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Exploring uncharted territory: Do urban greenspaces support mental health in low- and middle-income countries?

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Abstract

Exposure to urban greenspaces promotes an array of mental health benefits. Understanding these benefits is of paramount importance, particularly in low- and middle-income countries (LMICs), where cities are expanding at an unprecedented rate. However, the existing evidence-base for the health benefits of greenspaces has a strong bias towards high-income countries. Here we systematically assess the emerging evidence regarding the mental health benefits provided by urban greenspaces in LMICs. We carried out a scoping review to assess the extent, type and quality of evidence investigating the relationship between greenspaces and mental health in LMICs. We systematically searched the literature databases Web of Science, Medline, Embase and CAB Abstracts using key terms related to greenspaces and mental health in LMICs. We analysed the resulting studies using a narrative synthesis approach, taking into account study quality, to assess the overall effects on mental health. 36 studies met the inclusion criteria and were included in the narrative synthesis. Studies were heterogeneous in design, study population, greenspace and mental health assessment. While more than 90% of LMICs remain unstudied, we found that eight out of ten studies using validated mental health screening tools detected positive associations between greenspaces and one or more mental health outcomes. These studies mostly took place in upper-middle-income countries. However, there still is a lack of evidence from regions with the highest levels of urbanisation, and only four studies assessed lower-middle and low-income countries. Furthermore, the analysis of mediating and moderating factors indicates that the relationship between greenspaces and mental health in LMICs is context dependent and needs to be assessed in relation to locally relevant environmental and cultural settings. Based on the evidence reviewed here, exposure to urban greenspaces can support multiple mental health outcomes in upper-middle-income countries. However, we still know little about poorer, rapidly urbanising countries. Our findings highlight the need for high-quality, context specific research in those urban areas with the highest levels of urbanisation, and the need to address specific challenges regarding mediating and moderating factors. Future studies should combine robust ecological assessments of greenspaces with validated mental health screening tools.

Keywords

Global South, developing countries, natural environment, biodiversity, mental disorders

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1. Introduction

Cities in low- and middle-income countries (LMICs) are expanding at an unprecedented rate (Angel et al., 2011). Urban growth in these regions is placing tremendous pressure on the ability of cities to provide good living conditions for their residents (McPhearson et al., 2016). Not least because through urbanisation, people are less likely to have contact with natural environments such as greenspaces (Soga and Gaston, 2016), potentially with profound implications for mental health (Hartig et al., 2014).

Although urban living can convey many benefits such as providing better access to health care, employment and education (Dye, 2008), living in cities can be detrimental to mental health outcomes, attributable to individual, social and environmental factors (Gruebner et al., 2017). This is particularly true in LMICs, where rapid and unplanned urban growth often results in the expansion of informal settlements and slums (United Nations, 2014), which therefore house a large proportion of the population (McHale et al., 2013). Such settlements tend to be characterised by a lack of security of tenure, inadequate access to basic services and city infrastructure (United Nations, 2015). Informal settlements and slums are often situated in geographically and environmentally hazardous areas, and their residents are affected by poorer physical (Ezeh et al., 2017) and mental health (Subbaraman et al., 2014).

Indeed, mental illnesses affect more than one billion people globally (Rehm and Shield, 2019). Therefore, as cities increasingly shape the context in which people live, it is crucial to better understand the determinants of mental health of urban populations (Galea and Vlahov, 2005). Mental health is affected by a variety of factors including social, economic, psychological, physiological, behavioural, genetic, cultural and environmental factors (Meyer-Lindenberg, 2014). Indeed, interest in the role the natural environmental context in which people live plays for mental health has been growing (Markevych et al., 2017). Exposure to urban greenspaces promotes an array of mental health benefits (Lovell and Maxwell, 2018). Neighbourhood greenness is broadly associated with good mental health in adults (Gascon et al., 2015), reduced prevalence of depression (Roberts et al., 2019), improved social cohesion (Jennings and Bamkole, 2019) and improved measures of mental well-being such as quality of life (Stigsdotter et al., 2010) and life satisfaction (White et al., 2013). Greenspaces are linked to these mental health benefits through different pathways, which emphasise three general functions of greenspace: reducing harm (e.g. reducing air and noise pollution), restoring capacities

(e.g. attention restoration and stress recovery) and building capacities (e.g. encouraging physical activity and facilitating social cohesion) (Markevych et al., 2017). While a substantial amount of research investigates the impact of greenspaces on mental health, little is known about the contribution that different qualities of the environment, such as different types of greenspaces or biodiversity, have on mental health (Marselle et al., 2018). Determining which aspects of biodiversity are relevant to mental health is a key research frontier (Bratman et al., 2019).

Although increasingly compelling, the existing evidence has a strong bias towards temperate, high-income settings (Clark et al., 2014; Keniger et al., 2013; Pett et al., 2016). However, it cannot be assumed that findings from HICs are automatically transferrable, given the vast differences in urban conditions, environmental and cultural factors (Markevych et al., 2017). Indeed, current research largely excludes the types of urban environments in which the majority of the world's population live. This bias could be problematic as urban conditions in LMICs often differ from those in HICs for a number of reasons (United Nations, 2015). First, different factors might mediate and moderate the relationship between greenspaces and mental health, through different pathways (Markevych et al., 2017). The mental health benefits people derive from greenspaces may depend on the particular environmental context of a region, such as local climatic conditions (Botzat et al., 2016). Thus far studies have concentrated on a narrow range of temperate regions (Keniger et al., 2013).

Secondly, a society's relationship with the natural environment arises from, and reflects, its cultural norms (Selin, 2003). For instance, people in Turkey use urban parks generally for passive recreational activities such as resting and relaxing, whereas in most high-income countries, urban parks are predominantly used for physical activity (Özgüner, 2011). Hence, cultural norms will be important in underpinning how people interact with greenspaces (Li, 2014), with repercussions for mental health outcomes (Amano et al., 2018). Moreover, perceptions of health and illness, and the clinical expression of major mental disorders varies geographically and across cultures (Gopalkrishnan, 2018; Viswanath and Chaturvedi, 2012). In Nepal, for instance, there is no word for depression (Kohrt and Harper, 2008). It follows that the mechanisms and pathways by which greenspaces affect mental health are likely to vary between cultures (Hartig et al., 2014). Thus, the United Nations' Sustainable Development Goal 11 target 7, which aims to provide universal access to safe and accessible urban greenspaces by 2030

(United Nations, 2019), may be based on findings that are almost solely derived from, and therefore biased towards, conditions in HICs.

Although these biases have been long-standing (Markevych et al., 2017), thus far there has been no synthesis of the emerging body of literature on the mental health benefits people derive from greenspaces in cities in LMICs. There are a number of reviews focusing on the relationships between human health and greenspaces (Dzhambov and Dimitrova, 2014; Gascon et al., 2016, 2015; Hartig et al., 2014; James et al., 2015; Lachowycz and Jones, 2011; Lovell et al., 2014; Shuvo et al., 2020; Tzoulas et al., 2007) and more specifically on greenspaces and mental health (Bowler et al., 2010; Callaghan et al., 2020; Coon et al., 2011; Dadvand et al., 2015; Wendelboe-Nelson et al., 2019). However, to date no review exists which comprehensively assesses the relationship of urban greenspaces and mental health in LMICs. Here we systematically assess the published evidence for the mental health benefits greenspaces may provide to urban residents under different geographical, environmental and cultural conditions in LMICs. At this critical time of development of the field, the aim of our study is to assess the strengths and weaknesses of the available evidence regarding the mental health benefits provided by urban greenspaces in such regions, and to point out ways forward for future research. In particular, we address the following key questions: (1) Do greenspaces promote good mental health of urban residents in LMICs; (2) What are the geographic characteristics of the evidence from LMICs; (3) which environmental and cultural factors mediate and moderate how greenspaces and mental health are associated in LMICs; (4) how were greenspaces assessed and which mental health outcomes were studied in LMICs?

2. Methods

We carried out a scoping review to assess the extent, type and quality of evidence contained in the heterogeneous body of literature investigating the impact of greenspaces on mental health in LMICs. Scoping reviews are a type of knowledge synthesis. They follow a systematic approach to map evidence and examine the extent, range and nature of the evidence on a topic. Given the heterogeneity of the evidence and the breadth of the research questions, scoping review was the most appropriate approach (Tricco et al., 2018). We followed Arksey and O'Malley's (2005) framework and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) (Tricco et al., 2018). This re-

quires the *a priori* development of a review protocol (see Supplementary material), which defines eligibility criteria, information sources, the literature search strategy and the data extraction process. The protocol also defined how any evidence quality assessment is carried out.

2.1. Eligibility criteria

To be included in the review, studies needed to report on original research, be published in a peer-reviewed journal and be written in English. We found seven non-English studies, of which all would have been excluded due to not meeting other inclusion criteria. Hence, excluding those studies did not affect the findings. Study types included were randomised controlled trial studies, cohort studies, case-control studies, cross-sectional studies, before and after studies, time series, longitudinal studies, experimental studies and qualitative studies. Case reports, reviews, opinion pieces, editorials, comments, news, letters and grey literature were excluded. Studies needed to involve aspects of urban greenspaces and mental health and consider one or more LMICs. We defined urban greenspaces as all forms of 'living nature' of flora and fauna in cities (Hartig et al., 2014), including maintained and unmaintained environmental areas such as nature reserves, wilderness environments, urban parks and urban wildlife (Barton and Rogerson, 2017). We included private gardens because especially in informal settlements and slums, they can improve diets and increase food security (Audate et al., 2019) in particular for low-income residents (Orsini et al., 2013), which may indirectly affect mental health. For the assessment of greenspaces, we differentiate between objective and subjective measures of greenspaces. We define objective measures as assessing greenspaces exposure through remote sensing or ecological survey techniques, while subjective measures assess exposure through the participants' perceptions. We used the World Health Organisation's (2014) definition of health as 'a state of complete physical, mental and social well-being and not merely the absence of disease'. Mental disorders were defined through *The Diagnostic and Statistical Manual of Mental Disorders* (American Psychiatric Association, 2013). Studies needed to address the general urban population of upper/lower-middle-income or low-income countries, as defined by OECD's Development Assistance Committee, which is based on country classification data by the World Bank (DAC, 2017). For slums and informal settlements, we followed the definition of the United Nations (2016) (for definitions see Supplementary material section 3.1).

2.2. Information sources

Due to the interdisciplinary character of this review, we included a variety of electronic databases covering environmental and health sciences. We systematically searched the databases Web of Science Core Collection (1900 – Nov 2019), Medline (1946 – Nov 2019), Embase (1947 – Nov 2019) and CAB Abstracts (1910 – Nov 2019). Searches used queries that targeted studies on (1) greenspaces and (2) mental health in (3) urban areas in LMICs. The selection of search terms relating to (1) greenspaces followed the methodology used in a previous review on the mental health benefits of exposure to greenspaces (Gascon et al., 2015). For the (2) mental health and (3) LMICs search terms, existing search filters, optimised for the Medline database, were used (Academic Unit of Health Economics University of Leeds, 2018). We filtered for the LMICs on the DAC list in the initial database search. The Medline search filters were then translated for use in Embase, CAB Abstracts and Web of Science. Studies were included if they were conducted in a country which was listed as LMIC on the DAC list at the time of publication, regardless of current DAC statuses. Information on the search strategies and the selection of search terms used for each database are included in Supplementary material section 3.1.

2.3. Selection of sources of evidence and data extraction

Studies were extracted following a two-stage screening process performed independently by two researchers (MN and SG). In the first stage, title and abstract of all database search results were screened in order to select studies for inclusion that matched the stated eligibility criteria. Full-text screening of the remaining studies was conducted at a second screening stage independently by the same two researchers. All conflicts generated through the screening stages between the two reviewers were discussed until consensus was reached.

Using the stated eligibility criteria, a data extraction form was designed to abstract key information, including authors, title, year of publication, objectives, study population, methods, study design, health measure and outcome, measure of greenspace and general results. Differences in the extracted data were validated through discussion until consensus was reached.

2.4. Synthesis of results

Due to the marked heterogeneity of the identified evidence, meta-analyses and statistical methods of synthesis were inappropriate and instead we performed a narrative synthesis. One pitfall

of this approach is that narrative syntheses often rely on summarising literature through the use of summary statistics and vote-counting approaches. Even though this has known shortcomings, such as giving equal weight to studies with different sample and effect sizes, it is a helpful method for preliminary interpretation of findings across studies (Marselle et al., 2018).

Nevertheless, we mitigated for some of these shortcomings by characterising studies according to their quality, thereby ensuring that our narrative is not dominated by low-quality data. To do this we adapted two previously used approaches. For quantitative studies, methodological quality was assessed using an 9-item scale (Gascon et al., 2016);(Supplementary material Table S4). Studies could score one or two points for each item and points were summed between 0-11. We obtained a quality score (%) for each study (Supplementary material Table S3). We created five quality categories: excellent quality (>81%), good quality (61-80%), fair quality (41-60%), poor quality (21-40%) and very poor quality (<20%) (Gascon et al., 2016).

In order to be included into the narrative synthesis, studies needed to use validated mental health screening tools, as their use enables drawing reliable conclusions about specific mental health outcomes to compare between populations. Validated mental health screening tools are instruments which have been psychometrically tested for validity (the ability of the instrument to produce true results), reliability (the ability of the instrument to produce consistent results) and sensitivity (the probability of correctly identifying an individual with the condition) (The Joint Commission, 2020).

Data from quantitative studies using validated mental health screening tools were synthetized thematically to record the overall impacts of greenspaces on mental health as positive (significant positive relationships), neutral (no significant relationships) or negative (significant negative relationships), to describe the frequency of statistically significant findings (Table 1). Qualitative studies were included to facilitate understanding of the pathways and mechanisms through which greenspaces may affect mental health. The methodological quality of qualitative studies was assessed using the 10-item Critical Appraisal Skills Programme (CASP) tool (Supplementary material Table S5).

In order to explore the mechanisms and pathways by which greenspaces affect mental health in LMICs, we assessed the results of mediating and moderating analyses of quantitative studies.

We defined mediation analysis as the statistical assessment of variables which transmit an effect of an independent variable (greenspaces) on a dependent variable (mental health) (Mackinnon et al., 2007). For the assessment of mediating factors, we followed Markevych et al.'s (2017) domains of pathways linking greenspaces to mental health outcomes through reducing harm, restoring capacities and building capacities. We defined moderation analysis as the statistical assessment of variables which influence the direction and/or strength of the relationship between greenspaces and mental health (Hayes, 2017). For the analysis, moderating factors were classified as either personal or contextual (Marselle et al., 2018). In the synthesis of qualitative studies, we followed Markevych et al.'s (2017) domains of pathways to organise the findings.

3. Results

The electronic database search yielded 1,801 hits. Removal of duplicates, screening of title and abstract reduced this number to 105 references. Studies excluded at this stage did not meet the inclusion criteria, were not written in English or did not report primary research. Full-text screening further reduced the number of studies to 62 (Supplementary material section 3.3). One study (Gruebner et al., 2011) was excluded because it reported the same data as a related study (Gruebner et al., 2012). The review therefore included a final set of 36 quantitative studies using validated mental health screening tools (Table 1; 58% of studies) five studies using qualitative and one study using mixed research methods (Table 2). All studies examined, wholly or in part, the relationships between greenspaces and mental health in LMICs. The quality of quantitative studies ranged from fair quality (score: 55%) to excellent quality (score: 91%);(Supplementary material, Table S3). Three quarters of the identified studies were published in the last five years, demonstrating increased research interest in LMICs.

3.1. Mental health outcomes

Of the 36 studies using validated mental health screening tools, 31 highlighted one or more positive (defined as health promoting) relationships between greenspaces and one or more mental health outcomes. Eight studies found at least one neutral (i.e., there were no detected effects) impact of greenspaces on mental health. Only three studies reported explicitly negative relationships, of which one focused on slum dwellers in Bangladesh (Gruebner et al., 2012, 2011). The only study from a low-income country (Bangladesh) showed negative relationships. Five of the six studies from lower-middle-income countries showed positive relationships,

while eight out of ten studies from upper-middle-income countries showed one or more positive relationships.

To identify patterns in the results, we examined the evidence by mental health outcomes (Figure 1). Dimensions of positive mental health including mental well-being, quality of life and life satisfaction were assessed by 15 studies. Mental well-being was assessed by 9 studies mostly from Asia, which generally reported positive relationships (7). Three studies from Latin America showed positive associations between greenspaces and quality of life. Life satisfaction was assessed by one study from South Africa finding neutral impacts. While one study assessing mental well-being focused on a low-income country, all remaining studies concentrated on upper-middle-income countries.

Dimensions of mental ill-health were assessed by 14 studies. Out of 11 studies investigating depressive disorders, nine reported positive effects, and three reported mixed or neutral effects. Geographically, studies assessing depressive disorders were quite diverse and targeted Latin America, South/East Asia and South Africa. However, with the exception of two studies from India, a lower-middle-income country, all studies focused on upper-middle-income countries. Of the six studies assessing anxiety disorders, all but one reported positive relationships. The evidence for anxiety disorders remains limited to the upper-middle-income countries China and Serbia.

Two out of the three studies assessing risk factors for mental disorders such as stress demonstrated positive effects but are limited to upper-middle-income countries in Europe and Latin America. Three studies based in upper-middle-income China assessed affective states such as mood. All reported positive effects, suggesting similarities to findings from HICs. All of the eight studies assessing the potential of greenspaces for contributing to attention restoration showed at least one positive association. Two of the studies found negative associations between particular greenspace types and attention restoration. The studies were conducted in Asia and Latin America.

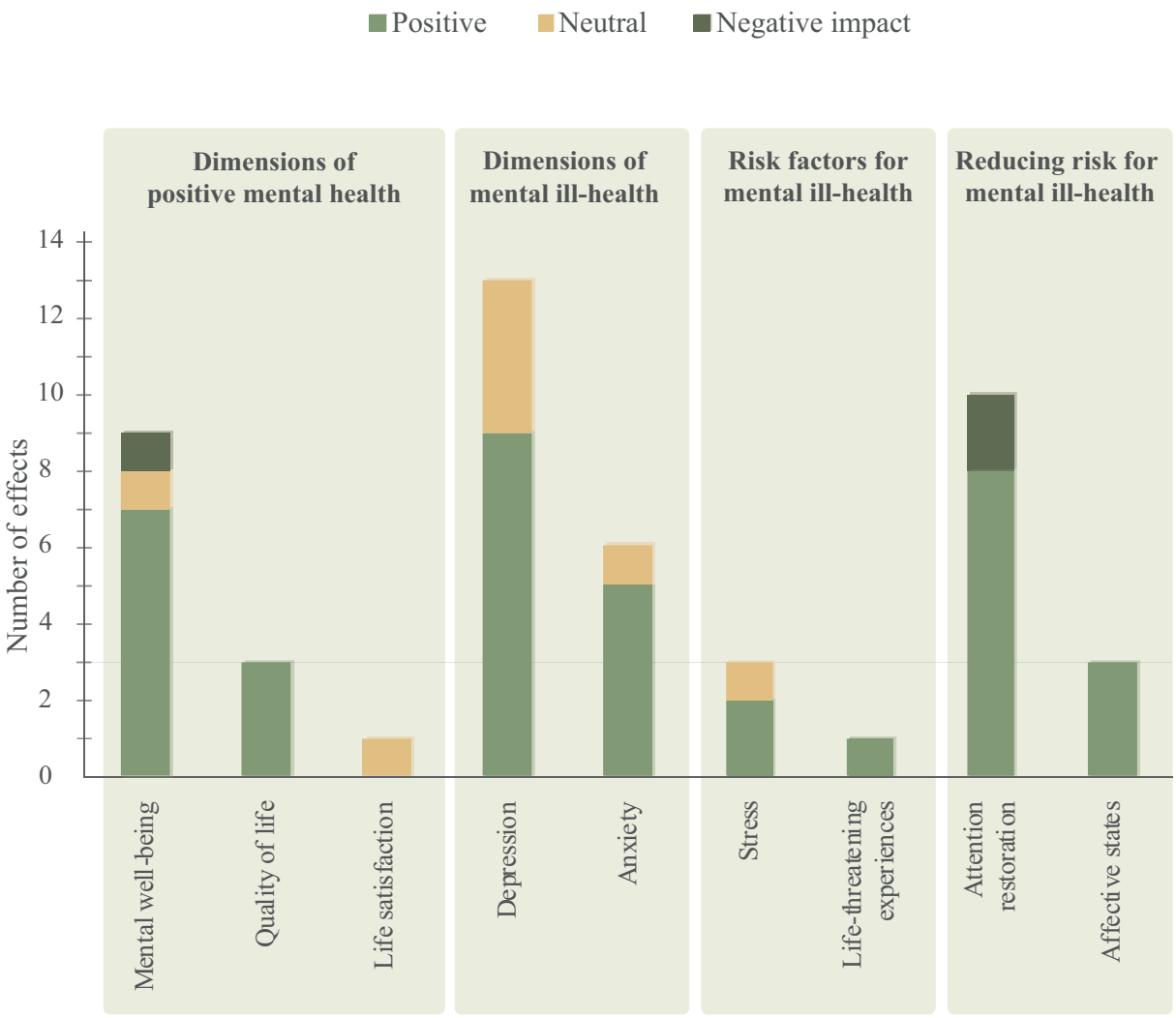

Figure 1: Mental health outcomes of 36 quantitative studies using validated mental health screening tools. Data were synthesised thematically to display the overall impacts of greenspaces on mental health as positive (significant positive relationships), neutral (no significant relationship) or negative (significant negative relationship), to describe the frequency of statistically significant findings. The number of effects does not match the number of reviewed studies, because some studies measured multiple mental health outcomes or showed varying effects for different greenspaces types. For depression, anxiety, stress and life-threatening experiences, a significant positive impact means that these conditions were reduced through exposure to greenspaces.

309

310 **3.2. Study designs and participants**

311 Most quantitative studies employed cross-sectional study designs (20), followed by experi-
312 mental (12), longitudinal (3) and uncontrolled before-after designs (1). Experimental in this
313 context refers to studies in which participants were exposed to greenspace, either directly or
314 through pictures/videos. All experimental studies used convenience sampling, predominantly

involving students from the research teams' university, limiting the generalisability of the results. All quantitative studies used questionnaire surveys to assess mental health (36). Other approaches used were interviews (6), focus groups (3), participant observation (1), physical measurements (1) and photovoice (1). Exposure to greenspaces was measured with a variety of approaches. Most studies were conducted through remote sensing techniques (13) and face-to-face (27), while eight were carried out in greenspaces.

The number of study participants varied considerably among the quantitative studies, ranging from 29 to more than 20,000 (Median: 687). Most studied were urban residents (12 studies) and university and school students (12), followed by park visitors (3). The remaining studies focused on the following target groups: slum dwellers (2), children with Autistic Spectrum Disorder (ASD; 1), psychiatric patients (1), university staff (1) and workers (1). Additional studies were solely on women (2) or the elderly (1).

Table 1: Main characteristics and results of 36 quantitative studies using validated mental health screening tools addressing greenspaces and mental health in low- and middle-income countries (LMICs). An overview over all assessed studies is provided in Supplementary material Table S2.

Study	Objectives	Study location	Study population	Study design	Methods	Health outcome and measures	Measure of greenspace	Mediators	Moderators	General result	Quality score
Adams et al. (2016)	Explored the relationship between children's perceptions of the natural environment and their subjective well-being	Cape Town (1-5m[1]), South Africa (subtropical climate), Upper-Middle-Income Country	Children from low- and middle-SES communities, age 12 years, n=1004	Cross-sectional	Questionnaire survey	Life satisfaction (Student Life Satisfaction Scale) and mental well-being (Personal Well-being Index: School Children)	Exposure to greenspace without control – engagement with nature measured through New Ecological Paradigm (NEP) Scale[2]	NA	NA	Mixed relationships – children's perceptions of the natural environment not related to domain-specific and global life satisfaction	Good quality (7)
Akpinar (2016)	Investigated the association between perceived restorativeness of high school greenness	Aydin (1-5m[1]), Turkey (subtropical climate), Upper-Middle-Income Country	High school students (from single school), age 12-20 years, n=223	Cross sectional	Questionnaire survey (mental health) and experts' opinions (greenspace)	Attention restoration (Perceived Restorativeness Scale) and self-perception of health	Cumulative opportunity – greenness scale; Experts' ranking of greenness from 0 (barely green) to 5 (predominantly green)	NA	NA	Mixed relationships – attention restoration, but not quality of life was associated with greenness	Good quality (7)
Aliyas (2019)	Investigated the influence of designed natural outdoor spaces and space type on the physical, mental and physiological health status of the elderly	Bandar Abbas (0.5-1m[1]), Iran (arid climate), Upper-Middle-Income Country	Elderly, age >65 years, n=912	Cross-sectional	Questionnaire survey	Mental well-being (Rand MOS Short Form 20)	Exposure to different greenspace types – self-report park and blue space access, visitation, length of stay, physical activity level[2]	Physical activity	NA	Mixed relationships – access to parks was not associated with better mental well-being; level of physical activity was associated with better mental health	Fair quality (5)
Ambrey and Shahni (2017)	Investigated how crime rate in the neighbourhood may moderate the link between greenspace and well-being	Tehran, Iran (5-10m[1]) (arid climate), Upper-Middle-Income Country	Urban residents, age unspecified, n=19060	Cross sectional	Questionnaire survey linked with GIS analysis	Mental well-being (GHQ-28)	Cumulative opportunity – percentage greenspace in residents' neighbourhood	NA	Crime	Mixed relationships – greenspace associated with mental well-being, but the effect was inhibited by crime	Good quality (8)

Barreto et al. (2019)	Investigated the association between exposure to green areas in the surroundings of the residence and the presence of common mental disorders among adults	Rio de Janeiro (>10m[1]), Brazil (tropical climate), Upper-Middle-Income Country	Administrative technical staff of single university, age 25-75, n=2584	Cross sectional	Questionnaire survey linked with GIS analysis	Depression, anxiety (GHQ-12)	Cumulative opportunity – Normalised Difference Vegetation Index (NDVI)	NA	NA	Positive relationships – presence of greenspaces was associated with reduced depression and anxiety in the intermediate income group (200 m buffer) and in the low-income group (400 and 1,500 m buffers)	Fair quality (6)
Bojorquez and Ojeda-Revah (2018)	Investigated the association between urban public park coverage and mental health in adult women	Tijuana (1-5m[1]), Mexico (subtropical climate), Upper-Middle-Income Country	Women, age 18-65 years, n=2345	Cross sectional	Questionnaire survey linked with measurement of urban park coverage	Depression (10 item CES-D)	Cumulative opportunity – percentage greenspace in residents' neighbourhood	NA	Age	Mixed relationships – public park coverage was associated with reduced depression for younger, but not for older women	Good quality (8)
Camargo et al. (2017)	Explored potential associations between individual and environmental correlates of quality of life in Colombian park users	Bucaramanga (0.5-1m[1]), Colombia (tropical climate), Upper-Middle-Income Country	Park visitors, age >12 years, n=1392	Cross sectional	Park in-situ questionnaire survey	Quality of life (EUROHIS-QOL 8-item Index, 5-level EQ-5D Index)	Exposure to greenspace without control – park use	NA	Perception of safety	Positive relationships – park use was associated with better quality of life	Good quality (7)
Chang et al. (2019)	Examined the role played by leisure satisfaction in the relationship between leisure settings (built and natural), subjective well-being and depression among midlife residents	Multiple Chinese cities (multiple climate zones), Upper-Middle-Income Country	Urban population, age 40-65, n=663	Cross sectional	Questionnaire survey	Depression (CES-D) and mental well-being (Dieners 5-item SWB scale)	Green vs. grey – survey questions (experiences of 17 leisure activities, including "leisure in nature: outdoor exercise and visiting a park")[2]	NA	NA	Positive relationships – leisure in nature was associated with life satisfaction and reduced depression	Fair quality (5)
Dong and Qin (2017)	Analysing associations between built and social environment with residents' mental well-being	Beijing (>10m[1]), China (temperate climate), Upper-Middle-	Urban residents, age 18-89 years old), n=712	Cross sectional	Questionnaire survey	Mental well-being (WEMWBS, 6-item)	Exposure to greenspace without control – distance from each neighbourhood to nearest park	NA	NA	Positive relationships – Living closer to an urban park was positively associated with better mental well-being	Fair quality (6)

		Income Country									
Firdaus and Ahmad (2016)	Identified temporal variation in the risk factors and prevalence rate of depression across the city at household level	Delhi (>10m[1]), India (subtropical climate), Lower-Middle-Income Country	Urban residents, age >18 years, n=3291	Longitudinal	Household questionnaire survey in 2003 and 2013	Depression (20-item CES-D)	Exposure to greenspace without control – survey questions: Accessibility to playground/park[2]	NA	NA	Positive relationships – lack of accessible parks associated with increased depression	Fair quality (6)
Gao et al. (2019)	Investigated the physiological (electroencephalogram, EEG), and psychological (attention, positive mood, negative mood) responses and individual preferences for different urban environments	Xianyang (5-10m[1]), China (temperate climate), Upper-Middle-Income Country	College students (from single university), age 20.7 (mean), n=120	Experimental	Exposure to virtual reality pictures	Emotions, mood (Profile of Mood States, 40-item)	Exposure to different greenspace types – pictures of grey space, blue space, open greenspace, partly open greenspace, partly closed greenspace, closed greenspace	NA	NA	Positive relationships – exposure to pictures of greenspace was associated with attention restoration and positive mood; Partly open greenspace had the most effective reduction of negative mood, followed by open greenspace, partly closed greenspace, blue space, and grey space, while closed greenspace had the least effect	Good quality (7)
Gruebner et al. (2012)	Assessed the factors that describe the mental well-being of poor populations residing in urban slums	Dhaka (>10m[1]), Bangladesh (tropical climate), Low-income Country	Slum dwellers, age >15 years, n=1938	Cross sectional	Face-to-face questionnaire survey linked with GIS analysis	Mental well-being (WHO-5)	Cumulative opportunity – distance to nearest river, park, vegetation ratio, water ratio, affected by flooding	NA	Infectious diseases, environmental pollution	Negative relationships – mental well-being negatively associated with vegetation patches, due to risk of infectious diseases and environmental pollution of greenspaces	Good quality (8)
Hassan et al. (2018)	Investigated the physiological and psychological relaxation effects of forest walking on adults	Chengdu (5-10m[1]), China (temperate climate), Upper-Middle-Income Country	University students (from single university), age 19-24 years, n=60	Experimental	Walks in urban or bamboo forests linked with questionnaire survey and physical	Anxiety (State-Trait Anxiety Inventory, Semantic Differential Method)	Green vs. grey – sampling in-situ, bamboo forests and urban area	NA	NA	Positive relationships – walking in bamboo forest was associated with improved mood and attention restoration, as well as with reduced anxiety	Fair quality (5)

					measure-ments						
Jiang et al. (2019)	Investigated the psychophysiological relaxation effects of viewing different landscape pictures on adults	Chengdu (5-10m[1]), China (temperate climate), Upper-Middle-Income Country	University students (from single university), age 22 (mean), n=50	Experimental	Questionnaire survey pre- and post-exposure to pictures of greenspaces	Anxiety (State-Trait Anxiety Inventory, Semantic Differential Method)	Exposure to different greenspace types – pictures of urban landscapes: urban city traffic, garden landscape, natural scenery, forest landscape and city landscape	NA	NA	Positive relationships – viewing greenspace pictures was associated with feeling more natural, relaxed, and comfortable; stress levels were significantly lower after looking at to T1 and T2 (both green), and increased after exposure to T0 (traffic)	Good quality (8)
Korn et al. (2018)	Investigated the effects of individual household gardens on the health of urban slum dwellers	Lima (>10m[1]), Peru (arid climate), Upper-Middle-Income Country	Adult slum dwellers, age unspecified, n=29	Longitudinal with repeated measures	Interviews, survey questionnaire after implementation of gardens	Quality of Life (WHOQOL-BREF), Stress (Perceived Stress Scale), Life-Threatening Experiences (LTE-Q), Social Capital (SCS)	Green vs. grey –private garden implementation	NA	NA	Positive relationships – 12-months post construction, the gardens were associated with improved quality of life, reduced life-threatening experiences, and increased social capital	Good quality (7)
Li et al. (2019b)	Investigated which type of park is most effective for psychological benefits	Shanghai (>10m[1]), China (subtropical climate), Upper-Middle-Income Country	Park visitors, age >60 years, n=200	Uncontrolled before-after study	GPS and pedometer records linked with questionnaire survey	Depression, anxiety (Visual Analogue Scale)	Exposure to greenspace without control – sampling in-situ, plan and land-cover maps, duration of stay indifferent areas through GPS (hard surface, lawn, tree cover, water, path/trail, children's playground, designated fitness area)	NA	NA	Positive relationships – park use was associated with reduced anxiety and depression, as well as with higher relaxation and contentment after park visit. Differences between activities: active park users were more relaxed and content than active walkers	Good quality (7)

Liu et al. (2019b)	Explored biopsychosocial pathways linking exposure to neighbourhood greenness to mental well-being	Guangzhou (>10m[1]), China (subtropical climate), Upper-Middle-Income Country	Urban residents, age 41 (mean), n=1029	Cross sectional	Questionnaire survey and GIS analysis	Mental well-being (WHO-5)	Cumulative opportunity – Normalised Difference Vegetation Index (NDVI)	Mitigation of air and noise pollution, stress reduction, physical activity, social cohesion	NA	Positive relationships – NDVI was positively associated with mental well-being; significant mediators were encouraging walking behaviours, facilitating neighbourhood cohesion, satisfaction with greenspaces	Excellent quality (9)
Liu et al. (2019a)	Explored biopsychosocial pathways linking residential greenness exposure to depression	Multiple provinces in China (multiple climate zones), Upper-Middle-Income Country	Rural and urban residents, age 15-64, n=20533	Cross sectional	Questionnaire survey and GIS analysis	Depression (CES-D 20-item)	Cumulative opportunity – percentage of greenspace in residents' neighbourhood	Stress reduction, physical activity, social cohesion	Urbanicity	Positive relationships – exposure to residential greenness was negatively associated with depression; physical activity, stress reduction, and neighbourhood social cohesion mediated the association	Good quality (8)
Lyu et al. (2019)	Examined the role of bamboo forests in the promotion of physical activity and positive mental health after park use	Chengdu (5-10m[1]), China (temperate climate), Upper-Middle-Income Country	Students from agricultural university (single university), age unspecified, n=120	Quasi-experimental	3 days field experiments; experience of the landscape followed by questionnaire survey (bamboo forest therapy)	Emotions, mood (Profile of Mood States)	Exposure to different greenspace types – sampling in-situ, urban or bamboo forests (3 types)	NA	NA	Positive relationships – interacting with bamboo forest was associated with reduced tension, anxiety, anger, hostility, depression, fatigue; vigour was lower in urban areas	Excellent quality (9)
Martínez-Soto et al. (2014)	Explored the possible restorative effects of variables related to urban nature and psychological transaction processes with the environment on emotional and	Mexico City (>10m[1]), Mexico (subtropical climate), Upper-Middle-Income Country	Urban residents, age 17-79 years, n=120	Cross sectional	Questionnaire survey	Attention restoration (Revised Scale of Perception of Restorative Environments, 26 item), (Reverse Order Digit Span Subtest), (Well-being Scale)	Exposure to greenspace without control – nature in the Home Scale, proximity of greenspaces, Transactions with Nature Scale (11 item)	NA	NA	Mixed relationships – improved cognitive function associated with potted plants and visiting green areas outside home; cognitive functioning improved by greater distance from common green area	Good quality (7)

	cognitive indicators of psychological restoration										
Martinez-Soto et al. (2014), study 2	Evaluated the restorative quality of three environments and assessed differences between them	Mexico City (>10m^{1}), Mexico (subtropical climate), Upper-Middle-Income Country	University students (from single university), age unspecified, n=96	Quasi-experimental	Viewing pictures of greenspaces linked with questionnaire survey	Attention restoration (Revised Scale of Perception of Restorative Environments, 25-item)	Exposure to different greenspace types – pictures including images of the natural environment, urban nature and urban landscape without nature	NA	NA	Positive relationships – greenspaces had greater restorative quality than urban with greenspaces and built-up without greenspaces; urban greenspace was perceived as having greater restorative quality than images without greenspaces	Good quality (7)
Martinez-Soto et al. (2014), study 1	Documented the affective qualities of three environment classes: natural, urban with nature, and built-up without nature	Mexico City (>10m^{1}), Mexico (subtropical climate), Upper-Middle-Income Country	University students (from single university), age unspecified, n=104	Quasi-experimental	Viewing pictures linked with questionnaire survey	Attention restoration (Self-assessment Manikin)	Exposure to different greenspace types – pictures of the natural environment, urban nature and urban landscape without nature	NA	NA	Positive relationships – affective valence (pleasure, arousal) was associated positively with image of greenspace, compared to urban with greenspace and greenspace vs built-up without greenspace	Good quality (7)
Memari et al. (2017)	Identified the relationship between environmental characteristics of restorative natural environments	Gorgan (0.3-0.5m^{1}), Iran (arid climate), Upper-Middle-Income Country	University students (from single university), age 19-26 years, n=124	Quasi-experimental	Viewing pictures linked with questionnaire survey	Attention restoration (Short-version Revised Restoration Scale, 8-item)	Exposure to different greenspace types – pictures representing the perceived sensory dimensions (eight components: serene, nature, rich in species, space, prospect, refuge, social, culture)	NA	NA	Mixed relationships – the pictures of "serene", "nature" and "refuge" greenspace resulted in most reduction of stress; "species richness" and "social" showed a negative association	Good quality (8)

Mukherjee et al. (2017)	Examined the association between park availability and major depression among adults with one or more chronic conditions	Delhi (>10m[1]), India (subtropical climate), Lower-Middle-Income Country	Urban residents with chronic condition(s), age >20 years, n=1208	Cross-sectional	Questionnaire survey linked to GIS analysis	Depression (Mini International Neuropsychiatric Interview, Section A)	Cumulative opportunity – park distance from households, area of nearest park, number and total area of all parks within 1km of home	Physical activity	NA	Positive relationships – area of the nearest park was positively associated with major depression	Excellent quality (9)
Mullings et al. (2013)	Explored the mental health effects of the urban neighbourhood on men and women in Jamaica and the implications for urban planning and social development	Country-wide, Jamaica (tropical climate), Upper-Middle-Income Country	Urban residents, age 15-74 years, n=2848	Cross-sectional	Secondary data from Health and Lifestyle Survey	Depression (Diagnostic and Statistical Manual of Mental Disorders DSM-5) [7]	Green vs. grey – presence/absence of greenspace in neighbourhood (lawn, ornamental plants, trees)	NA	NA	No relationships – no association between depression and greenspace	Fair quality (6)
Parra et al. (2010)	Examined associations between neighbourhood environment attributes and health related quality of life and self-rated health among older adults	Bogotá (>10m[1]), Colombia (subtropical climate), Upper-Middle-Income Country	Urban residents, age >60 years, n=1966	Cross-sectional	Face-to-face questionnaire survey	Quality of life (Short form 8)	Cumulative opportunity – walking levels and perceived environmental characteristics (safety, street noise, public park density, number of public transport stations and bicycle lanes)	Physical activity	Perception of safety	Positive relationships – perceptions of parks being safe were positively associated with higher quality of life; residents of areas with more than 8% of land covered by public park area were more likely to report good, very good, or excellent health status	Good quality (7)
Scopelliti et al. (2016)	Investigated the effects of contact with urban parks on well-being	Bogotá (>10m[1]), Colombia (subtropical climate), Upper-Middle-Income Country	Park visitors, age 18-80 years, n=300	Cross-sectional	In-situ greenspace questionnaire survey	Attention restoration (Connectedness to Nature Scale), (New Human Interdependence Paradigm Scale), (Perceived Restorativeness Scale), (Positive Affective Qualities), (Positive Emotions); Negative Emotions), (Physical and Psychological Well-being)	Cumulative opportunity – park size, residence distance to park, frequency of visit, visit length, main activity, frequency green	NA	Income	Positive relationships – respondents in larger urban parks experienced higher attention restoration compared to respondents in smaller district parks; the middle-income group experienced better outcomes compared to the higher- and lower-income groups	Good quality (7)

Shagdarsuren et al. (2017)	Examined patterns of perceived neighbourhood quality by residents and the associations between these patterns and self-reported general and mental health in middle-aged women	Ulaanbaatar (1-5m[1]), Mongolia (arid climate), Lower-Middle-Income Country	Women, age 40-60 years, n=830	Cross-sectional	Face-to-face questionnaire survey in participants homes	Depression (GHQ-12)	Exposure to greenspace without control – survey questions about the perception of the neighbourhood environment: easy to find green open spaces, river water is clean, nature is well preserved[2]	NA	NA	No relationships – perception of neighbourhood greenspace was not associated with depression	Fair quality (5)
Smyth et al. (2011)	Examined the relationship between environmental surroundings and personal well-being	Multiple cities in China (temperate climate), Upper-Middle-Income Country	Blue- and white-collar workers, age 18-60 years, n=3390	Cross sectional	Questionnaire survey and GIS analysis	Mental well-being (Personal Well-being Index)	Cumulative opportunity – green area per capita in 2003 in the city where respondents lived	NA	NA	Positive relationships – in cities with more parkland, respondents reported significantly higher levels of mental well-being	Good quality (7)
Tomita et al. (2017)	Investigated the effect of green living environments in potentially countering incident depression	Country-wide, South Africa (multiple climate zones), Upper-Middle-Income Country	Urban residents, age unspecified, n=11156	Longitudinal	Household and individual questionnaire survey linked with GIS analysis	Depression (CES-D, 10-item)	Cumulative opportunity – Normalised Difference Vegetation Index (NDVI)	NA	NA	Mixed relationships – uneven benefit of NDVI on incident depression; green living environment showed limited benefit across the study population as a whole, the analysis showed that higher NDVI was a predictor of lower incident depression among middle- income compared with low-income participants	Excellent quality (10)
Vujcic and Tomicevic-Dubljevic (2018)	Explored the restorative potential of urban forest environments and identified perceived benefits of physical activity on psychological well-being and social cohesion of	Belgrade (1-5m[1]), Serbia (subtropical climate), Upper-Middle-Income Country	University students (from single university), age 22-32 years, n=47	Quasi-experimental with repeated measures	Time spent either in greenspace or control linked with questionnaire survey	Depression, Anxiety, Stress (Depression, Anxiety, Stress Scale)	Green vs. grey – sampling in-situ, exposure to arboretum/control	NA	NA	No relationships – arboretum intervention was associated with reduced depression, anxiety and stress, but control group had similar effect	Good quality (7)

	the younger population										
Vujcic et al. (2017)	Aimed to understand how spending time and performing horticulture therapy in specifically designed urban green environments can improve mental health	Belgrade (1-5m[1]), Serbia (subtropical climate), Upper-Middle-Income Country	Psychiatric patients, age 25-65 years, n=30	Quasi-experimental with repeated measures	Horticultural therapy intervention linked with questionnaire survey	Depression, Anxiety, Stress (Depression, Anxiety, Stress Scale)	Green vs. grey – sampling in-situ, horticultural therapy intervention	NA	Gender, education	Positive relationships – significant stress reduction in the study group compared to the control group	Good quality (8)
Wang et al. (2016)	Explored the stress recovery effects of different videotaped scenes, using six urban parks and one urban roadway scene	Shanghai (>10m[1]), China (subtropical climate), Upper-Middle-Income Country	University students, age 18-24 years, n=140	Quasi-experimental with repeated measures	Questionnaire survey, stress induction (exam) followed by recovery (video scenes of parks)	Attention restoration (Perceived Restorativeness Scale), stress (State-Trait Anxiety Inventory), (Digit Span Backwards Test)	Exposure to different greenspace types – videotapes of 6 urban parks and 1 urban roadway, including nature-based vs. hardscape components, presence/absence of people, and level of openness	NA	NA	Positive relationships – viewing urban park scenes was associated with stress reduction and attention restoration, especially for scenes without people	Fair quality (6)
Wang et al. (2019)	To examine how streetscape and greenery affect well-being, including the assessment of mediators	Guangzhou (>10m[1]), China (subtropical climate), Upper-Middle-Income Country	Urban residents, age 41 (mean), n=1029	Cross-sectional	Questionnaire survey linked with GIS analysis	Mental well-being (WHO-5)	Cumulative opportunity – Normalised Difference Vegetation Index (NDVI), Streetscape greenery from street view data	Mitigation of air and noise pollution, stress reduction, physical activity, social cohesion	NA	Positive relationships – streetscape greenery and NDVI were positively associated with mental well-being; physical activity, stress, air quality, noise and social cohesion were mediating the relationship	Excellent quality (9)

Zhang et al. (2019)	Explored whether and how audio-visual contexts and experiences in urban parks influence psychological responses	Harbin (>10m[1]), China (temperate climate), Upper-Middle-Income Country	University students (from single university), age 22-33 years, n=36	Experimental	Audio-visual walk linked to questionnaire survey	Emotions, mood (Profile of Mood States, Positive and Negative Affect Scale)	Exposure to greenspace without control – sampling in-situ, sound pressure level, loudness, sharpness, roughness; landscape elements (plants, sky, paving)	NA	NA	Positive relationships – the impact intensity of acoustic comfort was significantly higher than that of visual comfort on emotions and mood, while visual comfort was significantly higher than acoustic comfort on psychological responses of cognition dimension	Good quality (8)
Zhao et al. (2018)	Aimed to find reliable evidence to inform landscape design of auditory-visual combinations aiming to improve the restorative quality	Xuzhou (5-10m[1]), China (temperate climate), Upper-Middle-Income Country	University students (from single university), age unspecified, n=382	Experimental	Viewing pictures and listening to sounds linked with questionnaire survey	Attention restoration (Short version Revised Restoration Scale)	Exposure to different greenspace types – pictures of 3 parks (categories: building, topographical variation, water body, plants), soundscapes (natural sounds: birdsong, sound of flowing water, sound of wind)	NA	NA	Positive relationships – viewing pictures of waterscape was associated with attention restoration; bird song and wind song increased attention restoration in highly vegetated areas	Good quality (7)

[1]Urban population in millions

[2]Study did not use objective measures of greenspaces

3.3. Geographic characteristics of the evidence

To date, the relationship between greenspaces and mental health remains unexplored in more than 90% of LMICs (Figure 2). Most studies were based in Asia (25), two in Europe, five in Africa, and ten in Latin America. Although 13 countries were studied, 55% of research was carried out in only three countries, China, Iran and South Africa. Almost two out of five studies (35%) focused on urban areas in China.

The body of evidence in Asia has been expanding rapidly and begins to cover a diversity of geographic regions and cultural groups. However, studies focused predominantly on upper-middle-income countries, and low-income countries remain unexplored with the exception of Bangladesh. In Africa, South Africa, an upper-middle-income country, is the only studied country, leaving unexplored a tremendous diversity of environmental and cultural conditions on a continent which is experiencing the fastest urbanisation globally (Angel et al., 2011). Latin America gained more research attention, yet again this was limited to upper-middle-income countries. Even though limited in numbers, ten studies covered a diversity of environmental and cultural conditions in Latin America.

The spatial scale at which linkages were assessed ranged from nationwide, inter-city comparisons to local, intra-city comparisons. Major cities with a population of more than one million (United Nations 2014, 2018) gained most attention, whereas small and medium-sized towns remain understudied in the LMIC context. Apart from five studies which performed inter-city comparisons, around half of the city-level studies (17) investigated mega-cities with a population of more than 10 million. Seven studies took place in cities with 5-10 million inhabitants, and nine in cities with 1-5 million inhabitants. Only one study from South Africa focused on a city with a population of less than 300,000 inhabitants. Three studies from South Africa assessed the relationship between greenspaces and mental health in informal settlements, whereas another two studies from Bangladesh and Peru focused on slums settlements.

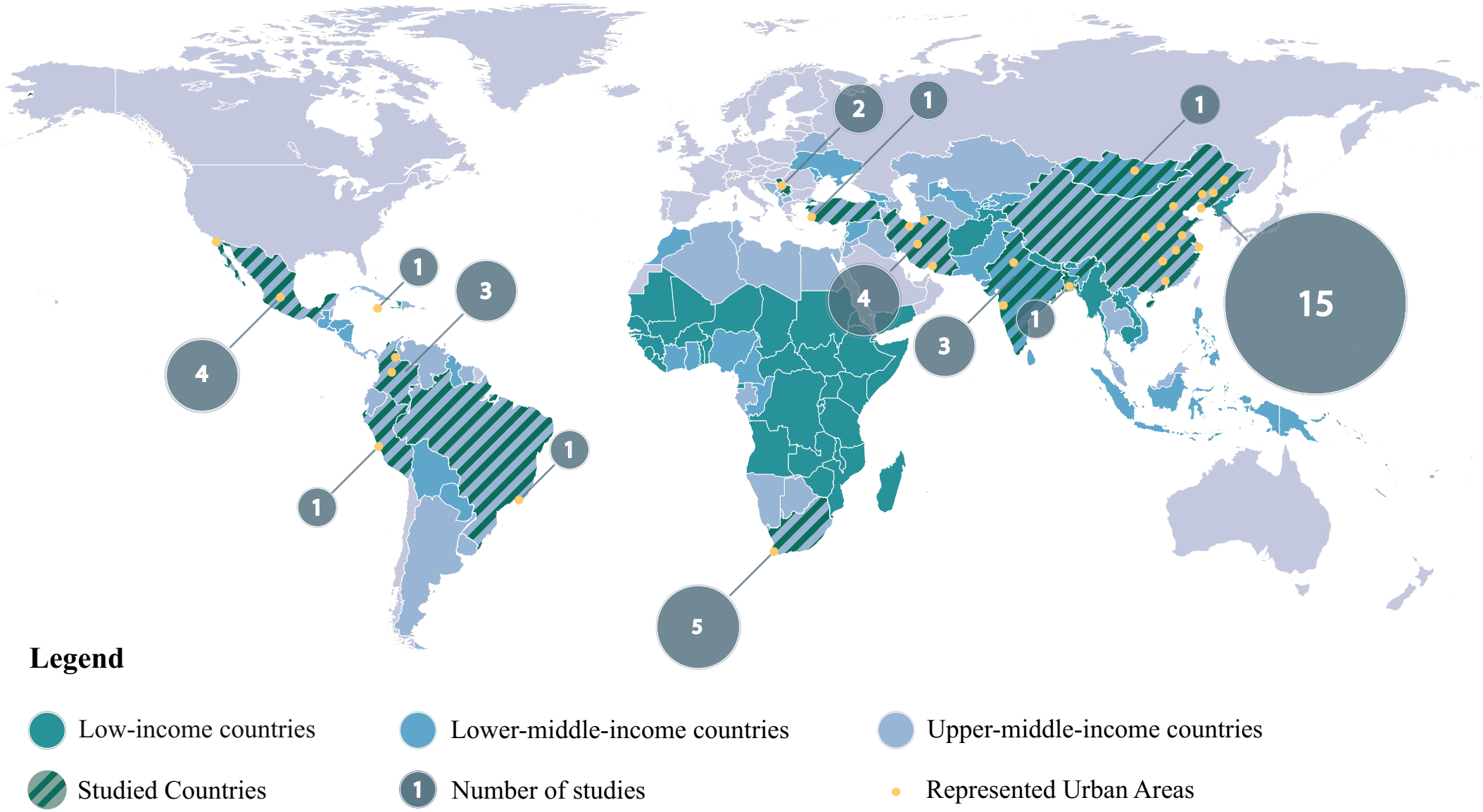

Figure 2: Geographic distribution of the 36 qualitative studies using validated mental health screening tools and the six qualitative studies. All studies assessed the relationship between greenspaces and mental health in LMICs. Shown are Development Assistance Committee (DAC) low- and middle-income countries (LMICs) and urban areas investigated by the studies included in this review. In some urban areas several studies were conducted. Hence, the number of represented urban areas does not correspond with the number of reviewed studies.

3.4. Greenspace assessment

Studies took into account a variety of greenspace types, including urban greenspaces (25 studies), urban parks (7), urban forests (3) and private gardens (1). The only study with focus on private gardens focused on a slum settlement in Lima, Peru (Korn et al., 2018).There was considerable variation across the 36 studies on how exposure to greenspaces was assessed, ranging from 'green vs. grey' (vegetated vs. non-vegetated) comparisons to assessing greenspace structural diversity. Eight studies assessed the effects of exposure to greenspaces without using experimental controls, such as exposure to non-green environments. Lacking experimental controls reduces the reliability of results since it is difficult to determine the effects of the independent variable (greenspaces) on the dependent variable (mental health). Four studies relied on the perception rather than on objective measures of greenspaces such as through assessing exposure with remote sensing or ecological survey techniques, while seven studies compared 'green vs. grey' scenarios. 13 studies estimated exposure to greenspaces through cumulative opportunity (Ekkel and de Vries, 2017), based on the proportion of greenspaces within a spatial unit that incorporates individuals' location such as a residence, commonly measured through the amount of greenness in an area, using metrics such as Normalised Difference Vegetation Index (NDVI) or green area per capita (Bratman et al., 2019). Nine studies assessed differences in the natural features characterising greenspaces such as size, composition, vegetation structure or tree canopy density and their effects on mental health (Bratman et al., 2019). However, most of such studies used pictures rather than ecological measures of greenspaces. A defining characteristic of the reviewed body of evidence is a lack of use of standard approaches for assessing ecological differences in greenspaces such as ecological surveys. This means that studies did not survey information on the distribution and abundance of animal and plant species present in greenspaces. Furthermore, despite being recognised as a key research frontier, none of the studies explored how different aspects of biodiversity may affect mental health. Further, only few of the studies considered other exposure metrics such as frequency and duration of exposure, or accessibility of greenspaces (Bratman et al., 2019).

The different strategies which were used for measuring exposure to greenspaces did not show clear differences in how greenspaces and mental health were associated, as most studies showed positive links. Six of the eight studies assessing greenspaces without using controls

such as non-green environments showed positive associations. Three of the five studies assessing the mental health effects of green vs. non-green environments showed positive relationships. Around 92% of the studies exploring relationships between the amount of greenness in an area (cumulative opportunity) and mental health outcomes showed positive results. Finally, eight of the nine studies assessing the mental health effects of the structural diversity of greenspaces showed positive relationships.

3.5. Mental health assessment

A variety of mental health outcomes were studied using a range of validated mental health screening tools (Table 1). None of the studies used a trained mental health professional to assess mental health. Most studies defined mental health 'positively' through measuring positive states of mental health, including mental well-being (9 studies), quality of life (3), or factors which are linked to positive mental health, including cognitive functioning (1), life satisfaction (1) and social capital (1). Some studies defined mental health 'negatively', as the absence of specific mental disorders, measuring prevalence of depressive disorders (11) and anxiety disorders (6). None examined severe mental ill-health such as schizophrenia or bipolar disorder. Four studies assessed risk factors for mental disorders such as stress (3) and life-threatening experiences (1). All studies focusing on stress were conducted in China. As a further limitation, all of the studies analysed the responses of university students. Some studies assessed the potential of greenspaces to reduce risk for developing disorders/to increase mental well-being (attention restoration; 8). The remaining studies assessed affective states (3) (short-term aspects of well-being) including emotions (4) and mood (3).

3.6. Mediation analysis

Mediation analyses were conducted in six studies (Table 1). The evidence for pathways through which greenspaces can reduce harm to mental health remains inconclusive. Two studies from China investigated the role of air and noise pollution for mediating the link between greenspaces and mental health, with contradicting results. In contrast to Liu et al. (2019b), Wang et al. (2019) found that reduced air and noise pollution mediated the mental health effects of greenness.

None of the studies explicitly took into account environmental factors such as local climatic conditions as a mediating factor impacting on the relationship between greenspaces and mental

health, nor did any study draw comparisons between cities in different climate zones. However, the studies were conducted in a variety of climatic conditions. A number of studies from China (8) assessed cities characterised by temperate climate, of which all showed positive relationships. A large proportion of the studies (17) examined cities in subtropical settings, covering four continents and a range of mental health outcomes. 90% of studies from subtropical cities showed positive relationships. A diversity of studies from arid regions in Latin America and Asia (5) demonstrated that greenspaces can support mental health in such regions. This suggests that greenspaces can support mental health in temperate, subtropical and arid settings.

Despite being relatively diverse in geographic distribution, the evidence from tropical LMICs did not indicate a clear relationship between greenspaces and mental health. Four studies took place in tropical regions in Latin America (Brazil, Colombia, Jamaica) and Asia (Bangladesh). While two studies from Latin America reported mental health promoting relationships with greenspaces, a study from Dhaka, Bangladesh, indicated a pathway through which greenspaces may affect mental health negatively under tropical conditions. They suggested that negative links between the presence of vegetation and mental well-being may be partially explained through a fear of risk of infectious diseases, which may occur more frequently in greenspaces in tropical regions (Gruebner et al., 2012). It is important to note that none of the studies explored reducing heat exposure as a mediating factor, which would have been of particular interest in regions characterised by hot climate.

Four studies took into account the potential of greenspaces for restoring psychological capacities. Two studies from China found that stress reduction mediated the effects of exposure to greenspaces on depression (Liu et al., 2019a) and on mental well-being (Wang et al., 2019). In contrast to previous findings, Liu et al., (2019b) found no evidence to indicate that stress reduction was a pathway linking greenspaces to mental well-being.

Greenspaces may support good mental health through building capacities by encouraging physical activity and facilitating social cohesion (Markevych et al., 2017). In this review, the evidence for the mediating role of physical activity is inconclusive. Physical activity was found to be a significant mediator to increase mental well-being (Aliyas, 2019; Liu et al., 2019a, 2019b; Wang et al., 2019) and to decrease depression (Liu et al., 2019a) in Chinese cities. In contrast, Parra et al.'s (2010) study found that physical activity did not mediate changes in quality of life related to park availability in Colombia. In Mukherjee et al.'s (2017) study, physical activity

played no role in reducing depression in India. Two studies found that social cohesion mediated the effects of greenspaces on mental well-being (Liu et al., 2019b; Wang et al., 2019).

3.7. Moderation analysis

Moderation analyses were conducted in nine studies (Table 1). These were classified as either personal (gender) or contextual (safety and crime, pollution, cultural factors) (Marselle et al., 2018). Most studies did not consider the moderating effects of demographic or socio-economic factors. Studies from Iran, South Africa and Colombia found that crime levels and perceptions of safety moderated the relationship between greenspaces and mental health. In Tehran, the mental well-being benefits linked with greenspaces were inhibited in areas with higher crime rates; against expectations, no gender differences were observed (Ambrey and Shahni, 2017). In their qualitative study, Adams et al. (2018) found that a lack of safety restricted children's discovery and exploration of greenspaces in Cape Town, thereby inhibiting potentially positive effects. In Bogotá, Parra et al. (2010) and Camargo et al. (2017) found that perceptions of safety in general and on the way to the park moderated the effects of density of parks and park use on quality of life.

In Dhaka, Bangladesh, Gruebner et al. (2012) assessed the mental well-being of slum dwellers. They found negative links between mental well-being and the presence of vegetation patches. Even though not assessed through moderation analysis, the authors suggest that the mental well-being benefits were inhibited by environmental pollution. Vegetated areas in the slums turned out to be low-lying and regularly flooded areas. Combined with poor sanitation, open wastewater drainage and garbage disposal, these vegetation patches increased the risk for infectious diseases, with negative repercussions for mental well-being. None of the studies took into account explicitly particular environmental and cultural factors impacting on how people interact with greenspaces, nor did they assess how such factors might moderate beneficial mental health effects.

3.8. Synthesis of qualitative studies

The five studies using qualitative research methods and one mixed methods study documented mostly positive impacts of greenspaces on mental health in LMICs (Table 2). The majority of these were of excellent and good quality, while only one study was of fair quality and one of

poor quality. In two cities in China, the parents and caregivers of children with Autism spectrum disorder (ASD) were questioned about the observed benefits of greenspace interactions (Li et al., 2019a). Exposure to greenspaces provided emotional and social benefits to children with ASD. Parents observed that spending time in greenspaces helped children to soothe stress and anxiety.

Two studies explored how greenspaces can support restoring capacities through psychological restoration and building capacities through encouraging physical activity and facilitating social cohesion. Elderly residents of Pune, India, expressed being able to derive psychological benefits such as relieving stress, mental peace, and restorative experiences such as feeling fresh and cheerful from visiting urban parks (Gaikwad and Shinde, 2018). Adding to this, spending time in urban parks was considered being an important resource for social interactions and for being physically active. In Isfahan, Iran, a green canal corridor was found to help urban residents to have a more physically active life, to promote a sense of restoration, calmness and concentration, as well as to foster social interactions (Vaeztavakoli and Lak, 2018).

Two studies focusing on informal settlements in Cape Town, South Africa documented positive relationships between greenspaces and mental health. Examining the psychological effects of urban agriculture, Olivier and Heinecken (2017) found that cultivation helped women to develop supportive networks that unlock benefits across the personal, social and economic spectrum. Beyond cultivating being an important livelihood strategy, women reported 'getting joy and fulfilment' from working on their plots. Similarly, another study from Cape Town used photovoice to explore the effects of urban agriculture for people in an informal settlement (Lucke et al., 2019). Informants reported that the act of harvesting made them happy, since it meant they had something to eat or sell. They also experienced a sense of pride from the achievement of growing vegetables. For some, having gardening as a task translated into meaning of life. Another study focusing on informal settlements in Cape Town, however, documented how safety issues can inhibit positive mental health effects of greenspaces. Exploring the meanings children in a low socio-economic status community attached to greenspaces, Adams et al. (2019) found that a lack of safety restricted children's discovery and exploration of greenspaces, thereby inhibiting potentially positive effects on subjective well-being.

518 *Table 2: Main characteristics and results of five qualitative and one mixed methods studies addressing*
519 *greenspaces and mental health in low- and middle-income countries (LMICs).*

Study	Objectives	Study location	Study population	Methods	Health measures	Measure of greenspace	General result
Adams et al. (2018)	Explored children's constructions and the meanings they attach to natural spaces and the impact on their subjective well-being	Cape Town (1-5m[1]), South Africa (subtropical climate), Upper-Middle-Income Country	Children from low-SES communities, age 13-14, n=32	FGDs, interviews	Interview themes around child friendly neighbourhoods and environmental awareness	NA	Children's perception of the natural environment was negative mainly due to safety issues (crime)
Gaikwad and Shinde (2018)	Contributed to understanding how neighbourhood amenities such as parks relate with active aging	Pune (5-10m[1]), India (arid climate), Lower-Middle-Income Country	Elderly park visitors, age unspecified, n=20 (interviews), 6 (FGDs), 31 (survey)	Visitor counts and questionnaires, non-participant observation, interviews, FGDs and feedback visitor register	Themes emerging from qualitative data about psychological benefits of interacting with greenspaces[7]	Sampling in-situ, park use	Interactions with greenspaces were associated with stress reduction and attention restoration
Li et al. (2019)	Investigated whether benefits associated with exposure to nature could be observed by parents of children diagnosed with ASD	Shanghai (>10m[1]) and Yantai (5-1m), China (subtropical climate), Upper-Middle-Income Country	Children with autism (ASD) (interviews through caregivers, not directly with children), age 4-7, n=22	Semi-structured interviews	Interview question: What are the benefits of visiting greenspace to your child? [7]	"How often does your child go outdoors" and "Is greenspace a part of his or her outdoor experience?"	Most parents (20 out of 22) perceived nature visits as being helpful for children to relax, promote positive emotions and reduce negative emotions; they also reduced stress and anxiety, but did not help with tantrums
Lucke et al. (2019)	Explored the motivation for, and potential effects of, participation in a township community garden	Masakhane (<0.3m[1]), South Africa (subtropical climate), Upper-Middle-Income Country	Township residents attending community garden, age 21-57, n=18	Photovoice	Guiding questions handed out with cameras, about "how does the garden make you feel?" [7]	Participation in community gardening	Engagement in gardening activities was motivated by psychological effects such as happiness, pride, self-encouragement, meaning of life, feeling of independence and stress reduction
Olivier and Heinecken (2017)	Established how NGO-run urban agriculture projects benefit women on the Cape Flats	Cape Town (1-5m[1]), South Africa (subtropical climate), Upper-Middle-Income Country	Adult agricultural cultivators, age unspecified, n=59	In-depth interviews, FGDs	Intangible social benefits of urban agriculture[7]	Participation in urban agriculture	Participation in urban agriculture provided a sense of accomplishment, belonging, fulfilment, relaxation, reconnection to rural roots and increased social capital

Vaeztavakoli and Lak (2018)	Explored the health aspects of urban water canals in physical, mental, and social dimensions based on the residents' experiences	Isfahan (1-5m[1]), Iran (arid climate), Upper-Middle-Income Country	Urban residents, age 15-85 years, n=200	Face-to-face interviews	Content analysis	Sampling in-situ at canals to target users	128/200 participants thought that the canal contributes to mental health, promotes comfort and relaxation, sense of safety, sensory richness, relaxation and sense of satisfaction

[1]Urban population in millions

4. Discussion

This scoping review provides novel insights into the relationship between greenspaces and mental health in LMICs. While a large majority of LMICs remain unexplored, we found that eight out of ten studies using validated mental health screening tools detected positive associations between greenspaces and one or more mental health outcomes. The findings suggest that greenspaces can generally support mental health in LMICs.

Regarding positive dimensions of mental health, the evidence indicates that mental well-being and quality of life can be supported by greenspaces in upper-middle-income countries. This supports the evidence from HICs for mental well-being (Houlden et al., 2018) and quality of life (Stigsdotter et al., 2010). For depressive disorders, the evidence is quite strong and indicates a positive relationship for a diversity of upper-middle-income countries. This confirms the evidence from HICs (Lovell and Maxwell, 2018). However, the relationship remains unexplored in lower-middle and low-income countries. Similarly, the evidence for anxiety disorders indicates that greenspaces may reduce anxiety levels in upper-middle-income countries. Altogether, the evidence from upper-middle-income countries for the impact of greenspaces on stress, affective states and attention restoration indicates to support the evidence from HICs.

4.1. Limitations of the reviewed evidence

A limitation of the evidence is that most studies used cross-sectional designs. In such studies, temporal relationships cannot be established, no conclusions about causality can be drawn (van den Berg et al., 2015) and changes in long-term mental health effects cannot be assessed (Bratman et al., 2019). Moreover, selection bias may have influenced results, particularly for those studies using convenience sampling to recruit study participants.

Geographically, the evidence in LMICs begins to cover a diversity of upper-middle-income countries in Asia and Latin America, the regions with the highest urbanisation rates in Asia and Africa, especially lower-middle-income and low-income countries, remain largely unexplored. None of the African studies, for instance, addressed cities outside of South Africa. Informal settlements and slums are the dominant type of settlement in many cities in LMICs (United Nations, 2015). By 2050, up to 3 billion people will be living in informal settlements and slums, mostly in LMICs (Nagendra, 2018). Even though relative numbers of people living in such environments have been decreasing, slums and informal settlements will remain a key urban challenge during the next decades (United Nations, 2015). So far, only few studies have focused on these particular urban settings. Research in LMICs took place overwhelmingly in large cities with a population of more than one million. Limiting research to the largest cities may be problematic, since small to medium-sized cities are growing the fastest and will be the home for a large majority of future urban populations (United Nations, 2014).

Only a few studies took into account mediating and moderating factors. Therefore, the evidence for the mediating pathways through which greenspaces reduce harm, restore capacities and build capacities for mental health in LMICs remains inconclusive. This is mainly due to the limited number of studies taking into account pathways linking greenspaces and mental health. A further limitation of the evidence is that all five studies taking into account mediating pathways focused on only one country, China.

Even though the evidence indicates a positive relationship between greenspaces and multiple mental health outcomes in upper-middle-income countries across temperate, subtropical, arid and tropical regions, none of the studies explicitly tested the impact of different climatic conditions. This gap is further exacerbated through climate change, which poses significant challenges to human health including increased numbers of heat waves, droughts and flooding events (EEA, 2016).

A number of the reviewed studies, predominantly those with focus on informal settlements and slums, found negative links between greenspaces and mental health. Negative links were associated with the moderating factors safety (or perception of safety) and environmental pollution (litter, open wastewater drainage) of greenspaces. These results are consistent with previous findings about the importance of such greenspace attributes (McCormack et al., 2010). Indeed, Amano et al. (2018) found that greenspaces were linked with decreased health for residents of

economically deprived cities in LMICs. The authors argued that the observed negative links were due to the poor quality of greenspaces in many urban low-income settings, which contrasts to a recent review of the links between greenspaces and general health in LMICs that reported mostly health benefits (Shuvo et al., 2020). Our review is substantially different from Shuvo et al. (2020) in that we focus on mental health specifically and included qualitative studies, which enabled us to identify and review a much higher number of studies and allowed deeper insights into the links between greenspaces and mental health in LMICs. This suggests that greenspaces can generally support mental health in urban low-income settings, unless beneficial effects are not inhibited by factors such as safety, environmental pollution or other factors compromising the quality of greenspaces.

Moreover, in biodiverse tropical regions, greenspaces can promote the introduction and survival of vector or host organisms for infectious pathogens such as habitats for mosquitoes and may increase exposure to pollen (Lohmus and Balbus, 2015). Zoonotic disease risk, for instance, is elevated in tropical regions where wildlife biodiversity is high, especially when experiencing land-use changes such as urbanisation (Allen et al., 2017).

Studies used a variety of approaches to measure greenspace exposure. However, none of the reviewed studies used robust ecological assessments such as ecological surveys. Adding to this, much of the evidence from LMICs treated greenspaces as uniform and lacked appropriate definitions of what was being measured. This is problematic, because recent research from HICs suggests that mental health effects may depend on metrics of biodiversity such as species richness and composition or the specific ecological traits of greenspaces (Marselle et al., 2018) and robust ecological assessments of greenspaces are needed to explore these metrics.

Some studies relied on participants' perceptions of greenspaces, rather than on objective measures such as measuring exposure through remote sensing or ecological survey techniques. While it is important to take into account perceptions, such studies do not allow drawing conclusions about actual mental health effects. A range of studies used imagery of greenspaces to assess health outcomes. Although using pictures or videos of greenspaces is an accessible way of testing hypotheses and there is some value in using such stated preference methods, these approaches fall short of producing generalisable results.

Only two studies investigated the mental health effects of engaging in urban agriculture. Evidence from HICs has shown that urban agriculture can improve mental well-being, contribute to stress reduction (Hofmann et al., 2018) and foster social cohesion (Yotti Kingsley and Townsend, 2006). The contribution of urban agriculture to mental health might be of particular importance in LMICs through the contributions to food security and improved nutrition outcomes (Audate et al., 2019), in particular for low-income urban residents (Orsini et al., 2013).

A variety of approaches was used to measure mental health outcomes. However, another limitation of the evidence is that many studies did not use validated mental health screening tools. Using self-developed questionnaires provides only limited insights into mental health benefits, as they do not allow drawing reliable conclusions about specific mental health outcomes. Using validated screening assessment tools, in contrast, enables to produce translatable results to compare between populations, as they aim to replicate psychiatric assessment (diagnostic interview) as close as possible (Ali et al., 2016). Such screening tools usually have to undergo cross-cultural translation to be validated for use in different languages and socio-cultural contexts (Kohrt et al., 2016), which may be one of the reasons for their infrequent use in the LMIC context.

4.2. Implications for future research

The recent expansion of research efforts into LMICs has begun to fill important research gaps. However, the insights these studies provide are limited by the fact that none of the studies explicitly considered local cultural and environmental factors mediating the relationship between greenspaces and mental health. So far, research in LMICs has failed to take into account these contextual factors. This will be of particular importance for future studies, because the evidence from this review indicates that the relationship between greenspaces and mental health is context dependent and needs to be assessed for the particular environmental and cultural setting of a given area. Reductions in heat exposure, for example, may be more important in hot climates than in temperate regions (Guenat et al., 2019). Therefore, more research is needed to explore how greenspaces and mental health are associated across climates, especially as those climates are shifting and urban populations will be exposed to higher temperatures and new threats such as an increase in vector-borne diseases (Müller et al., 2019). Adding to this, the use of greenspaces, and thereby their effects on mental health, can as well be determined by cultural norms (Elands et al., 2019). Mowafi et al. (2012), for instance, did not detect a

relationship between the availability of greenspace and physical activity assessed through Body Mass Index in Cairo, Egypt. The authors argued that utilising greenspace for the purpose of exercise is likely not culturally acceptable, especially for women. Taking into account cultural norms will therefore be crucial for understanding how greenspaces can benefit mental health locally. Additionally, future research in LMICs should consider moderating factors such as safety, environmental pollution and other factors compromising the quality of greenspaces. The findings of this review support the Sustainable Development Goal 11 target 7, which aims to provide universal access to urban greenspaces to increase public health.

The relationship between greenspaces and mental health in informal settlements and slums is critically understudied and needs to be explored through future research. Sub-Saharan Africa in particular is predicted to undergo the most rapid urbanisation globally over the next decades (Angel et al., 2011). Hence, it will be crucial to research a wide array of its cities. Moreover, research in LMICs should not remain limited to major cities and focus more on smaller towns and cities.

We found that a lack of appropriate sampling strategies for the population of interest decreased the comparability of the reviewed studies and thus will have to be addressed by further research, in order to reduce selection bias caused by convenience sampling. The quality of future studies could further be increased by conducting more longitudinal studies. Regarding the assessment of greenspaces, it will be crucial for future studies to use robust ecological methods such as ecological surveys to unpick the various components and traits of greenspaces leading to mental health effects, including finer scales of biodiversity such as species richness or ecological traits. This will be important for understanding the mechanisms through which greenspaces can support mental health in LMICs. We strongly encourage combining robust ecological assessments of greenspaces with validated mental health screening tools. Considering the high relevance of food security in particular for low-income residents in LMICs, we recommend to further explore how urban agriculture affects mental health in these regions.

5. Conclusions

Urbanisation during the coming decades may have profound implications for the mental health of urban populations in LMICs. The evidence indicates that greenspaces have the potential to improve the mental health of urban populations in these areas. These benefits, however, may

depend on the particular environmental and cultural conditions in a given area. Our findings highlight the need for high-quality, context specific research in those urban areas with the highest levels of urbanisation, and the need to address specific challenges regarding moderating factors impacting on the quality of greenspaces. This review pointed out important directions for future research in LMICs, ultimately aiming to inform environmental and health policies in cities in LMICs in our rapidly urbanising world.

Declaration of competing interest

We have no conflict of interest.

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