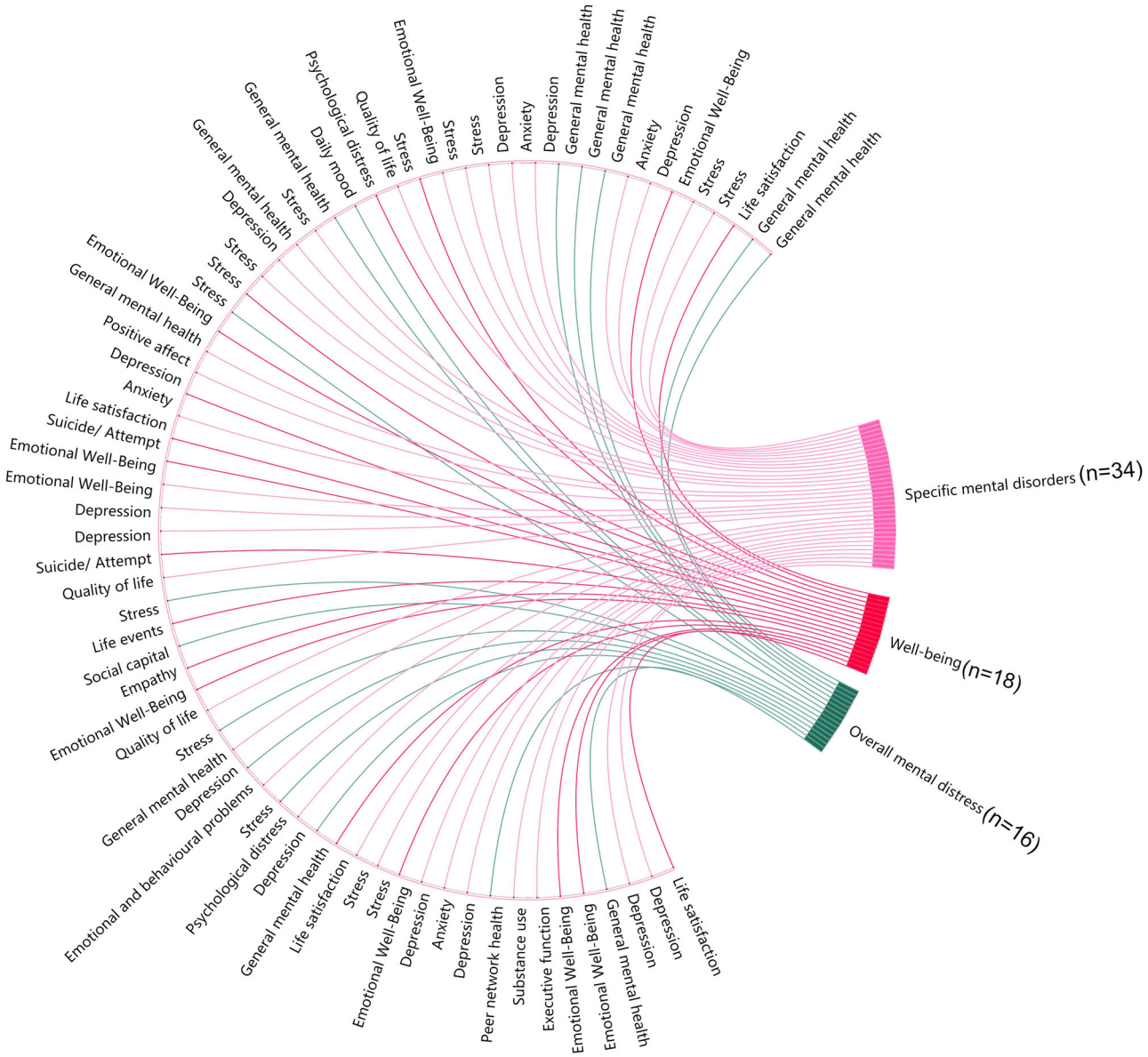

Fig. 4 The mental health metrics involved in each study and the results. The chord diagram summarizes the variables used to assess mental health in all the studies involved.

Subjective GS metrics. Figure 5 shows the metrics used to assess perceived quality, which yielded positive effects in 78% ($n = 7$) of the studies. Xiao et al. (2021) and Roe et al. (2017) found that judgements of perceived quality were more influential in shaping perceptions of GS than the number or proximity of available GS. Interestingly, perceiving the presence of high-quality GS, even if they are not used, was shown to improve mental health (Roe et al. 2017), and a study by Kodali et al. (2023) demonstrated a direct association between GS perceptions and quality of life (QoL). However, Sugiyama et al. (2016) assessed neighbourhood park attractiveness using the Public Open Space Auditing Tool (POSDAT) and found that the mental state of residents with different SES was not related to park attractiveness.

Of the metrics used to assess the perceived greenery visibility, 67% ($n = 2$) had a positive effect. Roe et al. (2017) suggested that older individuals experience sensory contact with nature through larger gardens and/or views from home, leading to reduced stress levels. However, Thompson et al. (2016) found that having a view of GS from home was not significantly correlated with perceived stress in economically deprived communities. A Spanish study of pregnant women also found no significant correlation in low-income groups (Subiza-Pérez et al. 2021).

Regarding horticultural activities, all metrics used in the studies ($n = 5$) showed positive effects. Three studies focused on site preparation, vegetation planting, and installation of fencing (Korn et al. 2018; South et al. 2018; Talhouk et al. 2021). Two other studies focused on increasing the type and number of plants in existing gardens, their maintenance, and their daily use (Ambrose et al. 2020; Chalmin-Pui et al. 2021).

Of the metrics used to assess perceived quantity, 50% ($n = 1$) showed a positive effect. Yang et al. (2020) found that social cohesion and perceived environment can indirectly improve mental health. However, there is no direct relationship between perceived quantity, perceived walking distance (Roe et al. 2017), accessibility (Kondo et al. 2022; Subiza-Pérez et al. 2021) and mental health status. Subiza-Pérez et al. (2021) found that the association between perceived greenness (the amount of perceived greenness and walking distance to the GS) and social cohesion was consistent across income groups.

Table 3 Associations between multiple GS exposures and mental health outcomes.

Studies included in the synthesis	Subjective metrics							Objective metrics			Mental health outcome			Protective effects
	Perceived quality	Perceived greenery visibility	Horticultural activities	Perceived quantity	Usage	Perceived distance/ accessibility	Ownership	Accessibility	Availability	Visibility	Well-being	Overall mental distress	Specific mental disorders	
Yang et al. (2020)				+								+		+
Xiao et al. (2021)	+							+	▲	▲		+		+
Wu et al. (2021)									+	+				+
Won and Lee (2020)	−												−	▲
Thompson et al. (2016)		+					+		+		+		+	+
Wang et al. (2022)	+								▲	+			+	+
Triguero-Mas et al. (2015)								▲	▲			▲	▲	▲
Tomita et al. (2017)									−				−	−
Thompson et al. (2012)									+		▲		+	+
Thompson et al. (2019)					−						−		−	−
Sugiyama et al. (2016)	▲								▲					▲
South et al. (2018)			+									+		+
Sarkar et al. (2018)									+				+	+
Roe et al. (2013)									+				+	+
Roe et al. (2017)	+	+				▲			+		+		+	+
Roberts et al. (2021)									+			+		+
Murphy et al. (2022)									−		−		−	−
Mouratidis (2020)									▲		▲		▲	▲
Mendoza et al. (2023)									+			+		+
McElroy et al. (2021)					+						+			+
McEachan et al. (2018)	+				▲				+		+			+
McEachan et al. (2016)								▲	+				+	+
Ma et al. (2022)								+					+	+

Table 3 (continued)

Studies included in the synthesis	Subjective metrics							Objective metrics			Mental health outcome			Protective effects
	Perceived quality	Perceived greenery visibility	Horticultural activities	Perceived quantity	Usage	Perceived distance/ accessibility	Ownership	Accessibility	Availability	Visibility	Well-being	Overall mental distress	Specific mental disorders	
Lee et al. (2023)									+			+		+
Korn et al. (2018)			+								+	+	−	+
Kondo et al. (2022)	+					▲			+		+			+
Kodali et al. (2023)	+				▲						+		▲	+
Hong et al. (2021)									−			−		−
Gonzales-Inca et al. (2022)									▲				▲	▲
Flouri et al. (2014)									+			+		+
Crouse et al. (2021)									▲			▲	▲	▲
Cottagiri et al. (2022)									+		+	+	+	+
Chalmin-Pui et al. (2021)			+								▲		+	+
Brown et al. (2018)									+				+	+
Barreto et al. (2019)									+				+	+
Mennis et al. (2021)										+		+	+	+
Zhang et al. (2020)									+		+			+
Ambrose et al. (2020)			+								+			+
Subiza-Pérez et al. (2021)		▲		▲		▲						▲		▲
Talhouk et al. (2021)			+										+	+
Afrad and Kawazoe (2020)	+						−				+		−	−

Note: + Positive, ▲ No correlation, - Negative.

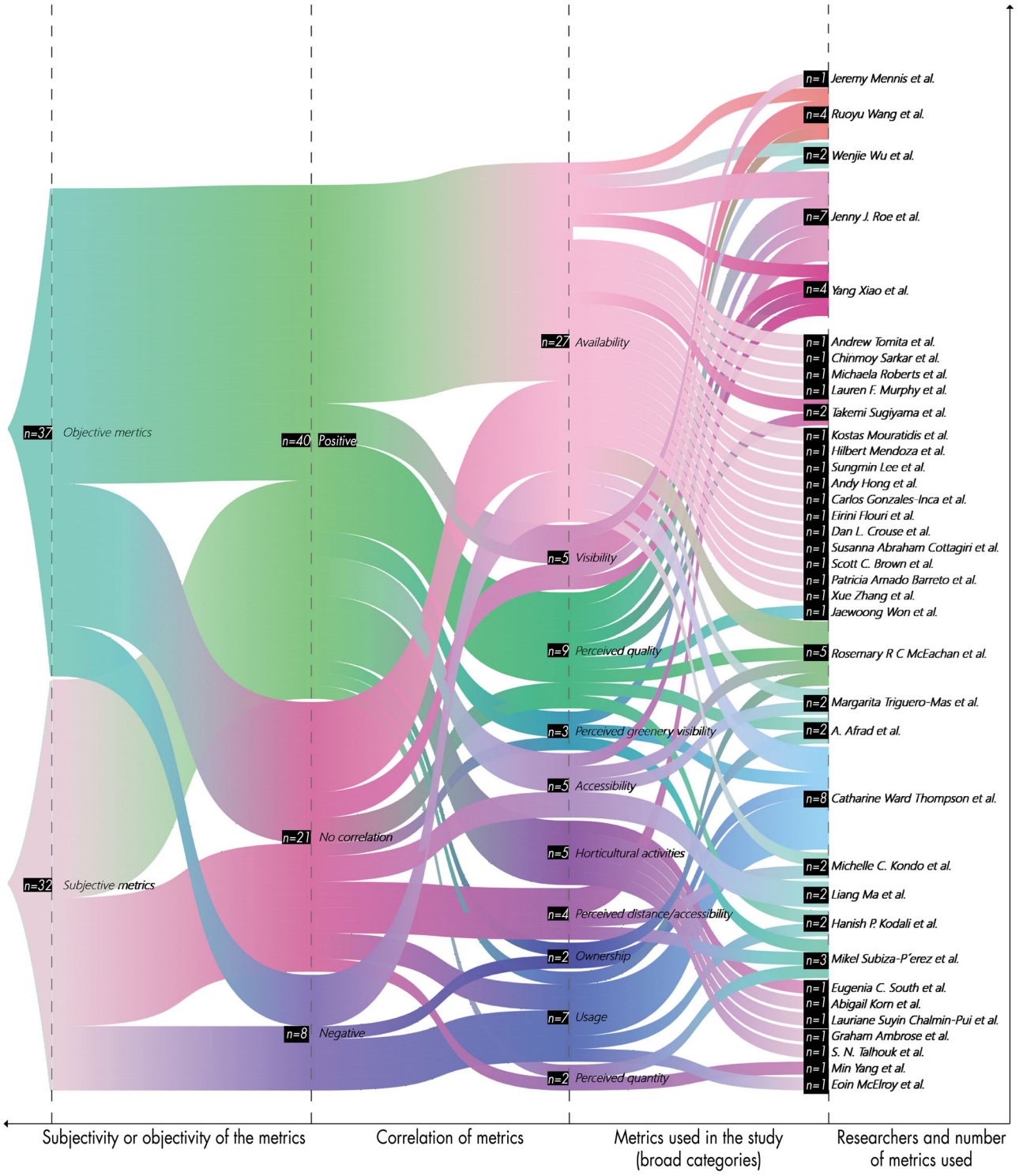

Fig. 5 Correlation of GS metrics across studies. The Sankey diagram shows the connection between the green space exposure indicators used in each study and the results of the study.

Among the metrics used to assess GS usage, only one study (14%) demonstrated a positive effect. GS interventions, such as providing a place for social activities, did not reduce mental burden, and sometimes and even exacerbated perceived stress. The timing and frequency of visits to nature did not explain the association between the intervention and increased perceived stress (Thompson et al. 2019) or ease the relationship between park use and QoL (Kodali et al. 2023). Children's time spent outdoors also has no effect on externalising and internalising behavioural difficulties or prosocial behaviours (McEachan et al. 2018). However, McElroy et al. (2021) found that the use of neighbourhood GS by disadvantaged groups as social venues could enhance feelings of intimacy and improve mental well-being.

Two studies on the ownership of GS with regard to private gardens, allotments, or small greenery have shown that the protective effect of neighbourhood GS is influenced more by the district and type of GS in which the disadvantaged group is

located 50% ($n = 1$) showed a positive effect. A study conducted in the UK (Thompson et al. 2016) showed that people who owned gardens or allotments experienced less stress, whereas a study of PSG in deprived areas of Morocco, found that garden owners had higher average depression scores than non-owners (Afrad and Kawazoe 2020).

Objective GS metrics. As shown in Fig. 5, of the metrics used to assess availability, 63% ($n = 17$) demonstrated positive effects. Neighbourhood GS exposure to significantly reduced the risk of depression or major depression in disadvantaged groups (Brown et al. 2018; Sarkar et al. 2018). However, this protective effect on mental health was not significant among high-income groups (Barreto et al. 2019; Zhang et al. 2020). Residential GS also alleviated the stress of residents in disadvantaged neighbourhoods (Thompson et al. 2016; Thompson et al. 2012), with higher levels of neighbourhood GS (>43% of the area) associated with lower perceived stress and a sharp decrease in cortisol secretion (Roe et al. 2013). In addition to mental health disorders, such as depression and stress, the health benefits of neighbourhood GS are reflected in prescription rates (Roberts et al. 2021) and suicide rates (Lee et al. 2023; Mendoza et al. 2023). McEachan et al. (2018) also found that GS availability alleviated mental health problems among non-white children in the UK. However, the NDVI effect was not significant in any buffer zone when GS satisfaction and time spent outdoors were included. The protective effect of GS availability may be diminished by simultaneous assessment of multiple subjective or objective indicators. Wang et al. (2022) found that GS quality moderated the relationship between SES indicators and mental health after simultaneously assessing NDVI, street-view greenness (SVG) quantity, and SVG quality, whereas NDVI had no moderating effect.

Regarding visibility metrics, 60% ($n = 3$) showed positive effects. For low-income populations, SVG were negatively associated with the probability of lower life satisfaction (OR = 0.597, 95% CI = 0.298–0.965) (Wu et al. 2021). Wang et al. (2022) assessed both SVG quality and quantity, and found that SVG quality was more important in disadvantaged groups. Mennis et al. (2021) assessed SVG and found that GS may play an important role in moderating the peer impact of substance use among disadvantaged urban youth. However, objective GS indicators, such as the streetscape Vegetation Index [VGI], NDVI, and park area, did not have a significant impact on the mental health of disadvantaged groups in high-density disadvantaged communities (Xiao et al. 2021). Regarding accessibility metrics, 60% ($n = 3$) showed positive effects. Ma et al. (2022) and Xiao et al. (2021) found that park distance and accessibility are significantly associated with mental health effects among those with lower incomes. However, the samples in McEachan et al. (2016) and McEachan et al. (2018) all lived near a GS, but no association was found between the distance to a GS and mental health.

Associations between different measures of mental health and mental health outcomes. As shown in Fig. 6 of the metrics used to assess well-being, 72% ($n = 13$) showed positive effects. Nine metrics directly assessed emotional well-being (EWB), and only two did not show a positive effect of GS on the subjective well-being from disadvantaged groups. Studies assessing life satisfaction ($n = 4$) are more likely to indicate improvements in subjective well-being among vulnerable individuals (Wu et al. 2021) as well as reduced depression (Afrad and Kawazoe 2020; Cottagiri et al. 2022). Mouratidis (2020) found no significant association between anxiety symptoms and quality of life for residents in deprived communities, even when infrastructure, such as GS and public transport were relatively evenly distributed.

In contrast, the improvement effect of neighbourhood GS on overall mental distress and specific mental disorders was relatively low, at 61% ($n = 11$) and 63% ($n = 20$), respectively. Individuals across different age groups, including children (Flouri et al. 2014), adolescents (Mennis et al. 2021), and middle-aged and older adults (Cottagiri et al. 2022), all benefit from neighbourhood GS. Furthermore, compared to depression and anxiety ($n = 8$, 57%), alleviation of stress ($n = 7$, 70%) was significantly more prominent, regardless of whether stress was self-reported (access to gardens and allotments, neighbourhood GS, horticulture, and park perception) (Kodali et al. 2023; Korn et al. 2018; Thompson et al. 2016) or based on biological markers (saliva cortisol) (Chalmin-Pui et al. 2021; Roe et al. 2013; Thompson et al. 2012).

Types of disadvantaged people and differences in mental health outcomes. Of the 30 studies conducted in developed countries, 73% ($n = 22$) reported positive results. However, protective effects were not observed in three of the four studies conducted in developed countries with high welfare. In a cohort study conducted in Finland (Gonzales-Inca et al. 2022), only moderate neighbourhood-level mental health was found to be associated with green exposure. Two studies conducted in Canada (Crouse et al. 2021) and Norway (Mouratidis, 2020) found no such correlations.

Regional differences were more pronounced in developing countries than in developed ones; the studies conducted in China ($n = 5$) all observed better protection effects, while half of the remaining six studies reported no or negative effects of GS on disadvantaged groups. The beneficial effects of neighbourhood greenery appear to be much stronger for people living in middle- and high-SES communities in South Africa (Tomita et al. 2017), and Colombia (Hong et al. 2021) than for low-income groups.

GS often has negative impacts when a sample includes individuals with disabilities or long-term illnesses. For people with spinal cord injuries, neighbourhoods with more GS reported higher levels of depression (Murphy et al. 2022). In addition, GS has the potential to provide a venue for trading and substance use for individuals with active substance use disorders (Mennis et al. 2021).

In studies involving both SES and race ($n = 6$), racial factors showed the same results as SES ones. Only one study found that neighbourhood GS failed to improve the mental health of ethnic minority residents (Mendoza et al. 2023). Among studies involving informal settlements ($n = 5$), three reflected positive effects. In Xiao et al. (2021), mental health status was only positively associated with subjective GS satisfaction, not with objective metrics. In Korean public housing communities, GS did not increase social capital or improve mental health (Won and Lee, 2020). In densely populated settlements with high poverty rates in Morocco, a small amount of GS contributes to higher levels of depression among owners (Chalmin-Pui et al. 2021).

Potential pathways and mechanisms by which a neighbourhood GS affects the mental health of disadvantaged people. Numerous studies have explored the pathways by which GS affects health, with well recognised pathways including noise reduction, air pollution reduction, psychological recovery and stress reduction, encouraging health-promoting behaviours (e.g. social interaction, PA) (Dzhambov et al. 2018; Hartig et al. 2014; White et al. 2013). Some indirect effects are seen, such as social cohesion, although corresponding mediating effects were found in studies by Dadvand et al. (2016), De Vries et al. (2013), and Maas et al. (2009), others failed to identify them. Some studies found that stress reduction (Triguero-Mas et al. 2017) and mitigation of traffic emissions (Gascon et al. 2018) were more

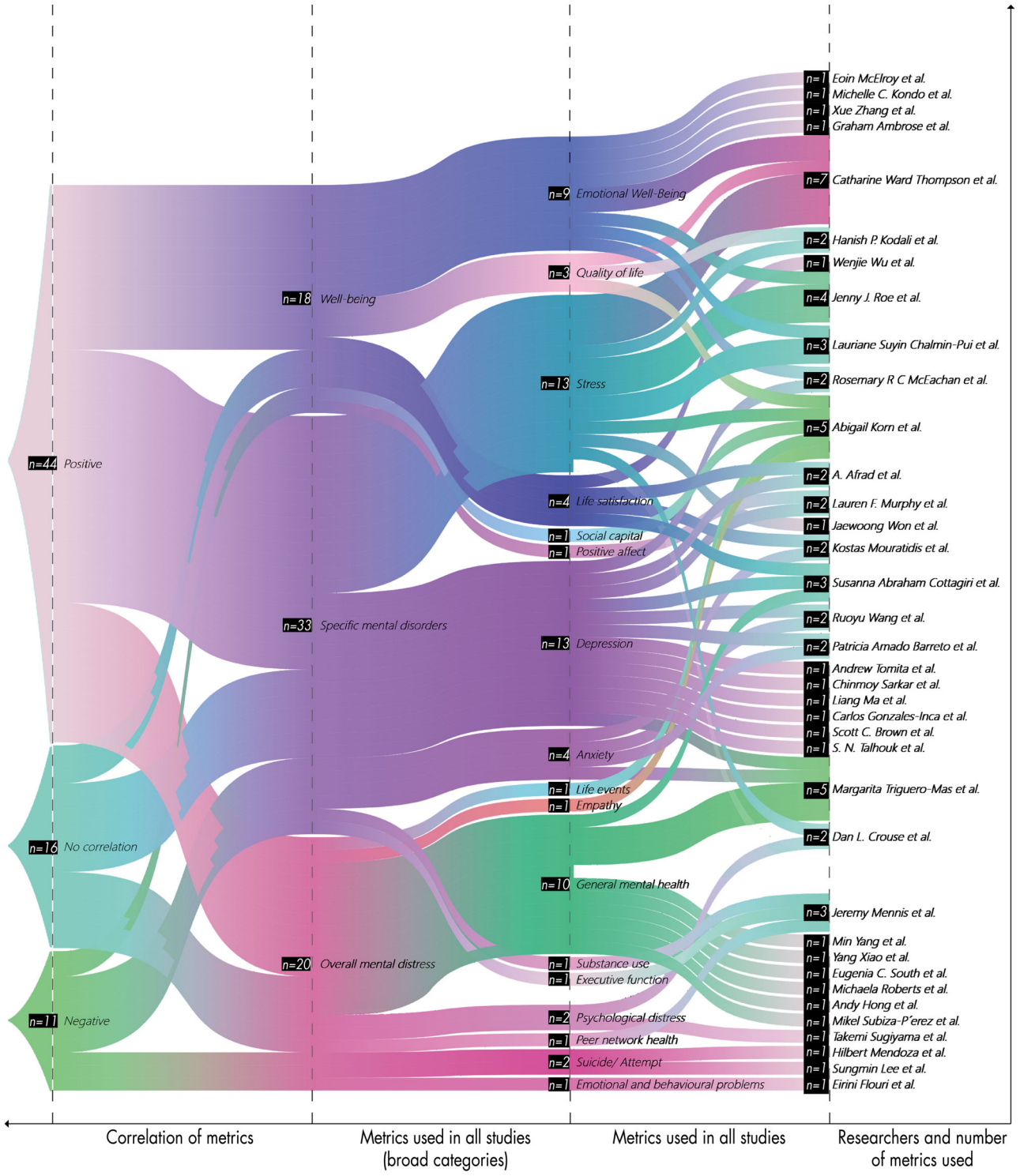

Fig. 6 Correlation of mental health outcomes across studies. This Sankey diagram shows the connection between the mental health outcomes used in each study and the results of the study.

important than PA and social cohesion. This may occur because the heterogeneity of the individual and group characteristics of the target population was not considered (Chen et al. 2021),and cross-sectional studies do not adequately consider various pathways. Therefore, a comprehensive summary for disadvantaged groups is required.

Yang et al. (2020) demonstrated that social cohesion is an important mediator between perceived GS and mental health in disadvantaged groups, with pathways involving environmental disturbances and social cohesion. This was further confirmed by Subiza-Pérez et al. (2021), who found that social cohesion positively influenced mental health in low- (−0.20) and middle-income (−0.28) groups. Thompson et al. (2016) discovered that a sense of place belonging, social isolation, and social well-being were mediators of neighbourhood GS and perceived stress. Wang et al. (2022) confirmed the quality of GS moderated the relationship between SES and mental health. In addition, for some vulnerable people, the perception of the presence of high-

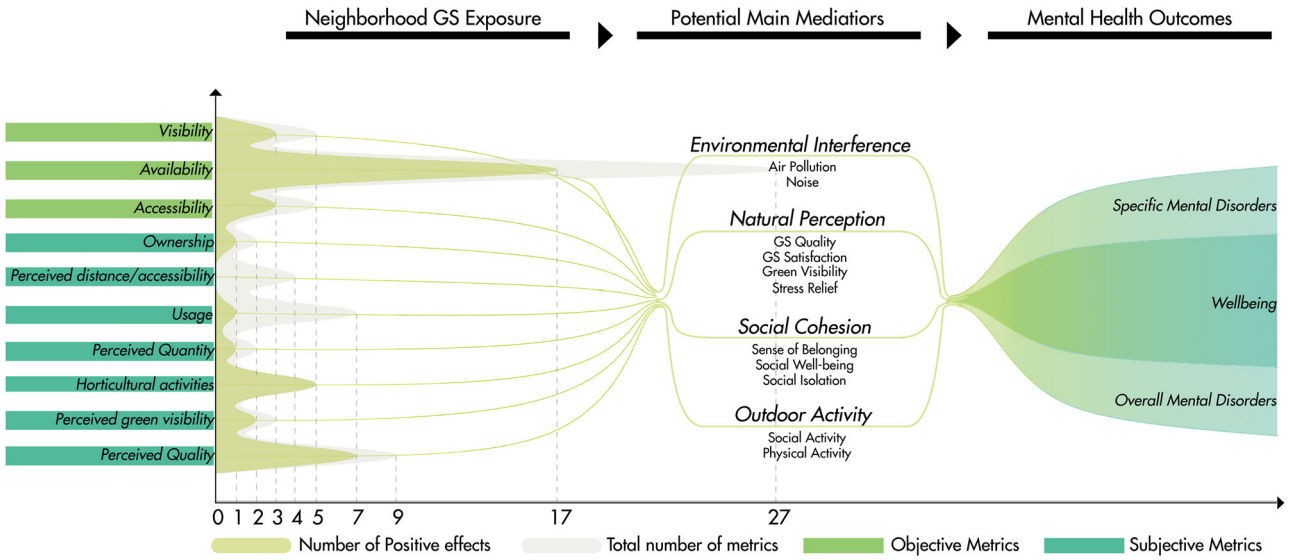

Fig. 7 A conceptual framework of neighbourhood GSs affecting the mental health of disadvantaged groups. This framework diagram categorizes green space exposure in terms of subjective and objective indicators, assesses which aspects of green space exposure are more significant in terms of mental health improvement for disadvantaged groups and why the associated psychological benefits are manifested, and reveals the potential mediating effects of neighbourhood green space that are more credible in terms of disadvantaged groups' mental health.

quality GS in the neighbourhood can improve their psychological condition (Roe et al. 2017). Similarly, McEachan et al. (2018) found that satisfaction with GS independently predicted mental health in South Asian children. Neither Mendoza et al. (2023) nor Yang et al. (2020) found evidence that residential outdoor air pollution was a potential mediator in the association between neighbourhood GS, mental health, and suicide mortality. GS does not appear to contribute to enhanced PA for relieving stress (Thompson et al. 2016). Among residents of deprived neighbourhoods, PA was found to be significantly associated with stress through measures of cortisol slope, but not with self-reported stress (PSS), suggesting that GS may be associated with subjective perceived stress through mechanisms other than PA (Thompson et al. 2012). During pregnancy, PA is only a partial mediator of the small indirect effects of GS on depressive symptoms (McEachan et al. 2016). Hong et al. (2021) and Barreto et al. (2019) also showed that PA does not mediate mental distress. Roe et al. (2017) confirmed that young people were more likely to improve their social well-being through PA and corresponding social events, whereas middle-aged and older adults were less likely to do so. Older adults are more likely to improve their mental condition by watching GS (Roe et al. 2017).

Synthesis of qualitative studies. While qualitative studies were excluded from our review, it is undeniable that some qualitative studies provide valuable insights, especially because they include a more diverse range of vulnerable groups that are often not captured in quantitative studies. Emphasising productive landscapes, such as community gardens and green roofs as green infrastructure can offer significant physiological and psychological health benefits to vulnerable populations by addressing inequalities. (Anderson et al. 2021; Beavers et al. 2022; Budowle and Porter 2022). This is evident in broader vulnerable groups, such as refugees (Eggert et al. 2015), dementia patients (Hassink et al. 2018), and veterans (Lehmann et al. 2018). Furthermore, GS has been shown to significantly improve the mental state of unhoused individuals (Plane and Klodawsky 2013) and assist indigenous communities (Hatala et al. 2020) in strengthening their connection with the land and nature.

Discussion

Our research indicates that neighbourhood GS has a beneficial effect on individual mental health, a finding that is particularly pronounced among vulnerable populations and in middle- to low- income countries. This aligns with previous systematic reviews (Nawrath et al. 2021; Rigolon et al. 2021). As the understanding of how various components of GS impact the mental health of underprivileged communities remains limited, it is unclear how mental health improvements would be expressed. Furthermore, owing to the varying levels of SES, ethnicity, and mobility among marginalised populations, the corresponding intermediary mechanisms that may account for heterogeneity among these underprivileged groups must be determined. Therefore, appropriate exposure assessments for disadvantaged groups are required to accurately guide relevant research. This study proposes a conceptual framework for classifying greenspace exposure in terms of subjective and objective metrics, considers heterogeneously disadvantaged group types and the characteristics of underprivileged neighbourhoods, explores differences by assessing which aspects of GS exposure are more significant in terms of mental health improvement for disadvantaged groups, assesses the benefits of GS exposure for disadvantaged groups, and reveals a more plausible, potential mediating effect of neighbourhood GS on the mental health of disadvantaged groups (Fig. 7).

Discrepancies in the results of subjective and objective indicators. Unlike subjective measurements, objective measurements more reliably forecast the positive effects of GS exposure on the psychological well-being of underprivileged groups. Among the objective indicators, visibility may be an effective predictor of mental health benefits derived from GS exposure. Accessibility and availability potentially predicted stronger mental health protection benefits of neighbourhood GS for disadvantaged people. When the heterogeneity of GS subjective metrics emerged, some tended to be more pronounced than objective metrics in identifying the protective effect of neighbourhood GS on the mental health of disadvantaged people.

Regarding subjective metrics, perceived quality and horticultural activities may better predict the mental health benefits of GS

exposure among disadvantaged people, which is consistent with the results of a systematic review (Nguyen et al. 2021). Ownership, perceived greenery visibility, and perceived quantity also potentially predict the mental health benefits of GS exposure on disadvantaged people but are more influenced by the type of disadvantaged people, the type of GS, and the quality of GS. By contrast, GS usage and perceived distance/accessibility were less likely to predict the protective effects of greenspace exposure.

The uniformity of objective indicators highlights standardised measurements and the environment's physical features, which are relatively stable across different individuals, often showing consistent and, moderate effectiveness in predicting mental health. However, subjective indicators are affected by factors beyond objective environmental conditions. The Mindsponge Theory states that a person's cultural background and personal experiences influence how they perceive and interpret their environment and process information according to their psychological models (Vuong 2022). Relationships within an individual's subjective experience are mental constructs, and may not correspond with those in the objective world (Nguyen et al. 2023).

Therefore, even with set objective environmental factors such as the amount, accessibility, and quality of greenery, people's individual perceptions and judgements can vary and be influenced by their own ways of seeing and internalising their environments. This can lead to variations in mental health outcomes (Howley 2011; Riemer et al. 2014; Zheng et al. 2023). Individuals' perceptions are shaped by past experiences, cultural values, and personal preferences. For example, someone who grew up without greenery in their surrounding environment might rate the green spaces in their current surroundings higher, even the greenery is not abundant or high quality. In subjective assessments, some indicators may be more tightly linked to an individual's specific mental needs and ways of adapting, making them more effective in predicting mental health (Campbell 1976).

Hence, subjective perception is key to assessing mental health, and may even outperform the predictive ability of objective measures. Subjective indicators show considerable variation owing to personal differences, psychological models, and cultural backgrounds. These variances emphasise the importance of considering both the objective traits of the environment and individual subjective views when examining how the environment affects mental health. This is particularly crucial when focusing on vulnerable groups, whose perception of their environment could be shaped by more complex social and economic factors.

Effectiveness and efficiency differences in the composition of GS exposure indicators

Subjective GS metrics. The subjective judgement of the GS is often affected by the heterogeneity of the subjects' individual differences, evaluation criteria, and questionnaire design. At the same time, due to the inequality of disadvantaged groups in terms of SES, ethnicity, and mobility, the level of planning and construction of GS in their neighbourhoods and their perceptions of facing neighbourhood GS are significantly different from those of non-disadvantaged groups. Therefore, we observed great heterogeneity of different subjective GS indicators in indicating the mental health of disadvantaged groups.

High-quality GS can provide additional resources and motivation for disadvantaged groups to engage in outdoor activities to improve their health and expand their social networks (De Vries et al. 2013; Jim and Shan 2013; Lu et al. 2019; Qin et al. 2021). They are often limited to GS designated for walking, yoga, or socialising, whereas high-SES groups have more options and tend not to use their neighbourhood GS as a first choice (Ma et al. 2022). High-quality GS provides residents with an attractive environment for mutual interaction and enhances their social cohesion. Conversely, low-quality GS may discourage usage due to concerns about safety, antisocial behaviour, cleanliness, and maintenance (Abbasi et al. 2016; Gidlow and Ellis 2011). This may explain why Sugiyama et al. (2016) did not observe a protective effect of GS quality on the mental health of disadvantaged residents, as the tool used to assess GS attractiveness lacked metrics to assess safety and maintenance. In addition, as disadvantages are mainly considered through economic circumstances such as income, job, vehicle, and home ownership, most studies on disadvantaged groups only consider adult samples in their empirical design, while adolescents who are less critical of GS quality are not included in the study; this could lead to results that are more biased towards the quality of GS (Roe et al. 2017). Astell-Burt, Mitchell et al. (2014) also noted that younger adults benefited more from GS quantity than middle-aged adults. The protective effect of GS quantity on disadvantaged groups may be moderated by GS quality, implying that the association between GS quantity and health outcomes is stronger when quality is higher (Lachowycz and Jones 2013).

Based on the results of qualitative and quantitative studies, we found that horticultural activities in neighbourhood GS, such as community gardens and farms, had a significant positive impact on the mental health of different vulnerable groups. Horticultural activities can enhance the sense of social belonging among people in disadvantaged neighbourhoods. By creating and sharing communal spaces, people are more likely to be open and receptive to their surroundings (Cohen et al. 2008). The presence of grass and trees further increases their informal interactions, deepening their understanding of each other and creating weak ties which allow them to help each other in their daily lives (Kuo et al. 1998). Horticultural activities stimulate creativity and self-expression, enhance self-worth, becoming a source of pride (Clayton 2007), and improve the sense of place (Laali et al. 2018). Gardening can be a significant distraction that alleviates mental disorders such as depression (Nolen-Hoeksema et al. 2008). Horticultural activities give individuals a reason to leave their house, providing them with a temporary break from the pain and stress of everyday life as well as tranquillity in the satisfaction gained by making their environment more attractive (Certomà 2015).

A number of systematic reviews investigating GS and mental health (Callaghan et al. 2021; Chen et al. 2021; Jabbar et al. 2021; Labib et al. 2020) have shown that viewing and using GS has a positive effect on mental recovery. However, there may be population heterogeneity in this mental health benefit, particularly for residents of disadvantaged neighbourhoods where the effects of GS visibility and use on mental health are more pronounced. For older adults with limited mobility, appreciating the natural landscape outside their windows can improve their mental state, even if they are often sedentary (Roe et al. 2017). However, for middle-aged people, the protective effect of green visibility is influenced more by the quality of the GS than its amount because lower levels of urbanisation may result in fewer man-made features that support PA or social interaction (Gascon et al. 2019; Marquet et al. 2020). Simply seeing more GS rather than being attracted to quality GS and thus socialising in it does not strengthen neighbourhood ties and interactions or enhance a sense of belonging and social well-being, which in turn reduces stress and improves mental states through social well-being (Thompson et al. 2016). Additionally, middle-aged people have higher expectations of the quality of their local environment (Roe et al. 2017), whereas those in lower-income neighbourhoods often lack adequate GS and GS quality (Space 2010). Issues such as untrimmed trees, presence of litter, and broken public facilities

may affect satisfaction with GS use. The impact of neighbourhood GS use on stress should be observed over time; therefore, the results were less evident in the study by Kodali et al. (2023). One of the two studies that assessed GS ownership in the UK found a stronger protective effect of neighbourhood GS on the mental health of disadvantaged people. This was possibly influenced by the type of GS involved, which in the UK existed as part of the dwelling in the form of private gardens or allotments and formed a clearer boundary through fencing. The Moroccan study had PSG as its subject, which usually clings to the façade of the dwelling or to a buffer zone placed at the articulation of the road, leading to a higher risk of theft and vandalism among owners.

For perceived distance/accessibility, such subjective indicators do not capture the true attitudes of disadvantaged groups toward neighbourhood GS because most disadvantaged adults commute long distances and work long hours to support their families, and older people and those with limited mobility may lack appropriate financial and social support. Even if they are aware of the presence of GS in the neighbourhood, it may be difficult for them to access it, and they may not be sufficiently exposed to the green environment of their communities (Yang et al. 2020). Simultaneously, unreasonable planning in disadvantaged neighbourhoods may lead to a longer actual walking distance, which is difficult to measure using satellite- or land-use-derived GS objective indicators. Thus, we observed large differences in the prediction of mental health outcomes between objective accessibility metrics and subjectively perceived distance and accessibility metrics.

Objective GS metrics. Epidemiological studies often use remote sensing measurements to assess the greenness and accessibility of green environments. Examples include the NDVI and land cover. Several review articles have confirmed that these methods are valid and practical for assessing the health impacts of neighbourhood GS (Ekkel and de Vries 2017; Gascon et al. 2015; Holland et al. 2021; Vilcins et al. 2022). However, most studies in this systematic review used data at a 30 m resolution, making it difficult to capture greenery in small-scale cities. Therefore, the accuracy of neighbourhood GS greenness capture is much lower than that of SVG, which comes from a human-perspective. Additionally, owing to the large heterogeneity in buffer size, measurement season, and differences in cloudiness at the time of capture (Geneshka et al. 2021), green exposure measurements can vary significantly. Furthermore, this method can only assess the overall level of vegetation and cannot distinguish between structured and unstructured vegetation, accordingly, it cannot assess GS quality (Markevych et al. 2017). As mentioned earlier, for disadvantaged groups, the quality of a GS is more important than its quantity. Therefore, aspects that reflect the quality of GS exposure such as time, duration, frequency, and intensity (Shanahan et al. 2016) are difficult to capture. Street-view map-based methods combined with deep learning can be used to observe the actual perceived green exposure of residents, which is often overlooked by remotely sensed data (Wang et al. 2019). It is important to note that remote sensing-based greenery may be more relevant to general health than SVG because remote sensing data capture overall vegetation amounts, whereas streetscape greenery may be more relevant to perceptions and behavioural pathways based on actual interactions (Dzhambov et al. 2020; Liu et al. 2020). Thus, street-level human-view angle greenness can be assessed through streetscape greenness to identify associations among GS exposure, reduced risk of mental disorders, and increased sense of place attachment.

The effect of GS exposure on different mental conditions in vulnerable groups. GS is protective in terms of well-being, overall mental distress, and specific mental disorders among disadvantaged individuals. However, mental health improvements in neighbourhood GS for disadvantaged people may be greater in the terms of well-being. Notably, de Keijzer et al. (2020) found an insufficient association between GS and well-being in a systematic review of non-disadvantaged groups; however, we found that the association was significant among disadvantaged groups.

This may be due to the relatively poor quality and quantity of greenery in disadvantaged neighbourhoods, which can lead to a sense of isolation and lack of social support among neighbourhood residents (Maas et al. 2009), for whom assessed indicators of well-being—such as feeling loved or having increased self-confidence,—have a more significant and sustained positive impact. Furthermore, in the context of persistent poverty, multiple social, economic, and poverty-related health problems may be the main drivers of depression, stress, and anxiety, and the impact of these factors may outweigh the potential risk to the surrounding natural environment (Tomita et al. 2017).

It is also important to note that the different instruments and indicators used to assess well-being and mental health may produce different results (Cheng et al. 2021). Studies that used the EWB scale to assess life satisfaction tended to better predict well-being among disadvantaged groups, whereas those that assessed QoL were less predictive. This may be because, when evaluating quality of life and life satisfaction, community residents consider more non-greenery-related differences in neighbourhood quality, such as neighbourhood infrastructure (e.g., ball fields, convenience stores, and bike racks) and environmental health (e.g., air quality, noise, and sewage) (Mouratidis 2020).

Geographic and individual variations in the general protective effect of GS on different vulnerable groups. Our research confirmed that the protective benefits of green exposure were unevenly distributed across the different types and regions of disadvantaged people. At the individual level, vulnerable groups in low and middle-income countries, face high poverty and significant wealth gaps. Although there is a positive correlation between GS and health, having more GS does not necessarily imply better health benefits if socioeconomic health disparities are not addressed. Improving socioeconomic conditions and meeting basic needs can help people escape poverty; after that other non-essential factors, such as the greenness of the living environment may be potential drivers of better mental health (Tomita et al. 2017). In high-income, high-welfare countries, such as the Nordic region, despite the wide distribution of GSs as a social infrastructure, the quality of GS needs further improvement, and the protective benefits of GS might not be sufficient to satisfy mental health needs. An individual's economic and social including their income, employment status, and education level, can also affect different aspects of their well-being and mental health (Manley et al. 2011), and anxiety, stress and depression symptoms may be more influenced by these factors than by the natural environment.

For neighbourhoods with a high number of people with disabilities, the lack of accessible facilities may result in people with disabilities using GSs less often than able-bodied people, thus hindering their participation in community activities. In such cases, the presence of a neighbourhood GS may exacerbate individuals' pessimistic perceptions of their disability and negatively impact their mental health. For these people, features or services which meet their basic daily needs, such as accessibility and safety maintenance, may be more important.

On a neighbourhood-level, disadvantaged neighbourhoods formed under the background of rapid urbanisation, with high building density and low neighbourhood greenery, and the

biopsychosocial pathways linking neighbourhood GS exposure to mental health, are not active in the same way because of the specific nature of the living space (Liu et al. 2019). In a study conducted in urban villages in Shanghai, China, mental health improved indirectly through residents' perceptions of private gardens formed by house voids and small open spaces, whereas the risk of vandalism or theft in high-density disadvantaged communities with poor social security and private GS may lead to poorer psychological states. Therefore, for cities where it is difficult to completely demolish and rebuild disadvantaged neighbourhoods, on the premise of improving neighbourhood security, encouraging and supporting the construction of private gardens can allow disadvantaged groups to obtain the health benefits of GS.

Underlying pathways link green exposure to disadvantaged groups' mental health. We summarised four categories of potential mediators of neighbourhood GS: environmental interference, nature perception, social cohesion, and outdoor activities. Environmental interference (air pollution) may affect mental health by disrupting residents' perceptions of the quality of green restorations (Von Lindern et al. 2016), and the resulting undesirable odours can affect psychological states through annoyance rather than through pathophysiology (Claeson et al. 2013). Of the reviewed articles considering environmental interferences, such as air pollution, none observed mediating effects; this may be, because measurement, specific attention to immigration, and other mediating adjustments reduced the importance of environmental interferences on mental health (Yang et al. 2020). In addition, the mediating effect of environmental disturbance is based more on aesthetic factors and is reflected in the SVG-tree or SVG-grass at the eye level rather than the NDVI (Wang et al. 2020); therefore, no mediating effect could be observed (Mendoza et al. 2023).

Either viewing or being exposed to nature helps disadvantaged groups relieve stress (Kaplan 1995). The perception that high-quality neighbourhood GS enhances individuals' satisfaction with the living environment further enhances their motivation to enter GS and engage in activities that encourage health, contributing to social cohesion and corresponding social perceptions, which reduces social isolation, enhances sense of local belonging and social well-being, and improves their mental health. The function of the social-based activities provided by the community is becoming increasingly important, especially as domestic activities (shopping and laundry) are replaced and diverted. Social cohesion often stems from bottom-up social interactions at the local level, which influence health by promoting health-related behaviours within the neighbourhood and, increasing access to services and amenities, or through psychosocial processes (Forrest and Kearns 2001). Neighbourhood greenery and community parks support neighbourhood contact and the maintenance of community ties (Thompson et al. 2016), strengthen the level of connection and solidarity between people in the community, and translate these connections into tangible goals of common interest (Echeverría et al. 2008), thus contributing to social cohesion. Close family ties, mutual aid, and voluntarism are strong characteristics of disadvantaged areas. These qualities make disadvantaged people more willing to participate in maintaining ties and social relationships within a community. Simultaneously, disadvantaged neighbourhoods often imply high levels of unemployment, high levels of single-parent households, or individuals who are older or have disabilities, who can spend more time at home and in community settings (Forrest and Kearns 2001; Henning and Lieberg 1996). Thus, the mediating benefits of social cohesion may be more pronounced in disadvantaged groups.

Furthermore, the potential pathways for green exposure to weakly connected low-SES groups to mental health showed some variation caused by age heterogeneity. PA showed a more pronounced mediating effect in young people, whereas the mediating effect of GS quality was more pronounced in middle- and older-aged adult. Younger people were more likely to be physically active and derive mental health benefits from GS than middle-aged and elderly individuals. A systematic review by Vanaken and Danckaerts (2018) suggested that this may be achieved through PA and the resulting social interactions. For disadvantaged older adult, reduced physical function combined with poor financial circumstances and often poorly treated physical conditions (World Health Organization 2022) make them less able to engage in PA in a GS, and are therefore more likely to engage with GS from home or by entering them for social activities (Roe et al. 2017). Middle-aged disadvantaged people often face significant financial and survival pressures and require more time for work or family commitments, making it clear that sports—which take up more time—are less likely to be their first choice for GS activities. Thus, a high-quality GS will significantly increase their satisfaction with the community and support them in socialising within the GS.

Strengths, implications, and limitations. The main strength of this systematic review was the selection of articles which synthesised keywords from previous systematic evaluations and incorporated a more comprehensive and extensive examination of the definitions of disadvantaged groups. Furthermore, we synthesised qualitative research to provide insights into a broader understanding of disadvantaged groups. Consequently, this review discusses disadvantaged groups other than low-SES groups, which provides a deeper understanding of disadvantaged groups. In addition, we focused more on the results of neighbourhood GS exposure and mental health sub-indicators rather than the positive or negative effects which the study ultimately pointed to, thus providing a more precise assessment of the specific aspects of disadvantaged groups affected by GS exposure.

Neighbourhood GS can help alleviate inequalities in disadvantaged neighbourhoods with disadvantaged groups being more affected by GS quality (perception, satisfaction, etc.) and less affected by distance, access, accessibility, and quantity. Specifically, only disadvantaged adolescents improved their mental health through PA. When new or renovated GSs are built, priority should be given to improving their quality, operation, and maintenance, rather than building a large number of low-quality GS, considering the age composition of the neighbourhood and providing social or sporting facilities accordingly. Additionally, for all vulnerable groups, using productive landscapes and associated gardening activities, such as community farms, is a great way to make GSs more equitable and boost health. We suggest that communities integrate these aspects as key components of their GS infrastructure. Besides, in areas with extremely high or low economic levels, the impact of GS exposure may be limited or even negative. Therefore, in developing countries, efforts should first be made to reduce socioeconomic disparities between classes and avoid gentrification in economically underdeveloped areas. In developed countries, services related to GS in deprived neighbourhoods should be strengthened, and emphasis should be placed on enhancing the overall neighbourhood environment.

This review had several methodological limitations. First, the review of research methods did not include articles published in languages other than English or qualitative studies involving disadvantaged groups, and the quantitative research we looked at mainly used data from general population surveys or health follow-ups, and GS exposure was assessed based on where people

lived. This means that disadvantaged groups who could not give home addresses, such as those the unhoused or runaways, were often left out of these studies, which may then have missed specific disadvantaged groups. Also, while we touched on qualitative research involving a wider range of vulnerable groups, the nature of qualitative research mean that its findings are less robust.

Second, for the evidence reviewed, the design of most included studies was cross-sectional and did not support strong causal inferences. Also, our study may have potential publication bias due to the search period and corresponding exclusion criteria. Third, in terms of empirical design, some studies have overlapping and nested definitions of subjective metrics (e.g., assessing satisfaction through accessibility) and a small number of certain metrics, leading to difficulties in classification and assessment. Fourth, most studies included in this review were conducted in developed countries. Despite the discussion of studies conducted in developing countries, they are inadequate in number. Therefore, more designed studies are needed to make confident recommendations on the subjective and objective metrics of GS, mental health outcomes, and the differences in disadvantaged populations across countries and regions.

Conclusions

This systematic review is among the first to assess the links between neighbourhood GS exposure and the mental health of underprivileged groups. It presents a comprehensive analysis of the indicators employed to assess neighbourhood GS exposure, various mental health outcomes for vulnerable people, moderating effects of regions, individual- and neighbourhood-level sociodemographic contexts, and types of disadvantaged residents. In addition, the potential mechanisms by which neighbourhood GS is associated with the mental health of disadvantaged populations were deciphered. We discussed the factors contributing to the variability in the results of subjective and objective indicators and identify several effective subjective and objective indicators which best predict the health benefits of neighbourhood GS exposure in disadvantaged groups. Furthermore, this study specifically analysed the heterogeneous effects of these mental health outcomes. These findings have implications for a comprehensive understanding of the associations and mechanisms be-tween neighbourhood GS and the mental health of disadvantaged groups. Further, it addresses the health equities probably induced by the unfair distribution of GS, and thus promotes health-oriented environmental planning and policies. Finally, more quantitative research should be designed and conducted that focuses on a wider array of vulnerable groups such as the unhoused or run away in the future. This will help researchers more accurately evaluate how neighbourhood GS affects the health of these communities.

Data availability

All data generated or analysed during this study are included in this published article [and its supplementary information files].

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The authors declare no competing interests.

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Additional information

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