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REVIEW AND SYNTHESIS

How do different types and characteristics of green space impact mental health? A scoping review

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Abstract

1. Green space matters for mental health but is under constant pressure in an increasingly urbanising world. Often there is little space available in cities for green areas, so it is vital to optimise the design and usage of these available green spaces. To achieve this, experts in planning, design and nature conservation need to know which types and characteristics of green spaces are most beneficial for residents' mental health.
2. A scoping review of studies that compare different green space types and characteristics on mental health was conducted. A total of 215 (experimental, observational and qualitative) papers were included in the scoping review.
3. This review highlights a high level of heterogeneity in study design, geographical locations, mental health outcomes and green space measures. Few of the included studies were specifically designed to enable direct comparisons between green space types and characteristics (e.g. between parks and forests). The included studies have predominantly experimental research designs looking at the effects of short-term exposure to green space on short-term mental health outcomes (e.g. affect and physiological stress). More studies enabled only indirect comparisons, either within the same study or between different studies.
4. Analysis of the direction of the mental health outcomes (positive, neutral, negative) from exposure to various types and characteristics of green space found

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positive (i.e. beneficial) effects across all green space types. However, green space characteristics did appear to render more diverse effects on mental health, which is especially the case for vegetation characteristics (e.g. higher vegetation density can be negative for mental health).
5. The scoping review reveals gaps in the present evidence base, with a specific need for more studies directly comparing green space types and characteristics within the same study. Proposed future research directions include the use of longitudinal research designs focusing on green space characteristics, considering actual exposure and systematically addressing heterogeneity in factors influencing the relation between green spaces and mental health (e.g. type of interaction, user experience).

KEYWORDS
biodiversity, gardens, green space quality, green space types, mental wellbeing, parks, trees

1 | INTRODUCTION

Mental health problems are one of the major disease burdens worldwide, with incidences continuing to rise (GBD Mental Health Collaborators, 2022). The recent Covid-19 pandemic has further accelerated the increase in mental health problems (Nochaiwong et al., 2021; WHO, 2022). Finding remedies to reduce this disease burden should be an important priority for health care systems worldwide. Exposure to green space has been shown to have beneficial effects on mental health (e.g. Gascon et al., 2015; Hartig et al., 2014; Houlden et al., 2018; Meredith et al., 2020; Tillmann, Tobin, et al., 2018; Van den Berg et al., 2015; Vanaken & Danckaerts, 2018). However, in parallel with the increase in mental health problems, urbanisation is growing. Two-thirds of the world's population is projected to live in urban areas by 2050 (Ritchie & Roser, 2018) with a concurrent large increase in population density (Dijkstra et al., 2021). Urbanisation has been found to be directly related to increases in mental health problems (van der Wal et al., 2021), while at the same time putting pressure on existing ecosystems (McDonald et al., 2020) and reducing urban dwellers' access to green space (Collins et al., 2020; Ekkel & de Vries, 2017; Marselle, Martens, et al., 2019; Van den Berg et al., 2015).

Preserving green spaces in urban areas can thus have profound benefits for both mental and physical health. But often there is little space available in cities for green areas, so it becomes vital to optimise the design and usage of these available green spaces, that is, land that is partially or entirely covered in 'green' vegetation such as trees, grass, shrubs or other green vegetation. To achieve this, we need to know which types and characteristics of green spaces have the most pronounced impacts on the health of urban dwellers and visitors. The focus of the present review will be on mental health, with a focus on both mental wellbeing (e.g. [momentary] happiness, stress) and mental illness (e.g. prevalence and severity of mental disorders).

More knowledge about which specific features of green space enhance health outcomes is essential to progress the research field on the health benefits of nature (Bratman et al., 2019; Frumkin et al., 2017; Marselle et al., 2021; Van den Bosch & Sang, 2017; Zürcher & Andreucci, 2017). At present, most studies looking at the benefits of green space on mental health investigate green space as a generic landcover type (Nguyen et al., 2021; Panduro & Veie, 2013), whereas some green spaces may have a different effect on mental health than others, for instance more stunning versus more mundane green spaces (Joye & Bolderdijk, 2015). There are, indeed, studies that look at different green space types (such as grassland vs. a forest) and find different effects of these land cover types on mental health (e.g. Alcock et al., 2015), or studies that compare a visit to the park with a visit to the forest and find different benefits on mental health (e.g. Lanki et al., 2017).

To our knowledge, only three other reviews have looked at how different green space types and green space qualities are related to different health outcomes (Nguyen et al., 2021; Reyes-Riveros et al., 2021; Velarde et al., 2007). The review by Velarde et al. (2007) found most studies described nature in broad categories (i.e. 'nature' vs. 'urban'). Due to a lack of information about specific landscape elements of the green space under investigation, Velarde et al.'s (2007) review was unable to answer what particular qualities of green space are beneficial for human health. Nguyen et al. (2021) concluded that most green space types and qualities matter for mental health but did not specifically look at the differences in terms of benefits between these green space types or qualities. Reyes-Riveros et al. (2021) looked at specific green space characteristics—biodiversity, naturalness and structure—on four dimensions of human wellbeing—none of which were mental health or mental wellbeing. While Reyes-Riveros et al. (2021) did report differences in human wellbeing between the green space characteristics, these differences were not based on statistical analyses (differences were looked at it in terms of the number of articles, the type of outcome and strength [weak for studies not reporting statistics and strong for those reporting statistics]). These three reviews show that different types of green spaces, as well as different characteristics of these green spaces

may influence mental health, but leave the question of which, if any, green space type or characteristic is best for mental health largely unanswered.

To answer this question about which type of green space type or characteristic is better or worse for mental health, there is a need to assess studies comparing different green space types or characteristics. Therefore, we performed a scoping review on studies that enabled a comparison between the mental health benefits of different green space types and characteristics. For mental health, we focus on more than the absence of mental disorders, by also including emotional, psychological and social wellbeing in line with the definitions of mental health of both the World Health Organization (WHO) (2022) and Keyes (2006).

This scoping review aims to:

a. Identify studies that compare different green space types or green space characteristics in terms of impact on mental health.
b. Systematically map these studies in terms of their design and other characteristics.
c. Make an overview of the outcomes of comparisons between different green space types and characteristics in terms of mental health benefits.
d. Identify potential gaps in the current evidence base.

1.1 | Conceptual framework for the scoping review

Distinguishing between the mental health benefits of different green space types and characteristics calls for studies looking at separate and measurable features of green spaces and their characteristics (Bratman et al., 2019; Frumkin et al., 2017; Marselle et al., 2021). Bratman et al. (2019) proposed a model including these separate features, with three different components: the natural environment, the amount of exposure and the type of the exposure. The natural environment is characterised in our review as different green space types (e.g. park, forest) and different green space characteristics (e.g. vegetation density, or quality of the greenery).

In their model, Bratman et al. (2019), further proposed that not only the characteristics of a natural environment matter, but also the type of exposure. Exposure can be direct (when people are present in green space) or indirect (when people see images, videos or virtual representations of nature). Exposure type can differ greatly, and consequently influence how the amount of exposure leads to potential mental health benefits. Importantly, the type of exposure is also dependent on the characteristics of the green space (Bratman et al., 2019; De Vries, 2022).

Others have also acknowledged the importance of exposure characteristics for the effects of green space on mental health (De Vries, 2022; Marselle et al., 2021). De Vries (2022) proposes three types of characteristics of nature contact, namely amount of exposure, type of engagement (e.g. type of activity) and how these are experienced. In this model, experience is seen as a result from exposure to and engagement with nature. Yet another framework (Marselle et al., 2021) proposes two types of nature contact—exposure and experience—with experience following exposure, and being the combination of both sensory experiences and engagement with green space elements.

It has been suggested that there are three types of pathways through which green space has beneficial effects on short-term and long-term mental health: mitigation, restoration and instoration (Markevych et al., 2017). Green spaces often lack traffic, have lower levels of air pollution, and are a remedy for urban heat islands (Bloemsma et al., 2022; Hartig et al., 2014; Klompmaker et al., 2019; Nieuwenhuijsen, 2021; Von Lindern et al., 2016; Zock et al., 2018). Avoiding the negative consequences from these potentially harmful factors is captured in the mitigation pathway. The restoration pathway refers to restoring depleted capacities, and these can be related to impacts on measures of stress, affect and attention (Kaplan, 1995; Kaplan & Berman, 2010; Ulrich et al., 1991). The third pathway, instoration, is about building individuals' capacities and resilience so that they can be better able to face future threats to mental health. For instance, green spaces often facilitate physical activity and social interactions, both of which have been shown to be related to better mental health (Dadvand et al., 2019; De Vries et al., 2013; Jennings & Bamkole, 2019; Nieuwenhuijsen, 2021). The potential mental health outcomes of green space exposure can range from short-term mental health effects (e.g. feeling happier after visiting the park) to more long-term effects (e.g. enhanced quality of life from living near to a park), that are often the result of accumulated experiences with green space (White et al., 2019). In addition, these pathways relate to both mental wellbeing and the prevalence and severity of mental disorders.

In addition to the scoping review, we also created a systematic evidence map. Systematic evidence mapping provides searchable databases that help characterise the current evidence base on a specific topic, providing a comprehensive overview of the evidence base (Haddaway et al., 2016). Systematic maps can, for instance, aid in decision-making processes (Wolffe et al., 2019) and therefore fit well with this review's question about which types and characteristics of green spaces are most beneficial for mental health. The structure for synthesising the available knowledge is presented in Figure 1, and it is based on the previously discussed models (Bratman et al., 2019; De Vries, 2022; Markevych et al., 2017; Marselle et al., 2021).

2 | METHOD

This scoping review consisted of six consecutive steps: protocol development, literature search, study selection, meta-data extraction, a descriptive and narrative synthesis and the development of two searchable Excel tables. This scoping review is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines for scoping reviews (Moher et al., 2010; Tricco et al., 2018). While, this review was not registered

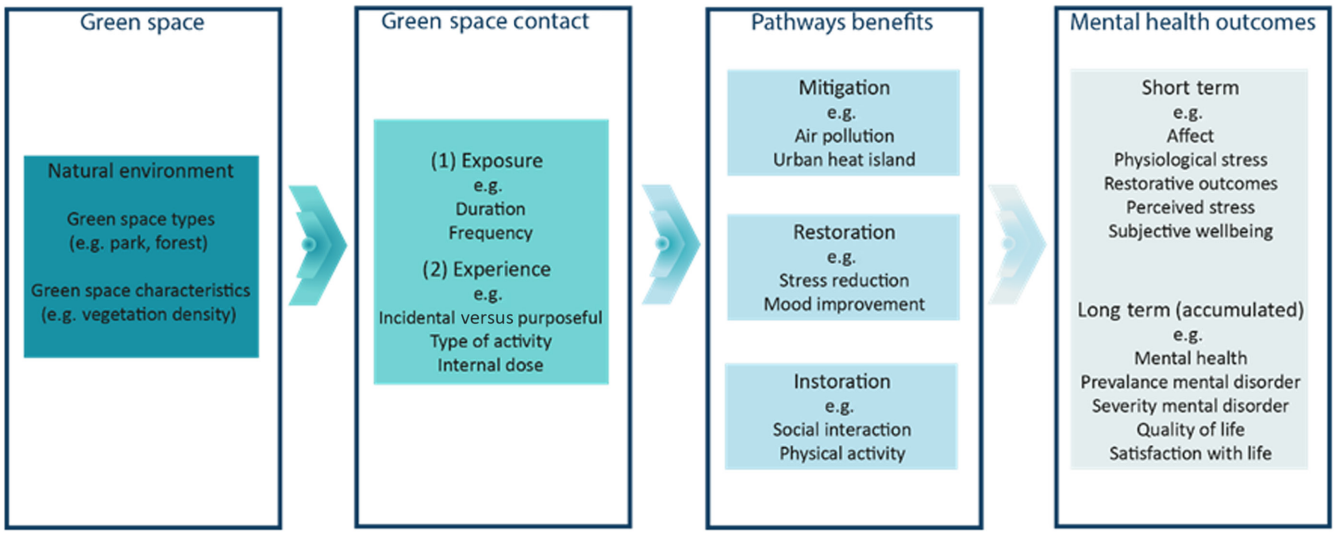

FIGURE 1 Conceptual framework for the systematic evidence mapping, adapted from: Bratman et al. (2019), De Vries (2022), Markevych et al. (2017) and Marselle et al. (2021).

in a protocol database, but a protocol was published separately (Andreucci et al., 2019).

2.1 | Search strategy

Initial searches were conducted by a qualified information specialist on 28 June 2019 in Scopus and MEDLINE (Ovid) and on 23 August 2019 in Scopus only. An updated search was performed by the information specialist on 31 March 2021 in Scopus and MEDLINE (Ovid) to capture relevant papers published since the initial searches.

Developing a search strategy for this topic was challenging because terms such as 'green', 'nature' and 'mental health' are used in many contexts; consequently, the record yield tends to be large if these terms are simply combined using the 'AND' operator. In cases like this it is accepted search practice to use several different search options to capture relevant records and to use specific approaches to reduce the chance of retrieving irrelevant records (Lefebvre et al., 2022). The first approach (used only with MEDLINE since Scopus does not have subject indexing) used only Medical Subject Headings (MeSH) for green spaces combined with MeSH for mental health. This approach found records that had been explicitly indexed with those headings (and therefore likely to be about mental health and green space). The second approach (used in MEDLINE and Scopus) combined terms for green spaces in the title and abstracts of records near to mental health terms using proximity operators. Using a proximity operator of 5, this approach identifies records where words about green space and mental health appear within five words of each other. When conducting proximity searches the safest approach (to make sure the search works correctly) is to have only a few terms in proximity to a set of other terms. Since there are many mental health terms, this results in quite a long series of individual searches where the full set of green terms are combined with a small number of mental health terms. The results of all the search lines are combined using the 'OR' operator to remove duplicates.

For mental health and wellbeing, we used generic (e.g. mental disorders, wellness) and specific (e.g. bipolar disorder, quality of life) search terms. For green space types and characteristics, we used both generic (e.g. green space, landscape, nature based) and specific (e.g. allotment, savanna, woodland) search terms. The full search strategy is available in Appendix S1.

2.2 | Study selection

We included all studies meeting the following PICO/PECO[1] criteria (Morgan et al., 2018; see Table 1):

a. Population: Human beings of all ages and genders.
b. Intervention: Environmental interventions that manipulated or changed exposure to a specific outdoor green space type (e.g. park, forest) or specific green space characteristic (e.g. biodiversity). Table 3 lists the outdoor green space types and characteristics included in this scoping review. Interventions that changed the amenities and/or facilities in a specific green space type or characteristics were also included. The amount or quantity of generic vegetation cover (e.g. the normalised difference vegetation index) were excluded. Studies of therapeutic interventions in which therapy is conducted in a natural environment were excluded.
c. Exposure: Any sort of exposure to an outdoor green space type or green space characteristic is eligible. Studies where participant's exposure to a specific outdoor green space type or characteristic is either intentional or incidental to another activity (Keniger et al., 2013; Marselle, Martens, et al., 2019) were included. Studies in which participants had direct interaction with

TABLE 1 Inclusion and exclusion criteria based on PI(E)CO descriptions.

	Inclusion criteria	Exclusion criteria
Population	All population types in studies with more than one participant	Single case or single-patient studies ($n=1$)
Intervention	Green space interventions that manipulated or changed exposure to green space, in terms of green space type or characteristic Studies on amenities and facilities	Studies focusing on efficacy of therapeutical interventions only
Exposure	Outdoor green space exposure Intentional and incidental exposure Direct interaction and indirect interaction (i.e. viewing virtual representations of nature, window views of nature)	Indoor green space exposure (e.g. house plants, green walls in schools)
Comparison	Direct comparisons within the same study (outdoor green space type or characteristic) Direct comparisons within the same study with the built environment Indirect comparisons within the same study (i.e. study reports on several different green space types or characteristics) Indirect comparison between studies (studies reporting on outcomes of a single type or characteristics, but with a pre–post-design)	Comparisons with indoor environments Compound measures of green space (i.e. including several different types or characteristics within one measure)
Outcome	Prevalence and severity of mental disorders (including subclinical levels), according to the World Health Organization ICD-10 mental health classification system (World Health Organization, 1992): • Affective disorders • Stress-related diseases • Schizophrenia, psychosis, paranoia • Personality disorders • Disorders of psychological development • Cognitive dysfunction • Neurodegenerative disease • Problem behaviour General mental wellbeing (quality of life, satisfaction with life, subjective wellbeing) Acute and direct effects on momentary mood, relaxation, stress, mental fatigue and brain activity Retrospective reporting of momentary mood (i.e. recalled restoration) Specific correlates of mental health (e.g. loneliness, sleep, pain, self-esteem)	Preference ratings Perceived restorativeness as a characteristic of the environment (e.g. Perceived Restorativeness Scale); anticipated/expected restoration Physical health correlates of mental health (e.g. physical activity) Attention/cognitive performance

a specific outdoor green space type or characteristic by being physically exposed to the environment were eligible. Studies where participants had indirect interactions with a specific type or characteristic of outdoor green space without actual exposure (e.g. viewing photographs, videos, virtual reality or through a window) were also eligible. Indoor green space exposure (e.g. house plants) was excluded to keep the focus on outdoor green space types and characteristics.

d. Comparator: The comparison environment was a different type(s) or characteristic(s) of outdoor green space or the built environment. Comparisons with indoor environments or generic measures of green space (e.g. vegetation cover) were excluded.
e. Outcomes: Studies that investigated mental ill health (e.g. personality disorder, psychosis) according to the ICD-10 (World Health Organization, 1992), mental wellbeing (e.g. life satisfaction, quality of life), momentary mood, stress, mental fatigue and correlates of mental health (e.g. loneliness) were included. Table 4 lists the mental health and wellbeing outcomes included in this scoping review. Studies that only measured preference, perceived restorativeness, cognitive performance or physical activity were excluded.

Regarding study design, all experimental, observational and qualitative designs were eligible.[2] Peer-reviewed articles, published in English, from any date were eligible. Systematic reviews and case studies were excluded.

Obviously ineligible records were first excluded by a single reviewer. Records were then loaded into Covidence (Veritas Health Innovation, Australia), where two reviewers independently screened titles and abstracts against the eligibility criteria. Full-text screening of eligible studies following the title/abstract screening was undertaken by two reviewers independently to determine the final set of included studies for the scoping review. Any disagreements were resolved through discussion between the two reviewers.

2.3 | Meta-data extraction

Meta-data were extracted from all eligible records, using a predetermined codebook. Data were extracted within four general themes: general study information, study methodology, green space and mental health (Appendix S2). If a paper contained more than one eligible study, the studies were treated as separate records. If two papers were included about the assumed same study, both were entered in the database but treated as relating to one study (one occasion).

Two searchable Excel tables were developed. The first searchable table (Appendix S2) provides a database of the most relevant parts of the extracted meta-data in a single Excel sheet. The second searchable table (Appendix S3) organises all studies investigating specific green space category and mental health combinations (e.g. 'park' and affect). Entries in both searchable tables are based on unique combinations of green space type and mental health outcomes. Therefore, one study may contribute multiple lines to the two searchable tables. For example, if a study looked at effects of the 'park' and the 'forest' on affect and perceived stress, there will be four lines for this study ('park'—affect, 'forest'—affect, 'park'—perceived stress and 'forest'—perceived stress).

2.4 | Descriptive and narrative synthesis

For the descriptive and narrative synthesis, overviews were made for green space categories (Table 3). In addition, there were also two miscellaneous categories, one for green space types ('other green space types') and one for the characteristics ('other green space characteristics'). Categorisation of the green space type or characteristics for each paper was based on the terms that were used in the papers themselves. Tables 3 and 4 provide an overview and description of the green space categories and mental health outcomes respectively.

To systematically map the studies (aim b) heatmaps were developed for the cross-tabulations of green space types based on geographical spread, study sample, health outcomes and the type of assessment context (e.g. residential, educational, health care).

To understand the differential effects between different green space types and characteristics on mental health outcomes (aim c), studies were categorised into three different comparison types:

1. 'Direct within study'—different environments were directly compared in the same study (e.g. the effects of a visit to the park vs. a visit to the forest on perceived stress).
2. 'Indirect within study'—different types and characteristics were analysed separately within the same study (e.g. a study looking at the effects of grass cover and tree cover on subjective wellbeing separately). For experimental study designs, the different types or characteristics of green space investigated in the same study often constitute different conditions within the same experiment. For observational study designs, the different types or characteristics of green space investigated in the same study may be included in the same analysis (e.g. regression model).
3. 'Indirect between studies'—studies reporting outcomes of a single green space type or characteristic. In these studies, comparisons need to be made with other studies.

For the purposes of this scoping review, we decided that 'direct within study' comparisons were the most reliable, because these comparisons were made within a single study, and with the same study design. Indirect comparisons could only be made by looking at the direction of the effects—either within the same study or between studies. Between the two types of indirect comparisons, we considered that 'indirect within study' comparisons would have more reliable results, because at least the study design, population type and methodology would be similar. We considered that 'indirect between studies' comparisons were the least reliable way of comparing the effects of green space types and characteristics, because of the comparison would be made between two different studies, which could vary on study design, population type and methodology.

Three comparisons had enough data for us to be confident that we could identify reliable outcomes: 'forest' versus 'park', 'forest' versus 'grass' and 'trees and other vegetation' versus 'grass'. For these comparisons, graphs were made displaying the direction of mental health outcomes between the two green space types. In these graphs, no weights were applied, meaning that equal importance was given to studies enabling 'direct within study' comparisons as to studies enabling 'indirect within study' comparisons. Finally, an overview was made of the direction of the outcomes (positive, negative and neutral) for each green space category.

3 | RESULTS

3.1 | Search outcomes

The initial search in 2019 yielded 18,338 records. Ten additional records were hand-selected based on a test-list and a parallel search that was performed for blue spaces; these records also included green space outcomes and were not retrieved in the initial search. Update search in 2021 yielded an additional 19,591 records (Figure 2; Table S1). After removing duplicates, a total of 29,576 records (16,581 records from the initial search and 12,995 records from the updated search, Figure 2) were assessed for eligibility.

Eligibility screening at title and abstract level removed a total of 28,684 records (Figure 2). Full-text screening removed a further 677 records (Figure 2). A total of 215 papers were included in the scoping review (118 experimental, 80 observational, 17 qualitative). The key characteristics of the 215 included studies are summarised in Table 2.

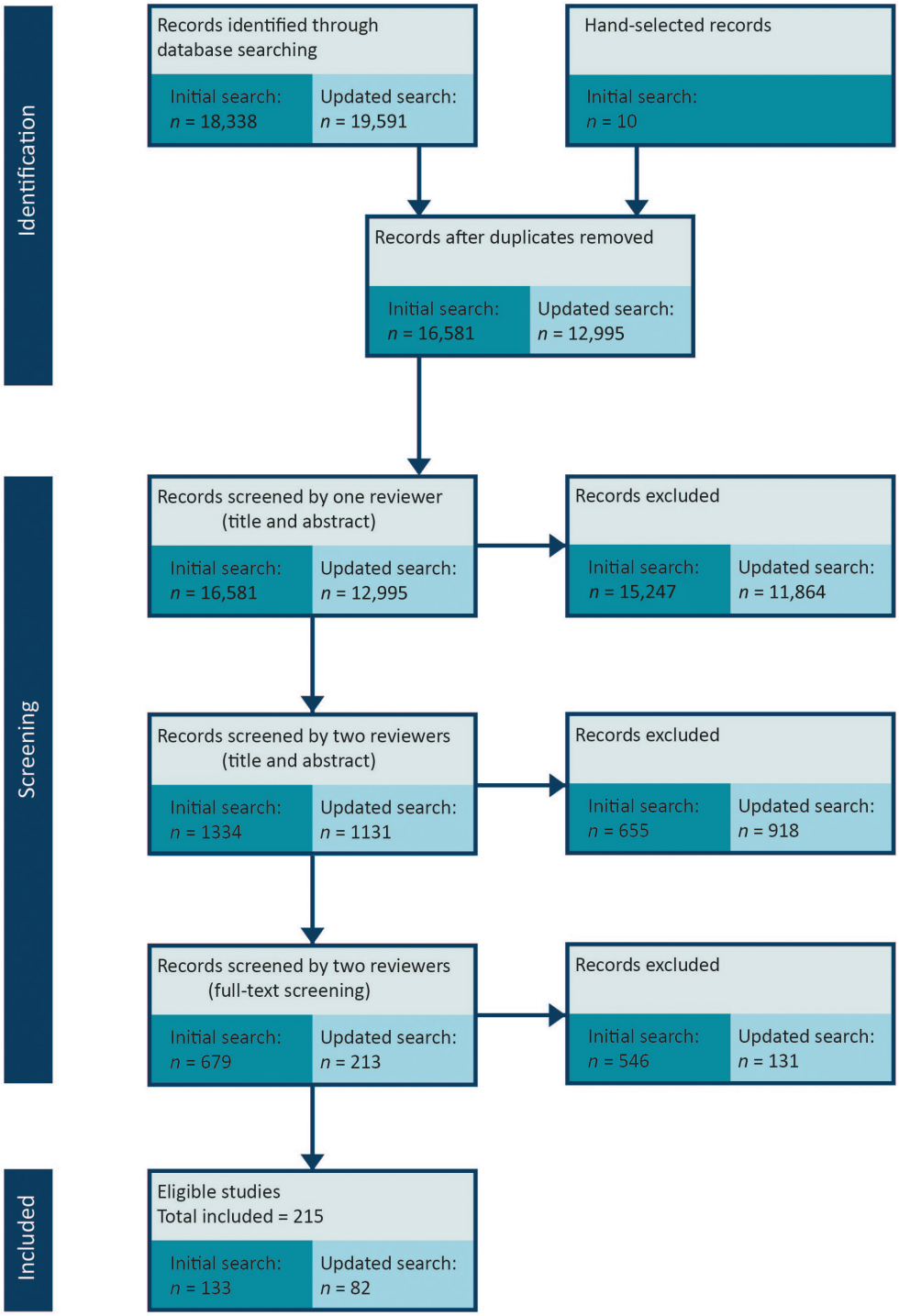

FIGURE 2 Prisma flow chart.

3.2 | Description of the studies included in the scoping review

Studies investigating the influence of either different types or characteristics of outdoor green spaces on mental health began to appear at the beginning of the 21st century. The number of papers has increased steadily over the years with a sizable leap in 2018 (Figure 3). Table S2 details the number of publications by year and study category.

Observational.

The 215 included papers were first categorised into 12 different green space categories: seven categories related to different green space types (e.g. 'park', 'forest'); and five categories related to green space characteristics (e.g. 'park characteristics', 'forest characteristics'; see Table 3 for definitions). All 12 green space categories were investigated across the 198 quantitative studies. Only eight of the 12 green space categories were investigated across the 17 qualitative

TABLE 2 Main characteristics of 215 included studies.

Author	CAT	Type/characteristic of green space	Mental health outcome
Adjei and Agyei (2015)	O	Biodiversity, garden, park	Affect
Aerts et al. (2020)	O	ToV, veg chars	Overall mental health
Alcock et al. (2015)	O	Forest, grass, OGST (mountain, heath, bog/blue space)	Overall mental health
Aliyas (2021)	O	Park, park chars	Overall mental health
Annerstedt et al. (2012)	O	OGSC (wild, lush, serene, spacious, culture)	Overall mental health
Arnberger, Eder, Allex, Hutter, et al. (2018)	E	Grass, veg chars	Perceived stress, restorative outcomes, subjective wellbeing
Arnberger, Eder, Allex, Ebenberger, et al. (2018)	E	Grass, veg chars	Perceived stress, physiological stress, subjective wellbeing
Aspinall et al. (2015)	E	Urban green space	Affect, physiological stress
Astell-Burt and Feng (2019)	O	Grass, ToV	Overall mental health, prevalence mental disorder
Astell-Burt et al. (2020)	O	Grass, ToV	Prevalence and severity mental disorder
Ayala-Azcárraga et al. (2019)	O	Park, park chars, OGSC (sound)	Satisfaction with life
Balseviciene et al. (2014)	O	Park	Problem behaviour
Benfield et al. (2018)	E	Park, park chars	Affect
Benita et al. (2019)	O	Park	Affect
Beyer et al. (2014)	O	ToV	Severity mental disorder
Bielinis et al. (2018)	E	Forest	Affect, restorative outcomes
Bielinis et al. (2020)	E	Forest	Affect, restorative outcomes
Bielinis et al. (2021)	E	Forest	Affect, restorative outcomes
Birch et al. (2020)	Q	Urban green space	Overall mental health, subjective wellbeing
Björk et al. (2008)	O	OGSC (wild, lush, serene, spacious, culture)	Affect
Bojorquez and Ojeda-Revah (2018)	O	Park, park chars, veg chars	Overall mental health
Boll et al. (2020)	O	Garden	Physiological stress
Brown et al. (2018)	O	Park, park chars	Restorative outcomes
Browning and Rigolon (2018)	O	ToV	Overall mental health, severity mental disorder
Burton et al. (2015)	O	Garden, ToV	Subjective wellbeing
Carrus et al. (2015)	E	Biodiversity	Restorative outcomes
Chang et al. (2016)	E	Biodiversity	Physiological stress
Chang et al. (2019)	E	OGST (wilderness), park	Perceived stress, physiological stress
Chen et al. (2020)	E	Garden	Affect, brain activity, restorative outcomes
Chiang et al. (2017)	E	Forest, forest chars, urban green space	Affect, physiological stress
Coldwell and Evans (2018)	O	OGST (countryside)	Affect, quality of life, subjective wellbeing
Cook (2019)	Q	Forest	Subjective wellbeing
Cordoza et al. (2018)	E	Garden	Affect, severity mental disorder
Houlden et al. (2018)	E	Urban green space	Affect, perceived stress
Dadvand et al. (2019)	O	Forest, garden, park	Other (self-image, social contacts)
de Brito et al. (2019)	E	Park	Affect
Deng et al. (2020)	E	Forest, grass	Affect, brain activity, physiological stress
Detweiler et al. (2008)	E	Garden	Problem behaviour
Detweiler et al. (2009)	E	Garden	Overall mental health
Dobbinson et al. (2020)	E	Park, park chars	Affect, other (social contact)
Du et al. (2021)	O	Urban green space	Affect
Dzhambov, Markevych, et al. (2018)	O	ToV	Overall mental health

TABLE 2 (Continued)

Author	CAT	Type/characteristic of green space	Mental health outcome
Dzhambov (2018)	O	ToV	Severity mental disorder, perceived stress, Other (mindfulness, rumination)
Elsadek, Sun, et al. (2019)	E	Garden	Affect, physiological stress
Elsadek, Liu, Lian, and Xie (2019)	E	Tov, veg chars	Affect, severity mental disorder, restorative outcomes
Elsadek, Liu, and Lian (2019)	E	ToV	Affect, brain activity, physiological stress
Elsadek et al. (2020)	E	Park	Affect, brain activity, physiological stress
Engemann et al. (2020)	O	OGST (farmland)	Prevalence mental disorder
Ewert and Chang (2018)	E	Forest, park	Perceived stress, physiological stress
Fisher et al. (2021)	O	Biodiversity	Affect
Foo (2016)	Q	Forest	Restorative outcomes
Gatersleben and Andrews (2013)	E	OGSC (prospect & refuge)	Affect, physiological stress
Gathright et al. (2006)	E	ToV	Affect, physiological stress, restorative outcomes
Gidlow et al. (2016)	E	Park	Affect, physiological stress, restorative outcomes
Gilchrist et al. (2015)	O	Forest, grass, ToV, OGST (countryside)	Subjective wellbeing
Goto et al. (2017)	E	Garden	Physiological stress, problem behaviour
Goto et al. (2018)	E	Garden	Physiological stress, problem behaviour
Goto et al. (2020)	E	Veg chars	Affect, physiological stress
Grazuleviciene et al. (2016)	E	Park	Affect, physiological stress
Greenwood and Gatersleben (2016)	E	GUGS	Affect, physiological stress
Guéguen and Stefan (2016)	E	Park	Affect
Guo et al. (2020)	E	ToV, veg chars	Affect, brain activity, physiological stress
Hadavi (2017)	O	Urban green space	Subjective wellbeing
Hansmann et al. (2007)	O	Forest, park, forest chars	Perceived stress, subjective wellbeing
Hedblom et al. (2017)	E	Forest, park	Physiological stress
Henderson-Wilson et al. (2017)	O	Park	Overall mental health, perceived stress
Herman et al. (2021)	E	Park, urban green space	Brain activity
Ho et al. (2016)	E	ToV, veg chars	Quality of life
(Houlden et al., 2021)	O	Park, urban green space, OGST (sports pitch)	Affect, satisfaction with life, quality of life
Hoyle et al. (2017)	O	Biodiversity, forest	Restorative outcomes
Huang et al. (2020)	E	Grass, ToV	Affect, physiological stress
Hull and Michael (1995)	E	Park	Affect
Hussain et al. (2019)	E	Biodiversity, forest, grass, ToV	Perceived stress, physiological stress, subjective wellbeing
Janeczko et al. (2020)	E	Forest	Affect, physiological stress, restorative outcomes
Jarvis et al. (2020)	O	Grass, ToV, veg chars	Overall mental health, prevalence mental disorder
Jiang, Larsen, et al. (2020)	E	ToV, veg chars	Overall mental health, perceived stress
Jiang, Hassan, et al. (2020)	E	Forest, garden	Brain activity, overall mental health, physiological stress
Jo et al. (2019)	E	Forest, OGSC (sound)	Affect, physiological stress
Johnson et al. (2018)	O	ToV, OGSC (sound)	Subjective wellbeing, other (sleep)
Jones (2021)	O	Forest	Satisfaction with life
Joung et al. (2015)	E	Forest	Affect, physiological stress

(Continues)

TABLE 2 (Continued)

Author	CAT	Type/characteristic of green space	Mental health outcome
Kabisch et al. (2021)	E	Park	Affect, physiological stress
Kajosaari and Pasanen (2021)	O	Forest, urban green space, OGST (sport pitch)	Restorative outcomes
Kexiu et al. (2021)	E	Tov, veg chars	Brain activity
Kim et al. (2016)	O	Forest, forest chars	Perceived stress, quality of life
Kim et al. (2020)	O	Forest, forest chars	Severity mental disorder
Kondo et al. (2015)	E	OGST (green stormwater infrastructure)	Perceived stress, physiological stress
Korn et al. (2018)	E	Garden	Perceived stress, physiological stress, problem behaviour, quality of life
Korpela et al. (2010)	O	Urban green space	Restorative outcomes
Koselka et al. (2019)	E	Forest	Affect, overall mental health, perceived stress
Krekel et al. (2016)	O	Forest, urban green space	Satisfaction with life
Kristjánsdóttir et al. (2020)	Q	Forest, park, OGST, OGSC	Restorative outcomes
Lanki et al. (2017)	E	Forest, park	Physiological stress
Larson et al. (2016)	O	Park, park chars	Subjective wellbeing
Larson et al. (2018)	O	ToV	Severity mental disorder
Lee et al. (2009)	E	Forest	Affect, physiological stress
Lee et al. (2011)	E	Forest	Affect, physiological stress
Lee (2017)	E	Garden	Affect, physiological stress
Li et al. (2019)	E	Park, park chars	Affect
Li et al. (2021)	E	Urban green space	Affect, physiological stress, restorative outcomes
Liao et al. (2018)	E	Garden	Subjective wellbeing
Lindemann-Matthies and Matthies (2018)	E	Biodiversity	Physiological stress
Liu et al. (2019)	E	ToV	Physiological stress
Liu et al. (2020)	E	Garden	Physiological stress
Lotfi et al. (2020)	E	ToV	Physiological stress
Ma et al. (2018)	O	Park, urban green space	Subjective wellbeing
MacKerron and Mourato (2013)	O	Forest, grass, OGST (mountains, moor, heathland; farmland)	Affect
Marselle et al. (2013)	O	Urban green space, OGST (farmland, green corridor)	Affect, perceived stress, severity mental disorder, subjective wellbeing
Marselle et al. (2020)	O	Biodiversity. ToV	Prevalence mental disorder
Marselle et al. (2016)	E	Biodiversity	Affect
Martens et al. (2011)	E	Forest, forest chars	Affect
Martensson et al. (2009)	E	OGSC (outdoor play environment categories; sky view factor)	Severity mental disorder
Maurer et al. (2021)	Q	Park, park chars	Subjective wellbeing
Mavoa et al. (2019)	O	Biodiversity	Subjective wellbeing
McAllister et al. (2017)	E	Forest, park	Affect
Methorst et al. (2021)	O	Biodiversity, garden, park, OGST (unprotected vs. protected)	Overall mental health
Meyer-Grandbastien et al. (2020)	O	OGSC (landscape heterogeneity)	Subjective wellbeing
Mitchell (2013)	O	Forest, garden, park, OGST (sport pitch)	Overall mental health, subjective wellbeing
Mokhtar et al. (2018)	E	Park	Affect, physiological stress, restorative outcomes

TABLE 2 (Continued)

Author	CAT	Type/characteristic of green space	Mental health outcome
Morita et al. (2007)	E	Forest	Affect, severity mental disorder
Moyle et al. (2018)	E, Q	Forest	Affect
Navarrete-Hernandez and Laffan (2019)	E	ToV	Affect, perceived stress
Neale et al. (2017)	E	Urban green space	Affect
Nghiem et al. (2021)	E	Biodiversity	Affect
Nishigaki et al. (2020)	O	Grass, ToV	Prevalence mental disorder
O'Brien et al. (2014)	Q	Forest	Subjective wellbeing
Ojala et al. (2019)	E	Forest, park	Affect, physiological stress, restorative outcomes
Olszewska-Guizzo et al. (2018)	E	OGST (contemplative space)	Brain activity
Olszewska-Guizzo et al. (2020)	E	Park, urban green space	Affect, brain activity
Orsega-Smith et al. (2004)	E	Park	Overall mental health, perceived stress, physiological stress
Packer (2013)	Q	Garden	Restorative outcomes
Pálsdóttir et al. (2018)	Q	Garden	Affect
Paraskevopoulou et al. (2018)	E	ToV, veg chars	Affect
Pazhouhanfar (2018)	E	Park, park chars	Affect
Pratiwi et al. (2019)	E	Park	Affect, physiological stress
Pratiwi et al. (2020)	E	Park, park chars	Affect, overall mental health, physiological stress
Rantakokko et al. (2018)	O	Biodiversity	Severity mental disorder, quality of life
Reeves et al. (2019)	E	OGST (blue space)	Affect, brain activity, physiological stress
Roe et al. (2020)	E	Urban green space	Affect, physiological stress, subjective wellbeing
Rogerson, Gladwell, et al. (2016)	E	OGST (sport pitch)	Affect
Rogerson, Brown, et al. (2016)	E	Grass, OGST (blue space)	Affect, perceived stress, other (self-image)
Rostami et al. (2014)	Q	Garden	Subjective wellbeing
Sajady et al. (2020)	O	ToV	Problem behaviour
Saw et al. (2015)	O	Park, OGST (green corridor, nature reserve)	Affect, perceived stress, satisfaction with life, subjective wellbeing
Schebella et al. (2019)	E	Biodiversity	Affect, perceived stress, physiological stress
Scott et al. (2018)	O	Park, ToV	Problem behaviour
Shu and Ma (2020)	E	OGSC (sound)	Affect, physiological stress
Sianoja et al. (2018)	E	Urban green space	Affect
Simkin et al. (2020)	E	Forest, forest chars	Affect, restorative outcomes
Song et al. (2013)	E	Park	Affect, physiological stress, severity mental disorder
Song et al. (2014)	E	Park	Affect, physiological stress, severity mental disorder
Song, Ikei, Igarashi, et al. (2015)	E	Park	Affect, physiological stress, severity mental disorder
Song, Ikei, Kobayashi, et al. (2015)	E	Forest	Affect, physiological stress
Song et al. (2018)	E	Forest	Affect
Song et al. (2019a)	E	Forest	Affect, physiological stress, severity mental disorder

(Continues)

TABLE 2 (Continued)

Author	CAT	Type/characteristic of green space	Mental health outcome
Song et al. (2019b)	E	Forest	Affect, overall mental health, physiological stress
Song et al. (2020)	E	Forest	Affect
Song, Lane, et al. (2019)	O	Forest	Severity mental disorder
Sonntag-Öström et al. (2014)	E	Forest, forest chars, OGST (rock outcrop)	Affect, physiological stress
Sonti and Svendsen (2018)	Q	Garden	Subjective wellbeing
Souter-Brown et al. (2021)	E	Garden	Physiological stress, subjective wellbeing
South et al. (2018)	E	Urban green space	Overall mental health
Southon et al. (2018)	O	Biodiversity, grass	Subjective wellbeing
Speldewinde et al. (2009)	O	OGSC (dryland salinity)	Prevalence mental disorder
Speldewinde et al. (2011)	O	OGSC (dryland salinity)	Other (suicide)
Stas et al. (2021)	O	Forest, garden, grass, ToV, veg chars	Affect, overall mental health, perceived stress
Stigsdotter et al. (2017)	E	Forest	Affect, physiological stress
Subiza-Pérez et al. (2020)	O	Park	Restorative outcomes
Sugiyama et al. (2016)	O	Park	Overall mental health
Takayama et al. (2014)	E	Forest	Affect, restorative outcomes
Takayama et al. (2017)	E	Forest	Affect, restorative outcomes
Takayama et al. (2019)	E	Forest	Affect, restorative outcomes
Hagerhall et al. (2015)			
Taylor et al. (2015)	O	ToV	Prevalence mental disorder
Taylor et al. (2020)	Q	Biodiversity, park	Restorative outcomes
Thomas (2015)	Q	OGSC	Restorative outcomes
Tillmann, Clark, et al. (2018)	O	Grass, park, ToV	Quality of life
Toda et al. (2013)	E	Forest	Affect, perceived stress, physiological stress
Tomao et al. (2018)	O	ToV, veg chars	Restorative outcomes
Tost et al. (2019)	E	Urban green space	Affect, brain activity
Tsai et al. (2018)	O	Forest, forest chars, ToV, veg chars	Overall mental health
Tsunetsugu et al. (2013)	E	Forest	Affect, physiological stress
Tsutsumi et al. (2017)	E	Forest	Affect, physiological stress
Tyrväinen et al. (2014)	E	Forest, park	Affect, physiological stress, restorative outcomes
Ulrich et al. (2020)	E	Garden	Affect
Van Aart et al. (2018)	O	Forest, OGST (farmland)	Affect, physiological stress, problem behaviour
van den Bosch et al. (2015)	O	OGSC	Overall mental health
van Dillen et al. (2012)	O	ToV, veg chars	Overall mental health
Vaz et al. (2020)	O	Grass, ToV, veg chars	Other (self-harm)
Wade et al. (2020)	E	Forest, grass, park, OGST (nature reserve)	Affect, perceived stress
Wallner et al. (2018)	E	Forest, park, park chars	Subjective wellbeing
Wang, Yang, et al. (2020)	O	Grass, ToV	Subjective wellbeing
Wang, Jiang, et al. (2020)	E	Forest, forest chars	Affect, brain activity, physiological stress
Wang et al. (2021)	E	Forest, forest chars	Affect, brain activity, physiological stress
Wang et al. (2016)	E	Park	Physiological stress, severity mental disorder
Wang et al. (2019)	E	Forest, forest chars	Affect, physiological stress

TABLE 2 (Continued)

Author	CAT	Type/characteristic of green space	Mental health outcome
White et al. (2013)	O	Forest, urban green space, OGST (farmland, hill/moor/mountain, blue space)	Restorative outcomes
Windhorst and Williams (2015)	Q	Garden, park, OGST (nature trail, conservation area)	Overall mental health
Wood et al. (2017)	O	Park, park chars	Subjective wellbeing
Wu and Jackson (2017)	O	Forest, grass, ToV	Prevalence mental disorder
Wyles et al. (2019)	O	Urban green space, OGST (countryside, protected/unprotected area)	Restorative outcomes
Yoshida et al. (2015)	E	Urban green space	Affect
Young et al. (2020)	O	Garden	Restorative outcomes
Yu et al. (2018)	E	Forest	Affect, physiological stress
Yuen and Jenkins (2019)	E	Park	Affect, satisfaction with life
Zabini et al. (2020)	E	Forest	Severity mental disorder
Zhang et al. (2018)	E	Garden, veg chars	Physiological stress
Zhang, Barnett, et al. (2019)	O	Park, park chars	Quality of life
Zhang and Tan (2019)	O	Park, ToV	Overall mental health
Zhang, Zhao, et al. (2019)	E	Park, park chars, OGSC (sound, sky view factor)	Affect, physiological stress
Zhou et al. (2019)	E	Park, park chars	Severity mental disorder

Abbreviations: CAT, research design category; E, experimental; forest chars., forest characteristics; O, observational; OGSC, other green space category; OGST, other green space type; Park chars., park characteristics; Q, qualitative; ToV, trees and other vegetation; UGS, urban green space; Veg. char., vegetation characteristics.

studies. 'Grassland', 'park characteristics', 'forest characteristics' and 'vegetation characteristics' were not investigated in any of the included qualitative studies.

The studies will be discussed in relation to these green space categorisations and in terms of mental health outcomes, geographical spread, population type, assessment area and direction of the health outcomes (positive, negative, neutral). Results are split between the experimental, observational and qualitative studies.

3.2.1 | Mental health outcomes

We defined 12 different categories for the mental health outcomes, and a miscellaneous category 'other' category (see Table 4). As an overall pattern, the experimental studies focused mostly on short-term mental health outcomes, particularly affect and physiological stress (Table 5). In contrast, the observational studies focused more on long-term mental health outcomes (e.g. overall mental health, subjective wellbeing) and included a wider range of mental health outcomes (Table 5). Qualitative studies focused on only four mental health outcomes, with the most frequently studied being restorative outcomes (Table 5).

Looking at the intersection between green space category and mental health outcomes, not all combinations of mental health outcomes and green space characteristics were investigated in the included papers (Table 5); most of these gaps were for the green space characteristics and long-term mental health outcomes. Most studies examined 'park' and 'forest' in relation to short-term mental health outcomes of affect ('park' 30%, $n=31$; 'forest' 36%, $n=46$) and physiological stress ('park' 17%, $n=18$; 'forest' 22%, $n=28$; Table 5).

For the other green space categories, there was a bit more variety in the main mental health outcomes investigated (Table 5). 'Trees and other vegetation' were studied most often in relation to the long-term mental health outcomes of overall mental health (16%, $n=11$) and prevalence of a mental disorder (12%, $n=8$), as well as the short-term mental health outcomes of affect (13%, $n=9$) and physiological stress (12%, $n=8$). 'Vegetation characteristics' were most often studied in relation to the long-term mental health outcome of overall mental health (32%, $n=6$). 'Urban green space' was most often studied in relation to short-term mental health outcome of affect (33%, $n=14$). Most studies examined 'gardens' in relation to the short-term mental health outcomes of physiological stress (23%, $n=10$) and affect (19%, $n=8$). For 'grass' environments, the most studies investigated the short-term mental health outcomes of affect (18%, $n=7$), perceived stress (15%, $n=6$) and subjective wellbeing (15%, $n=6$). For 'other green space types', the focus was also mostly on the short-term mental health outcomes of affect (24%, $n=11$), physiological stress (13%, $n=6$) and perceived stress (13%, $n=6$).

3.2.2 | Geographical spread

The studies reported in this scoping review were conducted mostly in European and Asian countries, and to a lesser extent North

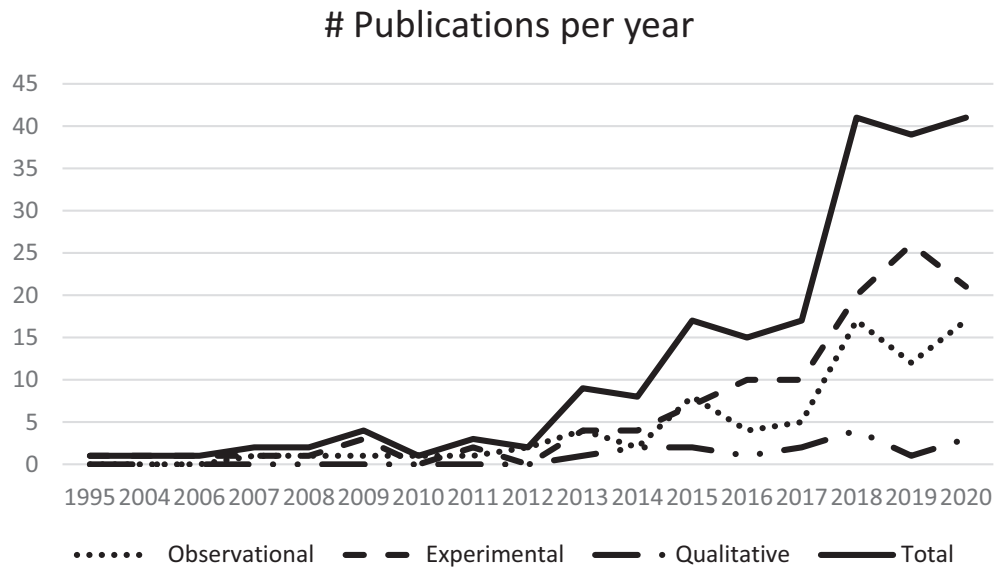

FIGURE 3 Number of publications per year and study category.

TABLE 3 Overview of the green space categories present in the scoping review.

Green space category	Description	Examples
Green space types		
Park	An area of vegetation used for recreation	Urban park, district park, neighbourhood park
Forest	An area mainly covered with trees and undergrowth cover	Deciduous, coniferous, mixed forest
Trees and other vegetation	Studies with a specific focus on plants, shrubs or vegetation cover (and not within a specific green space type)	Tree canopy cover, vegetation cover
Urban green space	Urban land covered by vegetation, which does not fall in one of the other categories such as parks or gardens	Street trees, green vegetation coverage in the city, informal green spaces
Garden	An area where plants and flowers are cultivated. This can be either a private garden (surrounding the house) or a public garden	Backyard or botanical garden
Grassland and meadows	An area mainly covered with grass	Mowed lawn, improved grassland (used for grazing), semi-natural grassland
Other green space type	Miscellaneous	
Green space characteristics		
Park characteristics	Characteristics specific for park environments	Size of the park, amenities in the park
Forest characteristics	Characteristics specific for forest environments	Location in the forest (edge, inside), density of the trees, edge contrast of the forest
Vegetation characteristics	Characteristics of the vegetation (and not within a particular green space type)	Vegetation density, vegetation species, edge contrast
Biodiversity	Studies focusing on the diversity in plants and animals	Flora richness, fauna richness
Other green space characteristics	Miscellaneous	

American countries (Figure 4). Research from South America, tropical regions, as well as from lower- and middle-income countries is mostly lacking in the current evidence base, particularly for qualitative studies. At the continent level, the majority of studies were conducted in Europe (42%, $n=138$) and Asia (27%, $n=89$; Table S3). In Europe, the United Kingdom contributed the most studies (35%, $n=48$). In Asia, China (40%, $n=36$) and Japan (33%, $n=29$) made the biggest contributions. In Oceania, almost all studies came from Australia (97%, $n=29$). In North America, the United States was the largest contributor (78%, $n=46$).

TABLE 4 Overview of the mental health outcomes present in the scoping review.

Mental health category	Description	Example objective and self-report measurement
Long-term mental health and wellbeing		
Overall mental health	Overall score for mental health, encompassing multiple aspects of mental health (e.g. depression and anxiety) and not specifically focusing on one mental disorder	General Health Questionnaire (Goldberg & Hillier, 1979)
Severity mental disorder	Severity of a specific mental disorder, expressed in level of symptoms or use of medication	CES-D (depression; Radloff, 1977)
Prevalence mental disorder	How often a specific mental disorder occurs within the general population	Prevalence of ADHD
Satisfaction with life	Global life satisfaction	Satisfaction With Life Scale (Diener et al., 1985)
Quality of life	Quality of life is the general wellbeing of an individual and can encompass multiple factors such as mental health, physical health and social health	World Health Organization Quality-of-Life Assessment short version (Whoqol Group, 1995)
Problem behaviour	Disruptive behaviour such as hyperactivity or agitation	Strengths and Difficulties Questionnaire (Goodman, 1997)
Short-term mental health and wellbeing		
Subjective wellbeing	Subjective ratings of wellbeing, encompassing different aspects of wellbeing such as happiness, life satisfaction and psychological functioning	Warwick-Edinburgh Mental Well-being Scale (Tennant et al., 2007)
Affect	Momentary measurements of mood and affective state, including for instance positive and negative affect but also state anxiety, including vitality	Positive And Negative Affect Schedule (Watson & Clark, 1999)
Restorative outcomes	Measures focused on the restorative effects following contact with green space, including psychological benefits such as relaxation and forgetting worries. Does not include perceived restorativeness, or anticipated/expected restoration	Restorative Outcomes Scale (Korpela et al., 2008)
Perceived stress	The amount of stress a person perceives they are under either right now or over a period of time	Perceived Stress Scale (Cohen et al., 1983)
Physiological stress	Physiological responses to stress, or activity of the autonomic nervous system as an 'objective' measure of stress.	Heart Rate Variability
Brain activity	Brain activity associated with emotional states, relaxation, etc. measured with, for example, mobile EEG or fNIRS device.	EEG (Davidson et al., 2009)
Other	Miscellaneous: Sleep quality, self-image, social contacts and suicide rate	For example, number of social contacts (Dadvand et al., 2019)

Abbreviations: ADHD, attention deficit hyperactivity disorder; CES-D, Centre for Epidemiologic Studies Depression Scale; EEG, electroencephalogram; fNIRS, functional near-infrared spectroscopy.

The green space categories under study were highly scattered across regions/countries (Table S3). There were, however, several things that stood out. The three most common green space categories investigated by geographical spread were the 'forest', 'park' and 'trees and other vegetation'. 'Forest' was the most studied category in Asia (30%, $n=27$) and Europe (20%, $n=28$). Japan contributed the most studies to the 'forest' category (25%, $n=15$). 'Parks' were most studied in Asia (22%, $n=20$), Europe (13%, $n=18$) and North America (20%, $n=12$). The United States contributed the most studies related to the 'park' category (16%, $n=10$). 'Trees and other vegetation' were most studied in Europe (11%, $n=15$) and North America (22%, $n=13$). The United States contributed the most 'trees and other vegetation' studies (23%, $n=10$). Almost half of the studies on 'gardens' were from Asia (42%, $n=11$). The majority of 'other green space types' studies came from Europe (77%, $n=17$).

3.2.3 | Type of population

Most of the 215 included papers included in the scoping review investigated the influence of green space types or characteristics on the mental health of healthy populations. Healthy populations were investigated using experimental ($n=108$), observational ($n=71$) and qualitative ($n=13$) designs. Twenty-three studies (10 experimental, eight observational and five qualitative) included a clinical population. Only two studies (one experimental and one observational) were conducted with a population at risk for mental illness.

Seventeen different types of populations were identified (Table 6). The most studied populations in the experimental studies were students (36%, $n=58$) and convenience samples (14%, $n=22$). The most studied populations in the observational studies were national residents (29%, $n=49$; green space visitors (16%, $n=27$

TABLE 5 Overview of the mental health outcomes per green space category.

Mental health outcome	Park			Park char.		Forest			Forest char.		ToV			Veg. Char.		UGS			Garden			Grass		OGST			Biodiversity			OGSC			Total			
	E	O	Q	E	O	E	O	Q	E	O	E	O	Q	E	O	E	O	Q	E	O	Q	E	O	E	O	Q	E	O	Q	E	O	Q	E	O	Q	T
Affect	27	4	0	5	0	43	2	1	5	0	8	1	0	2	0	10	4	0	5	2	1	5	2	5	6	0	3	2	0	4	1	0	122	24	2	148
Phys. stress	18	0	0	0	0	28	0	0	3	0	8	0	0	1	0	5	0	0	9	1	0	4	0	4	2	0	4	0	0	3	0	0	87	3	0	90
Overall m. health	2	7	2	0	3	3	4	0	0	1	1	10	0	0	6	2	0	1	2	3	0	0	4	0	3	1	0	2	0	0	4	1	10	47	5	62
Restorative outc.	5	2	2	0	1	11	3	2	0	0	3	2	1	1	1	1	4	0	1	1	1	3	0	0	3	1	2	1	1	0	0	1	27	18	9	54
Perc. stress	5	3	0	1	0	5	4	0	0	1	2	3	0	0	2	1	1	0	1	1	0	5	1	3	3	0	2	0	0	0	0	0	25	19	0	44
Subj. wellbeing	1	6	1	0	2	2	3	2	0	1	1	3	0	0	0	1	4	0	1	2	1	3	3	0	4	0	1	2	0	0	2	0	10	32	4	46
Severity m. d.	5	0	0	0	0	3	2	0	0	0	1	5	0	1	0	0	1	0	2	0	0	0	1	0	1	0	0	1	0	1	0	0	14	11	0	25
Brain activity	3	0	0	0	0	4	0	0	2	0	3	0	0	1	0	4	0	0	2	0	0	1	0	2	0	0	0	0	0	0	0	0	22	0	0	22
Prevalence m. d.	0	0	0	0	0	0	1	0	0	0	0	8	0	0	1	0	0	0	0	0	0	0	5	0	2	0	0	1	0	0	1	0	0	19	0	19
Quality of life	0	3	0	0	1	0	1	0	0	1	1	1	0	1	0	0	2	0	2	0	0	0	1	0	2	0	0	1	0	0	0	0	4	13	0	17
Other	0	2	0	1	0	0	1	0	0	0	0	3	0	0	2	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	1	0	2	11	0	13
Satisfaction w. life	1	3	0	0	1	0	2	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	1	11	0	12
Problem beh.	0	2	0	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	4	0	0	0	0	0	1	0	0	0	0	0	0	0	4	6	0	10

Individual scores	Total scores
1–5	1–10
6–10	11–20
11–15	21–30
16–20	31–40
21–30	41–50
31–40	51–60
41–50	61–

Note: The table includes all unique combinations; if one study looked at different mental health outcomes and/or green space categories, the sample will be counted in all relevant cells (e.g. 'park' and 'forest' categories for physiological stress). However, if a study measured a mental health outcome in more than one way (e.g. physiological stress measured using blood pressure and heart rate variability), this study would only be counted once. Many studies included multiple mental health outcomes and are therefore included multiple times in the table.

Abbreviations: E, experimental; forest char., forest characteristics; O, observational; OGSC, other green space category; OGST, other green space type; Overall m. health, overall mental health; Park char., park characteristics; Perc. stress, perceived stress; Phys. Stress, physiological stress; Prevalence. m. d., prevalence mental disorder; Problem beh., problem behaviour; Q, qualitative; Restorative Outc., restorative outcomes; Satisfaction w. life, satisfaction with life; severity m. d., severity mental disorder; Subj. wellbeing., subjective wellbeing; T, total; ToV, trees and other vegetation; UGS, urban green space; Veg. char., vegetation characteristics.

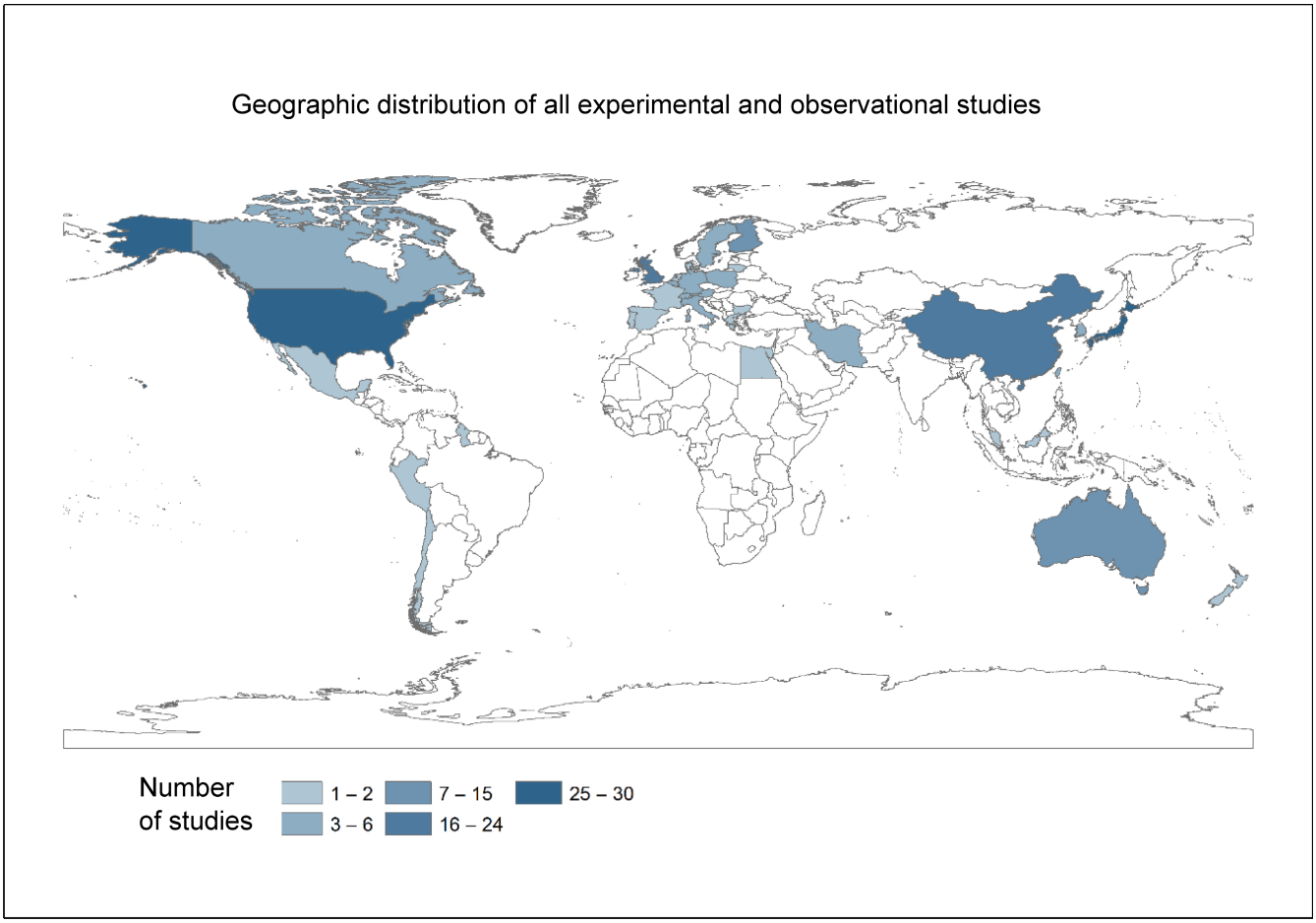

FIGURE 4 World map for the experimental and observational studies. If a study was performed in multiple countries, it was counted in all relevant countries.

and urban residents (16%, $n=27$). For the qualitative studies, the most frequently investigated population groups were patients with a mental disorder (29%, $n=8$) or green space visitors (25%, $n=7$). Across all studies, the least investigated population types were rural residents (1%, $n=2$); volunteers (1%, $n=3$); sports players (1%, $n=4$); panel members (1%, $n=4$); and local residents (3%, $n=9$).

The different population types were relatively scattered across the 12 green space categories (Table 6). However, some combinations of green space and population were more pronounced. For 'forest' environments, the most investigated population types were students (28%, $n=23$), national residents (15%, $n=12$) and employees (10%, $n=8$). For 'parks', most studies involved green space visitors[3] (23%, $n=15$), students (15%, $n=10$) and national residents (11%, $n=7$). For 'trees and other vegetation', most studies involved students (17%, $n=8$), national residents (15%, $n=7$) and urban residents (15%, $n=7$). 'Other green space types' were studied most often with national residents (29%, $n=9$).

3.2.4 | Type of assessment context

Type of assessment context refers to the context of the included papers, which tells us something about the applicability of the results. For example, results of studies assessing a green space category in a school context, may differ from results of a study assessing the same green space category in a residential context. Seven different types of assessment contexts were investigated (Table 7).

The most studied assessment context overall was people 'visiting green space' (44%, $n=150$). This was the main assessment context explored in the experimental (59%, $n=92$) and qualitative (86%, $n=19$) studies—and the second largest assessment context studied in the cross-sectional studies (24%, $n=39$). While 'visiting green space' was assessed in all green space types and characteristics, it was the main assessment context for studies investigating the influence of 'park' (64%, $n=41$), 'park characteristics' (54%, $n=7$), 'forest' (54%, $n=36$), 'urban green space' (54%, $n=14$), 'garden' (36%, $n=9$) and 'biodiversity' (63%, $n=10$) on mental health (Table 7).

Residential area was the second most studied assessment context (31%, $n=106$) overall; all but one of these studies were observational in design. Unsurprisingly, residential area was the main assessment context explored in the observational studies (64%, $n=105$). All green space categories were assessed in a residential context (Table 7). However, residential area was the main assessment context for studies investigating the influence of 'trees and other vegetation' (51%, $n=23$), 'vegetation characteristics' (67%,

TABLE 6 Overview of the population types used per green space category.

	Park			Park char.		Forest			Forest char.		ToV			Veg. Char.		UGS			Garden			Grass		OGST			Biodiversity			OGSC			Total			
Population type	E	O	Q	E	O	E	O	Q	E	O	E	O	Q	E	O	E	O	Q	E	O	Q	E	O	E	O	Q	E	O	Q	E	O	Q	E	O	Q	T
Students	8	1	1	2	0	23	0	0	2	0	7	1	0	1	0	3	0	0	4	0	1	3	0	2	1	1	1	0	0	2	0	0	58	3	3	64
National residents	0	7	0	0	3	0	12	0	0	1	0	7	0	0	2	0	2	0	0	3	0	0	2	0	9	0	0	1	0	0	4	0	0	49	0	49
Green space visitors	6	7	2	2	1	1	4	2	0	2	0	2	1	0	1	0	3	0	0	1	1	0	1	1	0	0	2	3	1	0	2	0	12	27	7	46
Urban residents	1	1	0	0	0	1	2	0	0	0	0	7	0	0	2	2	1	1	0	3	0	0	5	0	3	0	0	2	0	0	1	0	4	27	1	32
Elderly	4	2	0	1	2	3	0	0	0	0	0	3	0	0	0	0	0	0	4	1	0	0	1	0	0	0	1	1	0	0	0	0	13	10	0	23
Convenience sample	5	0	1	1	0	3	0	0	1	0	3	0	0	0	0	2	0	0	3	0	0	2	0	0	0	0	2	0	0	0	0	0	22	0	1	23
Employees	3	0	0	0	0	7	1	0	1	0	0	1	0	0	0	1	0	0	1	0	0	1	1	3	2	0	0	0	0	0	0	0	17	5	0	22
Patients (mental dis.)	0	0	1	0	0	1	1	3	0	0	1	2	0	1	0	0	0	0	0	0	2	0	1	1	0	1	0	0	0	0	1	1	4	5	8	17
Patients (phys. dis.)	1	0	1	0	0	1	1	2	0	0	1	2	0	0	2	0	0	0	0	1	0	0	1	0	0	1	0	1	0	0	0	1	3	8	5	16
School children, pupil	1	3	0	0	0	1	2	0	0	1	0	5	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0	4	12	0	16
Adolescents	2	2	0	0	0	2	1	0	0	0	0	0	0	0	0	2	0	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	8	4	1	13
Other	0	1	0	0	2	0	2	0	0	0	1	2	0	1	0	0	1	0	0	1	1	0	0	0	1	0	0	0	0	0	0	1	2	10	2	14
Local residents	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	2	1	0	0	0	0	0	0	0	6	3	0	9
Panel members	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	2	0	4
Sporters	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	4	0	0	4
Volunteers	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	3
Rural residents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	0	2

Individual scores	Total scores
1–5	1–10
6–10	11–20
11–15	21–30
16–20	31–40
21–30	41+

Note: The table includes all unique combinations; if one study looked at different samples and/or green space categories, the sample will be counted in all relevant cells.

Abbreviations: E, experimental; forest char., forest characteristics; O, observational; OGSC, other green space category.; OGST, other green space type; Park char., park characteristics; Q, qualitative; T, total; ToV, trees and other vegetation; UGS, urban green space; Veg. char., vegetation characteristics.

TABLE 7 Overview of the different types of assessment context per green space category.

	Park			Park char.		Forest			Forest char.		ToV			Veg. Char.		UGS			Garden			Grass		OGST			Biodiversity			OGSC			Total			
Assessment context	**E**	**O**	**Q**	**E**	**O**	**E**	**O**	**Q**	**E**	**O**	**E**	**O**	**Q**	**E**	**O**	**E**	**O**	**Q**	**E**	**O**	**Q**	**E**	**O**	**E**	**O**	**Q**	**E**	**O**	**Q**	**E**	**O**	**Q**	**E**	**O**	**Q**	**T**
Visiting green space	26	10	5	4	3	27	5	4	2	2	3	4	1	1	2	9	4	1	5	1	3	5	1	3	2	2	5	4	1	2	1	2	92	39	19	**150**
Residential area	0	13	0	0	5	0	10	0	0	2	0	23	0	0	8	0	5	0	0	4	0	0	10	1	11	0	0	5	0	0	9	0	1	105	0	**106**
Indirect (laboratory/ online)	7	0	0	1	0	14	0	1	4	0	8	0	0	1	0	3	0	0	4	0	0	1	0	1	0	0	1	0	0	4	0	0	49	0	1	**50**
Exercise	1	1	0	0	0	1	2	0	0	0	1	0	0	0	0	0	2	0	0	1	0	1	0	2	3	0	0	0	0	0	0	0	6	7	0	**13**
Other	0	1	0	0	0	0	2	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	1	9	0	**10**
Health care	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	6	1	2	**9**
School environment	0	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	1	0	0	1	4	0	**5**

Individual scores	**Total scores**
1–5	1–10
6–10	11–20
11–15	21–30
16–20	31–40
21–30	41–50
31–40	51–60
41–50	61+

Note: The table includes all unique combinations; if one study looked at different types of assessment context and/or green space categories, the sample will be counted in all relevant cells.

Abbreviations: E, experimental; forest char., forest characteristics; O, observational; OGSC, other green space category; OGST, other green space type; Park char., park characteristics; Q, Qualitative; T, total; ToV, trees and other vegetation; UGS, urban green space; Veg. char., vegetation characteristics.

$n=8$), 'grass' (48%, $n=10$), 'other green space types' (44%, $n=12$) and 'other green space characteristics' (47%, $n=9$) on mental health.

Indirect exposure to the green space environment (i.e. viewing representations of nature such as videos, images, virtual reality experiences in a laboratory) was the third most studied assessment context overall (15%, $n=50$; Table 7). All but one of the 50 studies involving this assessment context were experimental in design. Indirect exposure was the second largest assessment context in the experimental studies (31%, $n=49$). While the context of indirect exposure was assessed in all green space categories (Table 7), it was mostly assessed in studies researching effects of 'park' (11% $n=7$), 'forest' (22%, $n=15$) and 'trees and other vegetation' (18%, $n=8$) on mental health.

Across all studies, the least investigated assessment contexts were exercise (4%, $n=13$), health care (3%, $n=9$) and school (1%, $n=5$) environments. Exercise environments as an assessment context were explored equally in experimental and observational studies (Table 7). Health care environments were mostly investigated using experimental studies focused on the mental health impacts of gardens. School environments were mostly investigated in observational studies.

3.2.5 | Direction of the outcomes per green space category

For all quantitative studies, the direction of outcomes (positive, negative or neutral) reported per combination of mental health outcome and green space category were synthesised in Table 8. For the results of studies examining a specific combination of green space category and mental health outcome, please see Appendix S3.

At least one positive effect was reported on 368 occasions (63%, $n=231$ for the experimental studies; 37%, $n=137$ for the observational studies). At least one neutral effect, where there was no significant difference or clear direction in the relationship, was reported on 335 occasions (55% $n=185$ for the experimental studies; 45%, $n=150$ for the observational studies). At least one negative effect was reported on 57 occasions (39%, $n=22$ for the experimental studies; 61%, $n=35$ for the observational studies).

As stated in Section 3.2.1 above, experimental studies often focused on short-term mental health outcomes, particularly affect and physiological stress, while observational studies focused more on the long-term mental health outcomes, particularly overall mental health and subjective wellbeing. In the experimental studies, a similar proportion of results focusing on affect and physiological stress reported at least one positive effect (65%, $n=151$), as results reporting at least one neutral effect (63%, $n=117$). In the observational studies, a similar proportion of results focusing on overall mental health and subjective wellbeing reported at least one positive effect (39%, $n=53$), as results reporting at least one neutral effect (38%, $n=57$).

Most of the combinations of green space and mental health outcome with at least one negative effect were single occurrences. Although, there were also some clusters of results that may point to more consistent negative effects for certain green space categories (Table 8). Together, the 'trees and other vegetation' ($n=10$) and 'vegetation characteristics' ($n=15$) categories comprised 71% of the 35 observational studies reporting at least one negative effect. This concerned mostly the observational studies involving the combination of 'trees and other vegetation' with overall mental health, and 'vegetation characteristics' with overall mental health and prevalence of a mental disorder (Table 8). For the experimental studies, the combinations where at least one negative effect were reported were more scattered than the observational studies. The 'forest' and 'forest characteristics' categories comprised 45% ($n=10$) of the 22 experimental studies reporting at least one negative effect.

Most of the combinations of green space and mental health outcome with at least one positive effect were found in the 'park' ($n=75$), 'forest' ($n=85$), 'trees and other vegetation' ($n=41$), 'garden' ($n=36$) and 'urban green space' ($n=31$) categories. Half of the positive effects ($n=116$) found in the 231 experimental studies were from the 'forest' ($n=68$) and 'park' ($n=48$) environments—predominately for the short-term mental health outcomes of affect and physiological stress. For the observational studies, a third (33%) of all positive effects were from the 'park' ($n=26$) and 'trees and other vegetation' categories ($n=19$)—predominately for the long-term mental health outcome overall mental health.

Most of the combinations of green space and mental health outcome with at least one neutral outcome were 'forest' ($n=67$) and 'park' ($n=63$). Half (49%, $n=90$) of the 185 experimental studies reporting at least one neutral effect were found in the 'forest' ($n=49$) and 'park' ($n=41$)—often for affect and physiological stress. Nearly a third (30%, $n=45$) of the 150 observational studies reporting at least one neutral effect came from the 'park' ($n=22$) and 'trees and other vegetation' ($n=23$) categories—predominately for overall mental health.

3.2.6 | Comparison between different green space types and characteristics

In the quantitative studies, comparisons between different green space types and characteristics were achieved in three different ways: directly within a study, indirectly within a study and indirectly between studies (see Table S4). Few of the studies in this scoping review were 'direct within study' comparisons (16%, $n=49$) arguably the most reliable comparison type. Almost all studies enabling 'direct within study' comparisons had an experimental design ($n=45$). Over a third of the studies in this scoping review were 'indirect within study' comparisons (38%, $n=114$). Nearly all 'indirect within study' comparisons had an observational design (96%, $n=110$). Almost half of the studies in this scoping review were 'indirect between studies' comparisons (46%, $n=138$), the arguably the least reliable comparison type. 'Indirect between study' comparisons were largely experimental in design (59%, $n=82$), with fewer contributions of observational studies (30%, $n=41$; Table S4).

TABLE 8 Overview of the direction of the outcomes per green space category and per mental health outcome (quantitative studies only).

	Park	Park char.	Forest	Forest char.	ToV	Veg. Char.	UGS	Garden	Grass	OGST	Biodiversity	OGSC
Affect	+ + + + + + + + + + + + + + + + + + + ○ -	+ + + ○ ○ -	+ ○ - - -	+ + + + ○ ○ ○ -	+ + + + + ○ ○ ○ ○	+ + + ○	+ + + + + + + + + + + + ○ ○ ○ ○ ○ ○ ○ ○	+ + + + + + + ○ ○ ○ ○	+ + + + + ○ ○ ○ ○ -	+ + + + + ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○	+ + + ○ ○ ○ ○	+ + + + + + ○
Brain Act.	+ + ○ ○ ○		+ + + + ○ ○ ○	+ + ○ ○ -	+ + + ○ -	+	+ + + ○ ○ ○	+ + ○ ○	+ ○	+ + ○ ○		
Overall Mental Health	+ + + + + + + ○ ○ ○ ○ ○ ○ -	+ + ○ ○ ○	+ + + + + ○ ○ ○	+	+ + + + + + + + ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ - - - - -	+ ○ ○ ○ ○ - - - -	+ ○ ○ ○ ○	+ + + ○ -	○ ○ ○ ○	+ ○ ○ ○	+ + ○	+ + + ○ ○ ○ ○
Perc. stress	+ + + + + + ○ ○ ○ ○ ○	+	+ + + + + ○ ○ ○ ○ ○ ○ ○ ○ -	+ ○ -	+ + ○ ○ ○ ○ - -	+ - -	+ ○ ○	+ +	+ + + ○ ○ ○ ○	+ + ○ ○ ○ ○ ○ ○	+ ○ ○	
Physiological stress	+ + + + + + + + + + + + + + + ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ - -		+ + + + + + + + + + + + + + + + + ○ - - - -	+ + + ○ ○ -	+ + + + + ○ ○ - -	+ +	+ + + + + + ○ ○ ○	+ + + + + + + + + ○ ○ ○ ○ ○ ○ ○ ○ ○	+ + ○ ○ ○	+ + + ○ ○ ○ ○ ○ ○	+ + ○ ○ ○	+ + ○ ○
Prev. m. d.			○			+ + + + ○ - - - - - -	○ ○	+ + + + ○ ○ ○ ○	+ + ○	○	+	+
Probl. Beh.	+ ○ ○		○ ○		+ + ○ ○ ○			+ + + ○ -		+ ○ ○		
QoL	+ + ○ ○ ○ ○ -	+ ○	+ ○	+ ○	+ -	+	+ ○ ○	+ + ○	-	+ ○	+	
Rest. Outc.	+ + + + + + ○ ○ ○	+	+ + + + + + + + + + ○ ○ ○ ○ ○		+ + ○ ○ ○ ○ -	+ ○ ○ -	+ + + ○ ○	+ ○	○	+ + + + ○ ○	+ + ○ ○ ○ ○	
SwL	+ + + ○ ○ -	○	+ ○				+ +			○ ○ ○		+
Sev. m. d.	+ + + + + ○		+ + + + + ○ ○ -		+ + + + + ○	+ ○ ○ -	○	+ + ○	○	○	○	+ ○
Subj. w.	+ + + + + + + ○ ○ ○ ○ ○ -	+ + ○ ○	+ + + ○ ○ ○	○	+ + + ○ ○		+ + + ○	+ + + ○ ○ -	+ ○	+ + + ○ ○ ○	+ ○	+ + + ○ ○ ○
Other	+ + ○	○	+ -		+ + ○ -	-		+ +	+ + -			+

+ = positive experimental	+ = positive observational
○ = neutral experimental	○ = neutral observational
- = negative experimental	- = negative observational

Note: Each dot represents *at least one* effect reported per combination, and per study. If a study measured affect after a park visit with the Profile of Mood States scale and reported positive results on all six subscales (i.e. tension–anxiety, depression, anger–hostility, vigour, fatigue and confusion), this would be represented by a single solid dot. This was necessary to keep the contribution of each study to the table similar, as some studies only report outcomes of a total score of a questionnaire, whereas others report all subscales or even outcomes on single items.

Abbreviations: Brain act., brain activity; Forest char., forest characteristics; OGSC, other green space characteristic; OGST, other green space type; Park char., park characteristics; perc. Stress, perceived stress; Prev. m. d., prevalence mental disorder; Probl. beh., problem behaviour; QoL, quality of life; Rest. Outc., restorative outcomes; sev. m. d., severity mental disorder; Subj. w., subjective wellbeing; Swl, satisfaction with life; ToV, trees and other vegetation; UGS, general urban green space; Veg. char., vegetation characteristics.

Most of the results from the 'direct within study' and 'indirect within study' comparisons were scattered across the different green space types (Table S5). For brevity, we will discuss the results of studies looking at 'direct within study' and 'indirect within study' comparisons between: 'park' versus 'forest' (Figure 5); 'forest' versus 'grass' (Figure 6); and 'trees and other vegetation' versus 'grass' (Figure 7).

'Park' and 'forest' were directly and indirectly compared 12 times: nine experimental studies with 'direct within study' comparisons; and three observational studies using 'indirect within study'

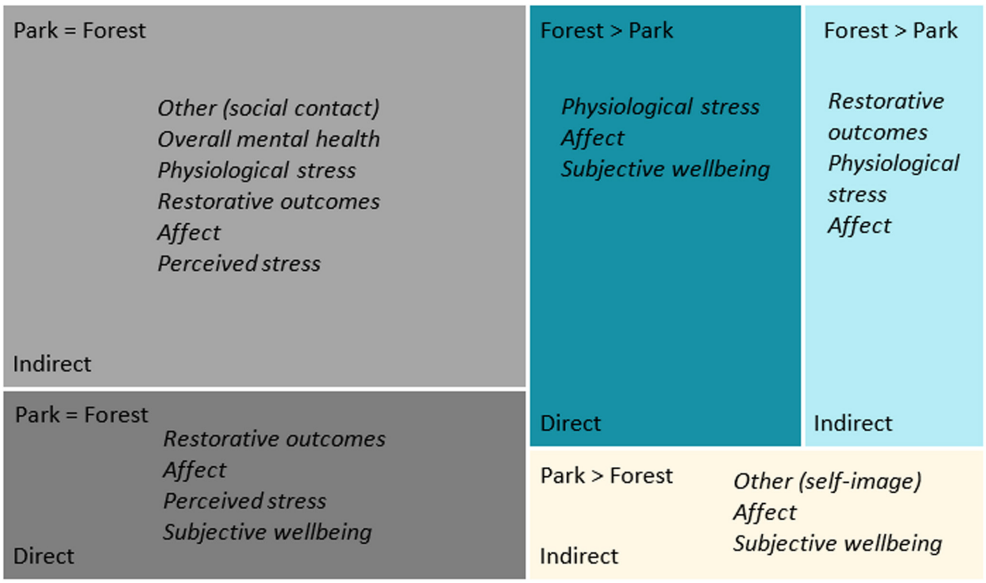

FIGURE 5 Results of the comparison of park and forest ($n = 12$), divided by direct with study ($n = 9$) and indirect with study ($n = 3$) comparisons and with the mental health outcomes included. The size of the boxes represents the number of comparisons. '=' indicates no significant differences found between the park and the forest on the listed mental health outcomes. '>' indicates beneficial mental health outcomes for the green space category on the left of the sign, compared the green space category on the right of the sign.

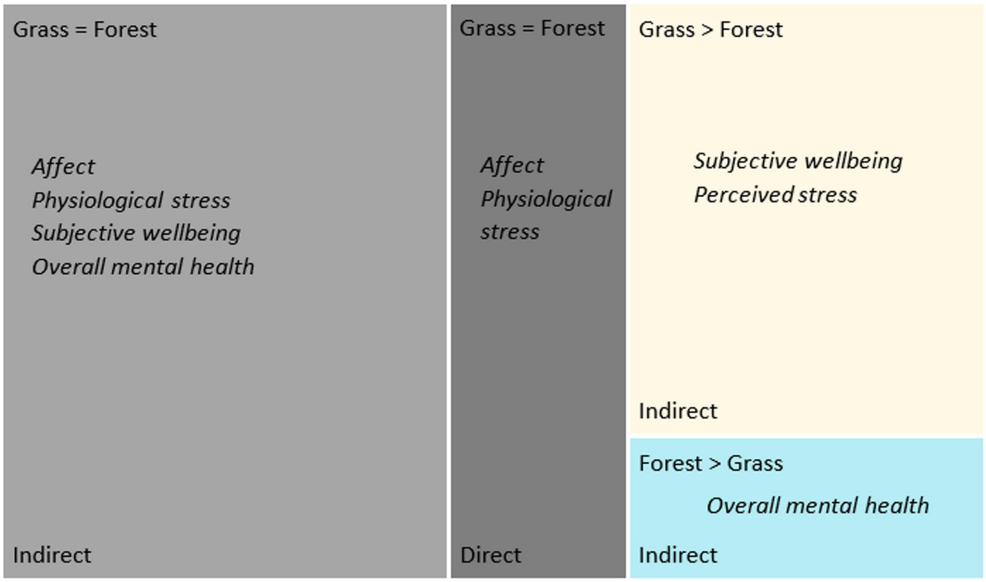

FIGURE 6 Results of the comparison of forest and grass ($n = 7$), divided by direct with study ($n = 2$) and indirect with study ($n = 5$) comparisons and with the mental health outcomes included. The size of the boxes represents the number of comparisons. '=' indicates no significant differences found between the park and the forest on the listed mental health outcomes. '>' indicates beneficial mental health outcomes for the green space category on the left of the sign, compared the green space category on the right of the sign.

comparisons (Table S5). The 'park' category contains vegetated areas used for recreation (e.g. district park), while the 'forest' category contains areas mainly covered with trees and undergrowth (e.g. coniferous forest; for definitions of green space categories see Table 3). Over half of the effects comparing 'park' versus 'forest' were neutral with no significant difference between the two types of green space on affect, overall mental health, physiological stress, perceived stress, restorative outcomes, subjective wellbeing and social contact (identified by grey boxes in Figure 5). Of the remaining studies, most reported better outcomes for the 'forest' than the 'park' (identified by blue boxes in Figure 5). 'Direct within study' comparisons revealed superior effects of the 'forest' on affect, physiological stress and subjective wellbeing. 'Indirect within study' comparisons also pointed at superior effects for the 'forest' on affect, physiological stress and restorative outcomes, compared to 'park'. Although, some studies, using 'indirect within study' comparisons,

FIGURE 7 Results of the comparison of 'trees and other vegetation' (ToV) and 'grass' ($n = 16$), divided by direct with study ($n = 2$) and indirect within study ($n = 14$) comparisons and with the mental health outcomes and types of trees and vegetation included. The size of the boxes represents the number of comparisons. Tov = 'trees and other vegetation'. '=' indicates no significant differences found between the park and the forest on the listed mental health outcomes. '>' indicates beneficial mental health outcomes for the green space category on the left of the sign, compared the green space category on the right of the sign.

found superior effects for the 'park' over the 'forest' for affect, self-image and subjective wellbeing (identified by the yellow box in Figure 5).

The 'forest' and 'grass' were directly and indirectly compared seven times: two experimental studies with 'direct within study' comparisons; and five observational studies with 'indirect within study' comparisons (Table S5). Just as the 'forest' category contains areas covered in trees, the 'grass' category contains areas largely covered with grass, like meadows (Table 2). Most outcomes from direct and indirect within study comparisons between 'forest' and 'grass' were neutral; no difference between the two green space categories was found for affect, physiological stress, overall mental health and subjective wellbeing (see grey boxes in Figure 6). More than half of the remaining 'indirect within study' comparisons showed superior effects for 'grass' compared to 'forest' on perceived stress and subjective wellbeing (see yellow box in Figure 6). Other 'indirect within study' comparisons indicated a superior effect of 'forest' compared to 'grass' on overall mental health (see blue box in Figure 6).

'Trees and other vegetation' and 'grass' were directly and indirectly compared in 16 studies: two experimental studies with 'direct within study' comparisons; and 14 observational studies with 'indirect within study' comparisons (Table S5). The 'trees and other vegetation' category contains trees, as well as other vegetation such as shrubs and herbaceous plants. While some studies in the 'grass' category combine grassland with shrubs. Consequently, there could be an overlap between these two green space categories. The results of these comparisons between 'trees and other vegetation' and 'grass' were highly mixed. No significant difference was found between 'trees and other vegetation' and 'grass' on overall mental health, physiological stress, the prevalence of a mental disorder and self-harm (see grey boxes in Figure 7). 'Direct within study' comparisons showed superior effects for 'grass' on affect—as well as superior effects of 'trees and other vegetation' on severity of a mental disorder (see dark yellow and blue boxes in Figure 7). The same number of studies with an 'indirect within study' comparison showed superior effects for 'trees and other vegetation' over 'grass' (see light blue box in Figure 7), as those showing superior effects of 'grass' over 'trees and other vegetation' (see light yellow box in Figure 7). 'Grass' scored better than 'trees and other vegetation' on perceived stress, problem behaviour, prevalence of a mental disorder, self-harm and subjective wellbeing (light yellow box in Figure 7). On the other hand, 'trees and other vegetation' scored better than 'grass' on overall mental health, prevalence of a mental disorder, subjective wellbeing and quality of life (light blue box in Figure 7). Both green space categories showed superior effects for prevalence of a mental disorder and subjective wellbeing—highlighting the inconsistency in results in the indirect within study comparisons between these two green space types.

For the green space characteristics, the majority of 'direct within study' and 'indirect within study' comparisons were mostly made within the same category (Table S6), meaning different aspects of the same green space characteristic were assessed within the same study. This was particularly the case for 'biodiversity' ($n = 10$, e.g. comparisons of plant vs. bird species richness), 'forest

characteristics' ($n = 8$, e.g. comparing forest patch number vs. forest density) and vegetation characteristics ($n = 6$, e.g. comparisons between different colours of vegetation).

For the qualitative studies, the outcomes could not directly be categorised as positive, negative or neutral but needed to be analysed in terms of (overarching) thematic themes, which were: restorative experiences from natural features, social interactions, memories and symbolism, weather and seasons, and escapism (see Beute et al., 2020 for a more thorough description). Even though the qualitative papers added to the evidence base by providing experiential data, they did not allow for comparisons as there were too few qualitative studies available, and those that were available often did not mention the specific type or characteristic of green space the quote was addressing.

4 | DISCUSSION

Green space can foster mental health, but exposure to their different types and components induces different effects and it is not yet clear which green space types or characteristics are most beneficial. Almost all green space categories included in the scoping review exhibited a positive effect on mental health (alongside with neutral effects), thereby corroborating previous research (Bratman et al., 2019; Gascon et al., 2015; Hartig et al., 2014; Houlden et al., 2018; Tillmann, Tobin, et al., 2018; Van den Berg et al., 2015). The green space category 'vegetation characteristics', on the other hand, had relatively many characteristics (such as vegetation density) of that also displayed a potential negative effect on mental health.

The main outcome of the scoping review is that there are too few studies that allow for direct comparisons between green space types or characteristics, and that it is currently very difficult to compare different green space types and characteristics and to draw conclusions on relative effect sizes of these comparisons due to a high level of complexity (especially when basing the comparison on indirect comparisons). This complexity is due to a high level of heterogeneity in terms of study designs, mental health outcomes, measurement or manipulation of the green space type or characteristic, and geographical spread of the studies. Previous (systematic) reviews have already indicated that this diversity makes drawing solid conclusions for generic green space difficult (Bowler et al., 2010; Bratman et al., 2012; Frumkin et al., 2017; Gascon et al., 2016; Hartig et al., 2014; Houlden et al., 2018; Tillmann, Clark, et al., 2018; Twohig-Bennett & Jones, 2018; Van den Berg et al., 2015; Weeland et al., 2019), but this heterogeneity may prove even more problematic when comparing specific green spaces and characteristics.

4.1 | Study design and characteristics

Most studies included in the review were quantitative (and most were experimental), with only a small proportion using qualitative methods. The three study categories differed greatly in terms of green space focus, geographical spread, mental health focus, strengths and weaknesses, and their ability to allow for direct comparisons between green space types and characteristics. Therefore, indirect comparisons across different research designs need to be made with high caution.

4.2 | Comparisons of green space types and characteristics in terms of mental health benefits: Challenges and gaps in the current evidence base

Direct comparisons within a single study were considered to provide the most reliable outcomes. Only one in six comparisons included in the scoping review could be made directly between different green space types or characteristics. In addition, these studies were often very specific in terms of study design (almost exclusively experimental), type of intervention (often involving a short exposure), mental health outcomes (short-term mental health), study participants (often students or another convenience sample) and geographical location (often in Asia, specifically Japan). This means that the generalisability of the current evidence base that allows for direct comparisons between different green space types and characteristics is limited.

The lack of studies enabling direct within study comparisons means that, at present, when comparing different green space types and characteristics most of the evidence must come from indirect comparisons. This was, for instance, also done in a previous reviews looking at different green space types or qualities (e.g. Chen et al., 2021; Li et al., 2022; Nguyen et al., 2021; Reyes-Riveros et al., 2021), where, for example, Nguyen and colleagues concluded that mental health benefits were consistently found when looking at tree canopy, whereas grassland did not provide a pronounced benefit for mental health (Nguyen et al., 2021). These comparisons are not without risk as both the direct and indirect within study comparisons differed substantially and consistently in research design, green space exposure measures and focus, mental health outcomes, study sample, assessment area and geographical focus.

In the present review, we retrieved enough studies for only three comparisons between green space types: the 'park' versus the 'forest'; 'grass' versus the 'forest'; and 'trees and other vegetation' versus 'grass'. All three comparisons produced mixed results, which may be due to differences between studies that look at direct and indirect comparisons (as with 'park' vs. 'forest'), but may also be due to other sources of heterogeneity.

Given that heterogeneity in research design and characteristics appears to play a key role in these mixed outcomes when comparing different green space types and characteristics, it is essential to have an overview of the potential sources of heterogeneity. In the present review we identified three potential sources of heterogeneity; geographical distribution; green space types and descriptions; and mental health outcomes.

4.3 | Heterogeneity in research design and characteristics

4.3.1 | Geographical distribution

The studies included in the review were mostly conducted in high-income countries, with a minority of studies in low- and middle-income countries (Shuvo et al., 2020), which limits the generalisability of the evidence base. There was a large geographical spread of the different green space categories, with different green space categories receiving attention within different countries or continents. One additional consequence of heterogeneity in geographical distribution is that studies may be impacted by variation in climate, culture and population density. For example, the presence of shady areas under trees may be of greater importance in tropical climates than in temperate climates (Richards et al., 2022), and forest bathing is a culturally important activity in forests in Asia (Beute & van den Berg, 2019). Related to the climate is the type of weather, or season in which the study is conducted. When looking at the effects of green space characteristics, seasonal differences may also be important (e.g. in some climate zones deciduous trees show large differences in foliage by season). These seasonal differences may also interact with weather parameters such as temperature or exposure to sunlight (Beute & de Kort, 2014). Not all included studies reported these factors. Most studies found a positive relationship between tree canopy and mental health, but this may change depending on season (e.g. autumn may not show a positive relationship, Dzhambov, Hartig, et al., 2018). There is thus a need for more research looking at climate, season and weather as characteristics of green spaces and its effects on mental health. This is particularly important given the impact that climate change has on both green space and mental health (Kabisch et al., 2016; Marselle, Stadler, et al., 2019; Pörtner et al., 2021). Population density can differ considerably between countries and is highly related with the amount of green space (Richards et al., 2017). When looking at the effects of green space on mental health, it may be worthwhile to include information on the density of the setting, as, some studies only reported significant outcomes for high-density districts (Tillmann, Clark, et al., 2018; Wu & Jackson, 2017). Heterogeneity in outcomes may thus also stem from differences in population density within the study areas. Differences in geographical location relates to for instance population density, cultural and climate differences, but also differences in green space characteristics and within green space types.

4.3.2 | Green space types and descriptions

There was also considerable overlap between the green space categories. For instance, studies of urban parks may also include extensive stretches of woodland and meadows of grass (e.g. de Brito et al., 2019; Kabisch et al., 2021; Li et al., 2019) urban green space was sometimes very close to being a park (e.g. Coldwell & Evans, 2018; Zhang, Barnett, et al., 2019). One way to circumvent the heterogeneity in green space categorisations would be for researchers to clearly describe the green space under investigation, and how it was defined and measured in the study. Future studies should also provide a rationale for choosing the specific type or characteristic of green space under investigation. This would make studies easier to compare, or at least to assess comparability.

A second issue with the heterogeneity is the green space descriptions used in the literature (see also: Bartesaghi Koc et al., 2017). Not all papers provided an extensive description of the green space under study, which made categorisation of the green spaces difficult. These issues arise partly because most studies included in the scoping review did not have the explicit goal to compare different green space types and characteristics. There is thus a need for more research that is designed specifically to compare green space types and characteristics.

4.3.3 | Mental health outcome measures

The mental health status of the participants may influence the effects of the green space. Healthy populations were included in most studies looking at different green space types and characteristics on mental health. The lack of studies that include either a clinical or an at-risk population presents a problem in this respect. Previous research on mental health outcomes has indicated that those with the worst mental health seem to benefit most from exposure to green space (Beute & de Kort, 2018; Ottosson & Grahn, 2008; Roe & Aspinall, 2011). As such, future research on the mental health impacts of different types of green space could usefully explore these under-researched populations. Importantly, mental health status may also influence how green spaces are used (Hull & Michael, 1995; Orsega-Smith et al., 2004; Pálsdóttir et al., 2018; Tester-Jones et al., 2020). This is especially important for observational studies since green space exposure in experimental studies is controlled.

4.4 | Explaining heterogeneity: Exposure and experience

An additional source of heterogeneity introduced by the differences in research designs of the studies discussed in this review are differences in exposure and experience, which may also prove important in explaining differential outcomes for specific green space types and characteristics. The duration of exposure to, and the activity performed in, the green space are important predictors for the effects of green space exposure on mental health outcomes (Bratman et al., 2019). In the conceptual framework for this scoping review, mental health outcomes were not only expected to differ due to differences in green space types and characteristics, but also in terms of the amount and characteristics of a person's exposure

to those green spaces and their experience in that space (Bratman et al., 2019; De Vries, 2022; Marselle et al., 2021). Differences in green space exposure and experience may also contribute to differences in comparison results, and even mental health outcomes for the same type of green space.

4.4.1 | Exposure

One important distinction between the 'direct within study' and 'indirect within study' comparisons was the type of mental health outcomes measured. 'Direct within study' comparisons almost exclusively based on experimental study designs focusing on short-term mental health outcomes following single and short visits to green spaces. 'Indirect within study' comparisons largely based on observational designs focusing on long-term mental health outcomes. The exposure time may be especially important for the long-term (accumulated) mental health outcomes. Recent research has indicated that at least 2 h of exposure per week is required to gain the most benefit for long-term health (White et al., 2019). Importantly, White et al. (2019) found no difference between one long visit and many short visits.

Another important distinction relevant to exposure is that in the 'direct within study' comparisons studies, participants were often taken to a particular natural environment (or viewed images or videos of that environment) rather than going to that environment by personal choice. This presents a potential problem with regards to the ecological validity of these studies. It could be, for example, that some of the participants would never normally visit that type of green space. Research has indicated that, on average, people only spend a very small percentage (around 2%) of their time in natural environments (Beute & de Kort, 2018; Wheeler et al., 2010), and the distribution of the time spent in green spaces between different types is still unknown. Therefore, the short-term mental health benefits reported in the experimental studies may differ from benefits found for long-term mental health outcomes.

Furthermore, in the 'indirect within study' comparisons, the availability of or proximity to a green space is often used as a proxy for real exposure (Bratman et al., 2019; Marselle et al., 2021). This proxy measure means there is uncertainty in the actual exposure time and whether the exposure is purposeful or incidental. Furthermore, using availability of or proximity to green space as a proxy for exposure means that the green space category under study may be confounded with other green space categories as different green spaces may act as substitutes for each other. Not having a park nearby may, for example, be substituted by visits to a nearby forest. Indeed, scoping reviews looking at generic green space exposure (i.e. not looking at a specific green space type) have pointed at better mental health (Van den Berg et al., 2015) and better emotional and behavioural functioning for children (Vanaken & Danckaerts, 2018) with an increase in the quantity of surrounding greenness. Therefore, studies looking at availability of or proximity to a specific type of green space may benefit from adding other green space types as covariates. In the case of high substitutability, studies looking at generic green space availability (independent of green space type) will produce more consistent results than studies looking at only one type of green space, ignoring other types.

There is thus a need to know the actual exposure to the green space type or characteristic (Bratman et al., 2019; Hartig et al., 2014; Meredith et al., 2020). This requires observational study designs that go beyond studying mere proximity or availability, as well as experimental study designs that go beyond studying the short-term mental health effects of single visits. This would require longitudinal and in-depth studies, which may benefit from innovative research methodologies such as big data analysis or ecological momentary assessment (Beute et al., 2016).

4.4.2 | Experience

Experience has received very little scientific attention as far as we can tell from this review. We have, however, excluded studies looking at perceived restorativeness, these studies might have focused more on these experiential aspects. Experience with green space is difficult to capture and can be seen as depending on both individual characteristics (e.g. experience of the park may differ between a child and an adult, or between a person with good vs. bad mental health) and the type of activity in which a person is engaged in the green space (Bratman et al., 2019). Paradoxically, integrating experience and how it can differ between and within an individual, would require a higher level of heterogeneity in terms of differentiation in, for example, user characteristics and activities performed in the green space. This needs to be studied in a more structured manner, for example using more longitudinal designs and explicitly comparing different user characteristics within a single study. Qualitative studies have an important role here as they can provide more insights into the experiential side of green space exposure. However, to do this, qualitative studies would need to have a better differentiation between green space types and characteristics in order to distinguish one's experience between them.

4.5 | Future research

The present review identifies a need for more research that directly compares different green space types and characteristics, as well as a need to address heterogeneity issues systematically. Future studies should use a common terminology for categorising the various types of green space found in the ecology, geography or landscape architecture disciplines, include a better assessment of actual exposure (beyond availability of green space as a proxy of exposure), and usefully consider assessing the impacts of repeated short-term visits or a stronger focus on impact on long-term mental health. In addition, the role of individual experience should receive greater attention than it has so far received when investigating effects of green space on mental health.

Most of the studies included in this review did not specifically aim to compare green space types or characteristics. There is, however, a large body of research enabling indirect comparisons within a single study (albeit these studies are mostly observational in design). Even though these studies may not have been designed with the aim to compare green space types and/or characteristics, they may have the data necessary to make direct comparisons. A re-analysis of these data, in which the effects of the different green space types and characteristics on mental health are directly compared, could enrich the current evidence base. These re-analyses would allow for conclusions that go beyond comparing the direction of the outcomes by looking, for instance, at superiority of one green space type or characteristic, or by comparing the strength of the effect or association.

4.6 | Limitations of the scoping review

There are limitations in the present review that may have influenced our conclusions. First, while we aimed to be comprehensive in our approach, there is a possibility that not all publications relevant to the inclusion criteria were identified by the search terms or two databases used. Second, while there was no limitation on the geographical scope of the studies, the language exclusion of non-English language studies may have introduced language, cultural and/or publication bias in the review. Third, judgements made when categorising the studies into various groupings for population, green space type and characteristics, and mental health outcomes, depended on the clarity and reporting detail within the included studies. Inappropriate categorisation is possible as not all studies used clear descriptions of the green space and there may also have been cultural or geographical differences between the categorisation of green spaces by the review authors. Fourth, the heterogeneity of the results, as well as the low number of studies conducting 'direct within study' comparisons and the low number of studies per green space–mental health outcome combination did not allow for a meta-analysis. When more suitable studies are available, running a meta-analysis would help shine more light on the relative effect sizes of the different green space types and characteristics. Fifth, there inevitably goes time between conducting the literature search and publication of the manuscript. New studies may provide different insights. However, the updated search we ran in 2021 did not alter conclusions drawn after the first search. In addition, several recent studies corroborate the conclusions drawn in the present scoping review, that high levels of heterogeneity prevent us from drawing robust conclusions about which green space type or characteristic is best. Several studies, for example, have enabled indirect comparisons of several green space types with grass and found highly mixed results, in line with the outcomes of the present scoping review (Aerts et al., 2022; Astell-Burt et al., 2022; De Vries et al., 2021; Maes et al., 2021). Notwithstanding these limitations, the 215 studies included in the scoping review allowed us to gain an extensive overview of the current research to discern the types and characteristics of green spaces and their relationship to mental health, to identify gaps in the literature and inform future research on this topic.

5 | CONCLUSION

Green space matters for mental health. However, distinguishing which types or characteristics of green space are most beneficial for mental health is difficult to answer with the current evidence base, as the current evidence base mostly has to rely on indirect comparisons between green space types and characteristics, which has proven difficult due to high levels of heterogeneity in study designs and exposure and outcome measurements. Even though research shows clear benefits of generic green space on mental health (e.g. Gascon et al., 2015; Hartig et al., 2014; Houlden et al., 2018; Meredith et al., 2020; Tillmann, Tobin, et al., 2018; Van den Berg et al., 2015; Vanaken & Danckaerts, 2018), our scoping review highlights a need for scholars to think beyond green space as a uniform landscape type. Future research should be interdisciplinary—integrating the natural, social and health sciences with the involvement of urban designers and planners—to measuring specific green space types and characteristics and assess their effects on mental health.

The evidence base would benefit from more studies looking at characteristics of green space such as biodiversity, vegetation density or landscape design aspects. Looking at green space characteristics rather than green space types may also help overcome problems with the substitution of one type of green space with another in observational studies looking at the relation between the proximity to or availability of green space and mental health.

AUTHOR CONTRIBUTIONS

All authors conceived the idea and designed the methodology; Sjerp de Vries, Annamaria Lammel and Maria Beatrice Andreucci were project administrators; Julie Glanville led the literature search; Femke Beute curated all data; Femke Beute and Melissa R. Marselle analysed the data and led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

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CONFLICT OF INTEREST STATEMENT

Melissa Marselle is an Associate Editor of People and Nature, but was not involved in the review process for this article. All other authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

All data supporting the results of the scoping review (including the Supplementary Excel tables, supplementary material and tables) have been archived on OSF https://osf.io/2ceah/?view_only=bb6478f293c24e749a866f2673018af9.

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ENDNOTES

[1] PICO stands for population, intervention, comparators and outcomes. PECO is similar, except that the E stands for exposure.

[2] The experimental category here included quantitative studies in which a planned intervention or experimental manipulation took place (e.g., randomised control trials, quasi-experiments). The observational studies category here included quantitative studies in which no planned intervention or experimental manipulation took place (e.g., epidemiological, longitudinal and prospective cross-sectional studies). The qualitative category here included studies which results were reported in a written format as opposed to quantitative (e.g., case study, ground theory).

[3] 'Green space visitors' describes research participants who were on-site in the environment—either by their own choice or as part of the research experiment.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Table S1. Literature search outcomes.

Table S2. Number of publications per year and study category.

Table S3. Overview of the geographical spread of the different green space categories over countries and continents for the experimental and observational studies.

Table S4. Overview of the number of experimental and observational studies that enabled comparisons between different green space types and characteristics.

Table S5. Overview of the comparisons made within studies (indirect and direct) for the green space types.

Table S6. Overview of the comparisons made within studies (indirect and direct) for the green space characteristics.

Appendix S1. Full search strategies.

Appendix S2. Excel database of the meta-data of all 215 studies.

Appendix S3. Searchable Table (Excel database) detailing all studies investigating specific green space category and mental health combinations (e.g. 'park' and affect).

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