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Types and characteristics of urban and peri-urban green spaces having an impact on human mental health and wellbeing: a systematic review

An EKLIPSE Expert Working Group report

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Types and characteristics of urban and peri-urban green spaces having an impact on human mental health and wellbeing: a systematic review

A report of the EKLIPSE Expert Working Group on Biodiversity and Mental Health to provide useful insights for the conservation, planning, design, and management of urban green and blue infrastructures

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Glossary

Term	Definition	Reference
Green space	Outdoor areas dominated by vegetation, such as urban parks, or isolated green elements, such as street trees.	Adapted from [1]
Blue space	"Outdoor environments that prominently feature water and are accessible to humans either proximally (being in, on or near water) or distally/virtually (being able to see, hear or otherwise sense water)." Examples are coasts, lake, ponds and pond systems, wadis, artificial buffer basins or water courses. Together with green spaces they form the green-blue infrastructure.	[2], p. 3
Mental Health	"A state of well-being in which every individual realizes his or her own potential, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to her or his community."	[3]
Mental Wellbeing	"The psychological, cognitive and emotional quality of a person's life. This includes the thoughts and feelings that individuals have about the state of their life, and a person's experience of happiness."	[4], p. 12
Urban	Relating to a city or town.	Oxford dictionary
Peri-urban	An area directly adjacent to a city or a town.	Oxford dictionary
Ecosystem Services	"The benefits people obtain from ecosystems". Four categories of ecosystem services can be identified: supporting, regulating, provisioning, and cultural services.	[5]
Salutogenic effects	Health-promoting effects, as opposed to pathogenic or detrimental health effects.	[6]
Green Space Type	A specific type of green area (e.g., a park, a garden, a forest)	EWG members
Green Space Characteristic	A distinguishing feature of a green space, not covered by its type. E.g. the number of trees or the path density in a park. Or the scenic beauty of a green space.	EWG members
Biodiversity	"The variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they	[7], p. 3

Term	Definition	Reference
	are part; this includes diversity within species, between species and of ecosystems”	

List of Abbreviations

CgA	Chromogranin A
EEG	Electroencephalogram
EWG	Expert Working Group
GSR	Galvanic Skin Resistance
fMRI	Functional Magnetic Resonance imaging
Hb	Haemoglobin
HR	Heart Rate
HRV	Heart Rate Variability
LAeq	Equivalent continuous sound pressure
LF/HF ratio	Low Frequency / High Frequency ratio
ln(HF)	Natural log of High Frequency
MTES	Ministry in charge of the Environment of France
OPEC	Outdoor Play Environment Categories
Oxy-Hb	Oxygen-haemoglobin
PANAS	Positive Affect Negative Affect Schedule
POMS	Profile Of Mood States
RMSSD	Root Mean Square of Successive differences between normal heartbeats
SD	Standard Deviation
SDNN	Standard Deviation of Normal to Normal heartbeats
SDQ	Strengths and Difficulties Questionnaire
SR	Systematic Review

UK	United Kingdom
USA	United States of America
VR	Virtual Reality
WHO	World Health Organisation

Executive Summary

Green spaces have been put forward as contributing to good mental health. In an urban context, space is a scarce resource while urbanisation and climate change are increasingly putting pressure on existing urban green space infrastructures and increasing morbidity caused by mental health disorders. Policy makers, designers, planners and other practitioners face the challenge of designing public open spaces as well as preserving and improving natural resources that are important for maintaining and optimizing human wellbeing. Knowing which types of blue and green spaces, with which characteristics, are most beneficial for mental health and wellbeing is critical.

EKLIPSE received a request from the Ministry in charge of the Environment of France (MTES) to review: "Which types of urban and peri-urban green and blue spaces, and which characteristics of such spaces, have a significant impact on human mental health and wellbeing?". After a preliminary scoping, a decision was made to perform two systematic reviews (SR) assessing the specific types and characteristics of blue space (SR1) and green space (SR2) with respect to mental health and wellbeing. This report presents the systematic review for green space (SR2).

Benefits of green space on mental health can follow several distinctive pathways. Three domains of pathways have been proposed for the beneficial effects of nature on health: 1) mitigation (reducing harm), 2) restoration (restoring capacities), and 3) instoration (building capacities). Examples of pathways include reducing air pollution (mitigation), reduced stress levels (restoration), and increased social interactions (instoration) in green spaces.

The question remains whether all the pathways always occur and at the same time, and whether they are equally important for every individual and for all types of green space. Some evidence exists for differential outcomes for individuals differing in for instance life stage or socio-economic status. The effects of green space may thus not be the same for everyone. Furthermore, different population segments may also need or prefer different types of green space, with different characteristics for the same function. For example, facilitation of physical activity in a park may be accomplished differently for children (e.g., providing challenging natural areas to allow for climbing, or large grass fields to practice sports) compared to elderly people or those with physical disabilities (e.g., providing accessible paths).

In research thus far, however, the focus has often been on exposure to rather generic green space imagery or on the amount of, or proximity to, green space or elements, rather than on the specific types or characteristics of green environments. This does not allow for differentiation either between different types of natural environments or different functions (e.g., for physical exercise or stress reduction). More knowledge of the importance of types and characteristics of green space may help to unlock its potential to contribute to human health [8-10] and can thus usefully determine planning and management decisions.

In order to generate this evidence-based knowledge, there is an explicit need to identify measurable outcomes of the various mental health benefits provided by different green spaces, and to identify key characteristics of those spaces. A recent conceptual model aimed at translating outcomes of research on the restorative effects of nature on mental health benefits and implementing solutions for the provision of ecosystem services also included specific features of a natural environment as

directly and indirectly influencing the mental health benefits derived from that natural environment. Its features are relevant for the amount of 'exposure', operationalized as actual time spent in the natural environment. Its features also affect the experience (also reflected as internal dose, controlling actual exposure for experiential influences) when people interact with the environment, even if only by looking at it. Both are deemed relevant for the size and the type of mental health benefit derived from the natural environment.

Outcomes of systematic reviews generally point at beneficial relations between green space and mental health, but an overarching conclusion in this research domain is that the geographical diversity of settings and the heterogeneity of objectives, theoretical frameworks, covariate data, target population, and research methods in the reviewed studies made the comparison and establishment of robust results difficult.

There is both a practical and a theoretical need to gain a better understanding of which types and characteristics of green space matter most for urbanites in terms of mental health and wellbeing. The objective of the present systematic review was to tackle this knowledge gap.

The systematic review (SR2) was performed according to the PRISMA guidelines for systematic reviews and incorporated three different categories of studies: experimental studies; cross-sectional studies; and qualitative studies. The literature search was conducted in two different databases: Scopus and Medline (Ovid). For paper selection, eligibility criteria were implemented along five dimensions: people, intervention, exposure, comparison, outcomes (PICO/PECO approach, see section 2.1 for a more detailed explanation).

First, all population types (e.g., children, elderly people, students, employees, general population, or clinical sample) were deemed eligible as long as the study included more than a single participant (single case, or single patient studies, were excluded). Second, eligible green space interventions were those that manipulated or changed the exposure to a green space, by targeting a specific type or characteristics. The amenities and facilities present in it were also of interest. Studies investigating only the efficacy of therapeutic interventions in green environments were excluded from the systematic review. Third, only studies investigating exposure to outdoor green space were deemed eligible. Studies looking at exposure to rural green space were also included in the review, as they could be relevant to mental health benefits of green space and their characteristics. Fourth, the comparison or reference environment was ideally another type of green space (though other comparisons with, for instance, a built environment or a blue space were also included), or the same type with different characteristics, for example a comparison between different tree species. Studies investigating a single environment but with pre-post- measurements were also included. Studies employing a compound measure of green space (e.g., taking grassland and forest within one category) were excluded. Fifth and last, a wide range of mental health and wellbeing outcomes were eligible for the review, ranging from momentary mood to suicide rates. The World Health Organization ICD-10 mental health classification system was adhered to: affective disorders, stress-related diseases; schizophrenia, psychosis, paranoia; personality disorders; disorders of psychological development; cognitive dysfunction; neurodegenerative disease; problem behaviour. Studies looking only at individuals' preference ratings, perceived restorativeness, expected restorative effects of physical health correlates to mental health (such as physical activity without looking directly at mental health outcomes) were excluded. Qualitative studies were searched for using the same

inclusion and exclusion criteria. Qualitative studies were included to identify in-depth insights from people's experiences of engaging with green spaces and the meanings people attributed to these experiences.

The search yielded a total of 16,581 unique (deduplicated) papers. After three rounds of eligibility screening, a total of 134 eligible studies were categorized as eligible: 55 cross-sectional papers, 67 experimental papers (68 studies), and 12 qualitative papers. Meta-data were extracted from these 134 papers in four categories: general information, methodology, green space manipulation, and mental health outcomes.

All included papers were systematically assessed on their potential for systematic bias (introduced for instance by the study design, method of selection of participants, or selection of green space manipulations) during the critical appraisal phase. Studies with low scores in the critical appraisal phase were excluded from the next step, the synthesis.

Both a descriptive synthesis and a narrative synthesis were performed for each group of papers by study design (experimental, cross-sectional and qualitative). Before starting the synthesis, all papers were divided into seven different categories according to green space types and included: urban green space; park; garden; forest and woodland; grassland and meadows; trees and other plants; other green space types (miscellaneous category). Two categories included papers looking into green space characteristics: biodiversity; other green space characteristic (miscellaneous category). One study could represent several categories (e.g., forest and grassland) and could therefore be included in more than one category. As the main purpose of the review is to look at differential effects between green space types and characteristics, all studies comparing different green space types or characteristics were gathered for each category and treated separately. Groupings and tabulations were also made per health outcome measure, divided into fourteen categories: mental health, severity of a mental disorder, prevalence of a mental disorder, satisfaction with life, quality of life, subjective wellbeing for long term health and affect, vitality, restorative outcomes, perceived stress, physiological stress, problem behaviour, and brain activity for short term health. The last category comprised of a miscellaneous category.

The descriptive synthesis included six different factors: the country in which the study was conducted; whether the sample was drawn from a general, at-risk, or clinical population; the type of population (e.g., students, local residents); the type of health outcomes; the assessment environment (e.g., residential area, school environment, or green space visit); and the design of the study (cross-sectional versus longitudinal, or within- between- mixed- subjects design or pre-post design). A further distinction was made between studies with direct exposure versus those with indirect representations of green space (e.g., videos and Virtual Reality) within the experimental study category, as no indirect exposure was present in the cross-sectional and qualitative studies.

After these overviews were created, the narrative synthesis was performed, where results were further analysed by looking at differences in possible mediators, such as the type of activity, the study design, the sample, as well as the risk of bias (outcomes of the critical appraisal), to understand the observed heterogeneity in outcomes. Conceptual maps were created to reveal patterns in the outcomes and to further explain heterogeneity.

Not all studies, however, enabled a direct comparison between different green space types and different green space characteristics. Therefore, conclusions sometimes had to be based on indirect

comparisons. A study in which two green space types both showed significant positive outcomes compared to for example a built-up environment were rated as having similar effects in the indirect comparison. However, there may still exist differences between these green spaces types in effect size.

Most studies focused on green space types, and fewer on green space characteristics. Predominantly beneficial effects were reported for all green space categories and characteristics. Parks, forests, grassland, and other urban green spaces (such as green community squares, or greenways) can independently improve mental health. Not only designated urban green spaces such as urban parks or forests appeared to matter, but also informal street greenery and tree canopy. Outcomes indicated in particular a clear relation between more trees and better mental health. On the other hand, shrubland – especially when dense and highly connected – may be negatively associated with mental health. Higher biodiversity generally resulted in better mental health outcomes.

Even though the benefits of green spaces were quite consistent, the direct comparisons of the different green space types and characteristics yielded very mixed results. The largest group of studies focussed on either the park (and the urban green space) or the forest. Contradictory effects were found in direct comparisons between the two, with superior effects for the forest than the park on short-term mental health outcomes reported in most experimental studies and the exact opposite in three cross-sectional studies on long-term mental health outcomes. At least two explanations can be provided for the heterogeneity in these comparison results: diversity in user characteristics and needs as well as microclimatic circumstances and different cultural representations; and/or the need for a better measurement of actual exposure.

First, the heterogeneity in outcomes for the comparisons between different green space types and characteristics may suggest that there is not one single green space type or characteristic that is best, or a 'gold standard' that works best for everyone, everywhere, and at every time. Instead, there may be a need for variety in green space types to suit different users with different needs and also undertaking varied activities. What adds complexity is that these variations not only occur between individuals, but also within a single person. On a bad day, a person may benefit more from a specific green space or characteristic than on a good day. In addition, factors such as geographical location, cultural perspectives, and climatic conditions may also influence how a specific green space type and/or characteristic influence mental health. Here also lies a potential challenge as climate change is not only affecting biodiversity in the cities, but also the microclimate within different urban areas within a city.

Second, contradictory findings may be due to outcomes depending on the (actual and accumulated) amount of exposure. Total exposure over time is assumed to be important for long-term wellbeing benefits. Most experimental and cross-sectional studies did not fully capture actual exposure though. In the majority of the experimental studies, participants were taken to a certain green space environment – rather than choosing an environment themselves – which may thus not reflect their actual exposure in daily life. In the cross-sectional category, on the other hand, many studies investigated effects of proximity or availability of green space types as a proxy for actual exposure. Having a park nearby does not automatically imply that an individual will actually use it. Consequently, there is a need for more research looking at actual exposure.

In addition to the actual exposure, there is also a need to know more about the experiences that people have and develop in the green spaces. Users' characteristics and culture can influence

whether and how a person benefits in terms of mental health from the different green spaces and related characteristics, and also which dose of the green space or green space characteristic is necessary to reach a certain effect. This partly re-confirms the first explanation of the heterogenous results indicating that effects of different green space types and characteristics may differ based on factors such as life stage, gender, socio-economic status, or connectedness to nature. At the same time, effects may also depend on geographical location, season, or microclimatic aspects which can influence one's green space experience.

The studies included in the review were highly heterogeneous in terms of objectives, theoretical frameworks, covariate data, target population, and research methods. Previous systematic reviews have indicated that this diversity makes drawing solid conclusions difficult. This was also the case for the present review as it was not possible to draw firm conclusions on how exactly exposure and experience influence mental health benefits of urban green spaces. At the same time, the present review has indicated that when trying to identify benefits of specific green space types and specific green space characteristics on mental health, this diversity in outcomes and user characteristics may not necessarily be a weakness but, instead, a prerequisite for gaining a better understanding of how exactly different green space types and characteristics influence mental health and wellbeing. However, there needs to be a more systematic way to study this, with for instance a larger contribution from longitudinal studies. Another way to go about this is to purposefully address this heterogeneity in the research methodology by enabling, for instance, a direct comparison not only between different green space types and characteristics, but also between different users (e.g., age, mental health status), different activities (e.g., active versus passive activities), different locations (geographical locations, or in areas with different population densities), or different seasons.

The present review has once again established a general beneficial relation between green space and mental health, an association that seems to hold for most green space types. Comparisons between different green space types have revealed a heterogeneity in outcomes that points at potential underlying pathways that deserve further attention. Two main avenues for future research are consequently proposed: a better assessment of the actual exposure as well as of the role of individual experiences within specific green spaces. Gaining knowledge on how actual exposure to – and experience with – specific natural features can help improve and maintain mental health will enhance the understanding of which types, characteristics, and variety of green space are required to tailor urban green space design to the specific needs and preferences of increasingly vulnerable urban communities in an attempt to face not only increased urbanisation but also climate change.

1. Background

In an increasingly urbanized world, pressures are growing on ecosystems. Furthermore, urbanization is associated with an increase of several mental disorders [11]. Conversely, a lack of green space availability has been found to be related to worse mental and physical health [12, 13].To reduce negative mental health effects in cities, functional and healthy ecosystems are a necessity [14]. Policy makers, designers, planners and other practitioners face the challenge of designing natural resources and preserving and conserving existing ones that are important for maintaining and optimizing human wellbeing. In an urban context, space is a scarce resource. Therefore, knowing which type of blue and green spaces, with which characteristics, are most beneficial for health and wellbeing is critical. It is exactly this question that lies at the core of the request put to EKLIPSE's experts.

1.1 Aims and objectives

In March 2017, EKLIPSE called for experts (call for experts No. 2/2017) to assess and share existing knowledge on this issue across disciplines, following up a request initially formulated by the Expert Working Group Biodiversity & Health, 3rd National Plan on Health and Environment (PNSE3) – Ministry in charge of the Environment (MTES), France. MTES requested advice for the "conservation,creation, design and management of natural spaces that would benefit urban citizens, by maintaining or enhancing their mental health and wellbeing", as well as promoting systematic, interdisciplinary, and cross-cultural research**.**

1.2 The request

The request was as follows:

"Which types of urban and peri-urban green and blue spaces, and which characteristics of such spaces, have a significant impact on human mental health and wellbeing?"

The intention of the request was to provide advice to policy makers, practitioners and researchers regarding the planning, design, construction, and management of green and blue spaces in urban or peri-urban areas to promote the mental health and wellbeing of urbanites as well as those visiting urban areas.

After a preliminary scoping exercise, it was agreed with the requestor (MTES) to specifically focus on comparing different types of urban and peri-urban green and blue spaces and/or variations in green/blue space characteristics. It was agreed that two systematic reviews, one for blue and one for green space, would be undertaken. This report presents the outcomes for the green space systematic review.

1.3 The expert working group

The expert working group was composed of 11 members from 7 countries. A range of disciplines and backgrounds were covered: urban ecology, biology, landscape architecture, medicine, environmental science, psychology, anthropology, political science, economy, and sociology. Communication was maintained across the team via email and virtual meetings, with a series of face-to-face meetings organised by EKLIPSE to facilitate key stages of the work. Experts worked intuitu personae, and on a voluntarily basis without receiving financial compensation. A post-doc fellow joined the expert working group in April 2019 to help coordinate and conduct the work, benefitting from the financial

support of EKLIPSE. Information specialists were employed to support the expert working group, conducting the systematic literature searches and assisting with the first stages of the eligibility screening. This was made possible with additional financial support from the World Health Organization.

1.4 Theoretical framework: Green space and mental health and wellbeing

Green and blue infrastructure in cities plays an important role in the health and wellbeing of urban dwellers. More and more people live in cities nowadays and existing urban areas are growing in both size and density. The recent pandemic outbreak of Covid-19 has painfully pointed at the different roles that urban green infrastructure play for health in general and mental health in particular. In many cities around the world, social gatherings in the park were no longer allowed and not everyone had a private garden or even a balcony available to allow for access to the outdoors. With many places in lock-down, this has potentially had marked effects on urbanites' mental health. At the same time, in those areas with less strict lock-down rules an increased interest in nature and nature visits was registered [15]. In response, large metropolitan areas are now considering redesigning the city to create more space for pedestrians and cyclists, to keep out polluting cars and lower pressure on public transport. This redesign could potentially also give more space to nature in cities, which once again underlines the need to know more about which types and characteristics of nature are key to mental health.

Three domains of pathways have been proposed for the beneficial effects of nature on health [16]: 1) mitigation (reducing harm), 2) restoration (restoring capacities), and 3) instoration (building capacities), see Figure 1. Mitigation of environmental stressors include for instance air pollutants. Air pollutants do not only have pronounced negative effects on physical health and mortality [18, 19], but also on mental health [20-22], and cognitive performance [23] [24]. Besides a direct link between air pollution and mental health, it has also been proposed that air pollution, together with traffic-related noise, can constrain the restorative potential of an environment [25]. Trees and other plants may also release pollen which can aggravate allergies [17, 26]. Another example of how green space can help mitigate stressors is by cooling down the city [27], which is a topic that is increasingly gaining attention while facing global warming combined with increasing urbanization [28]. The mitigation of noise and crowding in more natural environments can also help reduce stress [17]. In the present systematic review, the focus is on ecosystem services but ecosystem disservices can also present an important avenue of investigation.

Restoration theories have proposed evolutionary-based positive affective responses to nature (Stress Reduction Theory; [29]), as well as cognitive recovery and resource replenishment after viewing natural settings (Attention Restoration Theory; [30]). These two theories mainly rely on aesthetic and visual qualities of the natural environments, and are related to presumed intrinsic characteristics of nature. In a separate theory, humans are posited to have an intrinsic affection toward unthreatening nature, a term that has been labelled 'biophilia', as opposed to 'biophobia' (i.e., the fear of nature) relating for instance to innate fight or flight responses that humans have toward snakes and spiders [31, 32]. As the focus of the present review is on mental health, the effects of green space on stress is of particular interest. Other potential pathways relate to greater aesthetic appreciation of and higher residential satisfaction with greener residential areas.

Instoration is also an umbrella pathway entailing a large variety of different pathways, such as increased social cohesion, improving immune function, or increasing physical activity. Improvements

in social interactions (at the individual level) [33] and social cohesion (at the neighbourhood level) [34, 35] is a third proposed pathway linking nature exposure with mental health. The design of green space, such as urban parks, can have an impact in terms of the relation between green space and social cohesion [36]. The link between social interaction and mental health has been firmly established [37] although the relationship between green space and social interactions or social cohesion has received less research attention than the first two pathways. In addition, an emerging field is looking at a microbial pathway relating health, but also mental health, with biodiversity [38, 39].

Physical activity (as opposed to sedentary behaviour) has demonstrated positive effects on mental health [40-42]. Experimental studies have pointed at added benefits of physical activity in green areas as opposed to indoor or urban areas [43-46]. Cross-sectional or epidemiological studies on the neighbourhood level show unclear results though [34, 47-52]. Besides green space availability, the characteristics of the urban green space may facilitate, or hinder, physical activity. A study in Denmark found that it was not necessarily the amount of green space in the proximity of participants' homes, but the presence of certain elements or characteristics such as walking routes, wooded areas, a water area, or a pleasant view that was conducive to physical activity [53].

These three domains of pathways present an umbrella theory that includes a wide variety of mechanisms for the beneficial effects of green space on health. The question remains whether all the pathways always occur and at the same time, and whether they are equally important for every individual and for all types of green spaces. A number of studies have already indicated that the mental health benefits of green space exposure may differ during different stages in life and between different population types. People that already experience mental health problems may benefit more from exposure to green space than those without mental health problems [54-56]. Another study points at different effects of green space on psychiatric morbidity over the life course, a pattern that also differed between males and females [57], whereas the effects of green space on mortality (including self-harm) was found to be stronger for people with a lower socio-economic status [58]. The effects of green spaces may thus not be the same for everyone. Furthermore, different population segments may also need or prefer different types of green spaces, with different characteristics for the same function. For example, facilitation of physical activity in a park may be accomplished differently for children (e.g., providing challenging natural areas to allow for climbing, or large grass fields to practice sports) than for elderly people or people with a physical disability (e.g., providing accessible paths).

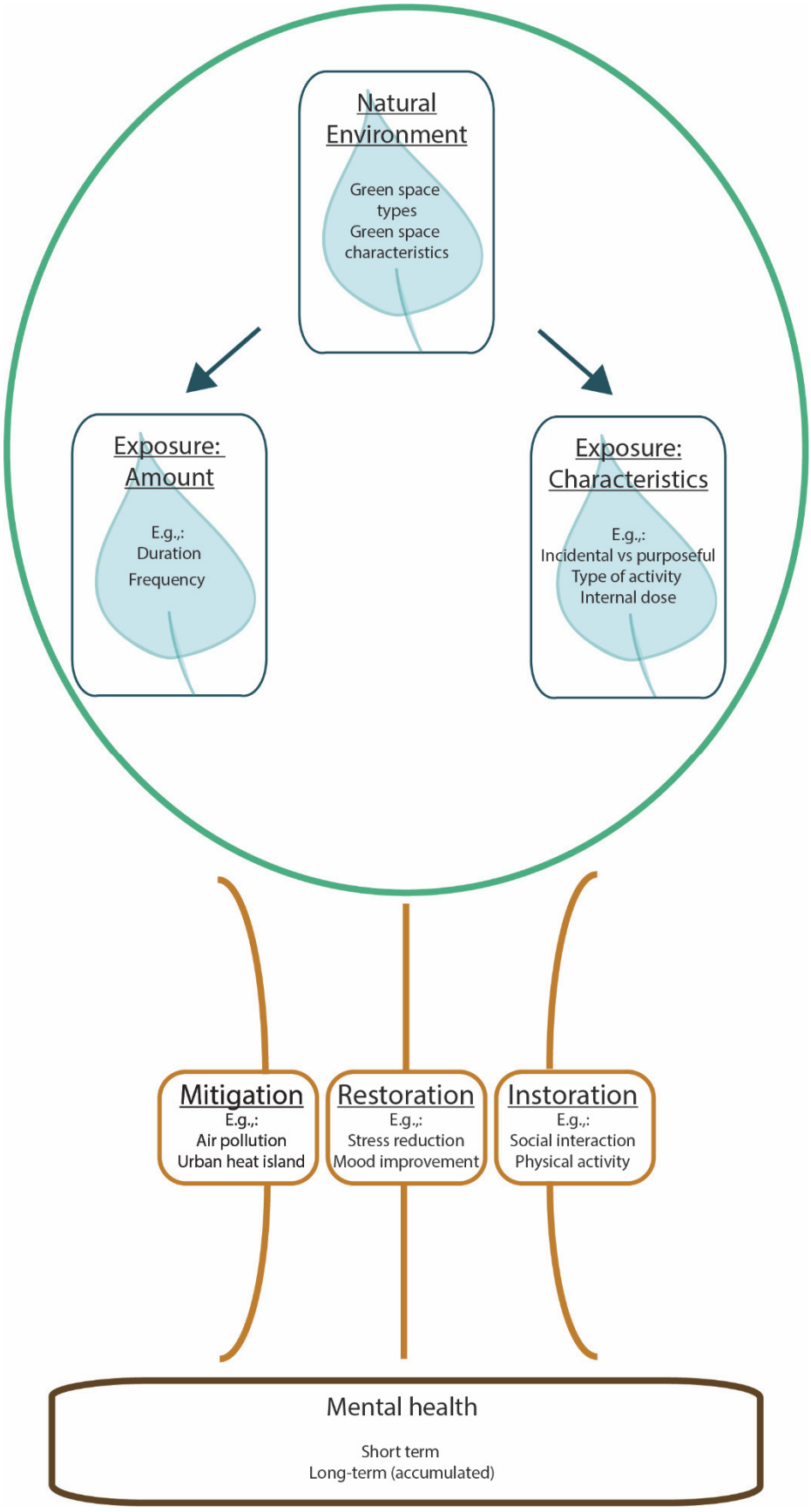

Figure 1. Proposed pathways for the mental health benefits of green space, integrating models proposed by Bratman at al. (2019) and Markevych et al. (2017) [16, 59].

In research published thus far, however, the focus is often on exposure to rather generic green space imagery or the amount of or proximity to green space rather than specific types or characteristics of green environments. This focus on either generic greenspace or amount or proximity measures does not allow for differentiation between the different functions (e.g., for physical exercise or stress reduction) or types of nature. According to a recently proposed international research agenda [8] on the health-benefits of nature contact, the research outcomes have not progressed significantly. The authors conclude that "standard exposure measures are not grounded in the ecological elements most relevant to human health and wellbeing" (p. 6). For example, the quantity of nature is often measured using aerial photography or remote sensing techniques. Such data offer little information on the quality of the landscape view from the ground level, do not account for how often residents interact with these natural environments, or do not focus on other attributes which may be important in terms of generating positive health outcomes. More knowledge on the importance of the type and characteristics of green space may help to unlock its potential to contribute to human health [8-10] and can thus inform planning and management decisions.

In order to generate this knowledge, there is an explicit need to identify measurable elements of nature and to identify the key characteristic of this natural element [8]. Similarly, a recent conceptual model aimed at translating outcomes of research on the restorative effects of nature on mental health benefits and implementing solutions for the provision of ecosystem services [59] also included natural features as a key component. Specifically, the authors refer to differences in biodiversity and differences in vegetation as important measures of an environment's natural features. The model also points at two important mediating factors for the effects of green space on health, which are the amount of exposure (actual time spent in nature, and accessibility and proximity as a proxy of exposure) as well as the characteristics of this exposure ('experience', the (sensory) qualities of natural areas, the way people interact with it, and the 'internal absorbed dose') which are related to the design and composition of natural landscapes. In other words, a distinction is made between "objective" exposure and how much effect this exposure has by moderating factors in, for instance, the experience, connectivity with – or attention to – nature.

A number of systematic reviews have already been conducted investigating the effects of green space on mental health (see, e.g., [60-68]). Some systematic reviews have had a specific focus on for instance study design (i.e., epidemiological research; [62]), specific geographical areas such as urban green spaces [69], a specific activity in green space such as exercising [65], or specific life stages such as childhood [60]) and adulthood [63]. However, all reviews have focused on effects of green space in general, not taking into account specific types or characteristics of green space.

There are a number of (systematic) reviews that have focused on a specific green space type (e.g., urban trees; [70]), though not all had focused on the direct effects of urban green space on mental health. One systematic review of reviews on the health benefits of urban green spaces indicates that there is a benefit of urban green space on perceived mental health [9], while another concludes that urban green space is important for both ecosystem and human health [71]. Other reviews reported beneficial associations between urban parks and physical activity, as well as the importance of certain characteristics of parks such as the presence of paths [72]. A second review found that parks can, amongst other results, improve mental health and social cohesion [73]. Urban green space can also mitigate the negative perception of noise in cities [74] and cool down the urban built environment [27].

Outcomes of systematic reviews thus generally point at beneficial relations between urban green space and mental health, but an overarching conclusion in many systematic reviews in this research domain is that the geographical diversity of settings and the heterogeneity of objectives, theoretical frameworks, covariate data, target population, and research methods in the reviewed studies made the comparison and establishment of robust results difficult [8, 13, 17, 62-64, 66, 75-77]. Part of the problem arises from the fact that green space benefits are the focal point in different scientific disciplines with different research traditions (e.g., landscape architecture, medicine, experimental psychology, clinical psychology) and with different research designs, including laboratory experiment, field studies, epidemiological studies, and qualitative explorations. Parallel with these different research designs are the different focal areas of green space exposure, viewing nature (e.g., in a laboratory setting), access and proximity to nature (e.g., using satellite data to calculate amount of green space around the residence coupled with national health surveys), and visiting natural spaces (e.g., pre-post visit measurements). Moreover, green space benefits have been reported within a very wide range of health outcomes, including not only mental but also physical health.

There is, consequently, both a practical and theoretical need to gain a better understanding of which types and characteristics of green space matter most for urban residents in terms of mental health and wellbeing. The objective of the present systematic review was to tackle this knowledge gap. This review aims to inform decision makers in several domains, such as health promotion, nature management, spatial policy, as well as urban planning and design.

2. Method

This systematic review is reported according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines [78]. The systematic review consisted of seven consecutive steps: protocol development, literature search, eligibility screening, meta-data extraction, critical appraisal, descriptive synthesis, and narrative synthesis. A protocol of the systematic review is available on the EKLIPSE website (http://www.eklipse-mechanism.eu/health_activities).

2.1 Literature search

2.1.1 Search strategy

The search strategy to retrieve evidence for the systematic review of the impact of green spaces on mental health conditions was developed in Ovid MEDLINE.

The search strategies were conducted to identify records that reported information on green spaces (variously described) and mental health (variously described). The search followed two approaches; the first used only subject headings for green spaces and mental health terms and the second used free text search terms in the title, abstracts and author keywords of the records. The free text terms combined terms for green spaces and mental health using adjacency operators to achieve a focused search strategy. The search was constructed as follows:

1. Strand 1: Subject Headings for green spaces AND general or specific mental health issues (lines 1 to 10)

2. Strand 2: Free text terms for green spaces in title/abstract/author keywords ADJ mental health terms (lines 11 to 34)

3. Strand 1 OR strand 2 (line 36)

In the MEDLINE strategy, animal studies were removed using a standard algorithm (line 37) and publication types were also excluded which were unlikely to yield relevant information, such as comments, editorial, news, letters and case reports (line 38). The searches were limited to English language to keep the workload and generated output manageable.

In the Scopus strategy animal studies were removed and studies from MEDLINE were removed to limit the search results to Scopus only.

The search strategy was developed using a test set of known relevant studies and its expected performance was tested by determining how many of the test set records were found by the search strategy. Despite the sensitive search it only captured 13/33 (40%) of the test set studies. In this light, a second strategy was then developed for Scopus alone (since the missed studies were not indexed in MEDLINE). This strategy found 12 additional test list studies, bringing the total retrieved by the searches to 76%. Full search strategies are provided in Appendix B (only available online version).

The resources searched were Scopus and Medline (Ovid), a subset of Scopus.

The titles and abstracts of bibliographic records were downloaded and imported into EndNote bibliographic management software and duplicate records were removed using several algorithms.

Eligibility

To perform this systematic review a set of eligibility criteria was developed to guide the process. Eligibility criteria for this review were framed as PICO which stands for Population (or Patient or Problem), Intervention, Comparison, and Outcome. Defining the PICO terms is an integral part of a Cochrane Review [78]. Another framework, PECO, replaces the I with E where the E stands for Exposure and allows for the inclusion of cross-sectional and longitudinal studies (without an intervention), which, even though such studies do not allow for unambiguous causal inferences, can be highly informative in this field of research.

Population

No restrictions were made in terms of the population other than that single-case or single-patient studies (n=1) were excluded. In other words, all population types (e.g., children, elderly, students, employees, general population, or clinical sample) were deemed eligible as long as the study included more than a single participant (single case, or single patient studies, were excluded).

Intervention

Eligible green space interventions were those that manipulated or changed the exposure to green space, either by targeting its green space characteristics or green space type. The amenities and facilities present in a green space were also of interest, as these may influence accessibility, affordances, and attractiveness, and, thereby, the exposure and type of contact. Studies investigating only the efficacy of therapeutic interventions in green environments were excluded from the systematic review. This is because the intervention is focused on human beings, unless these studies also included an intervention on the physical environment, such as the design of a therapy garden incorporating green space.

Exposure

Only studies investigating exposure to outdoor green space were deemed eligible (e.g., studies investigating effects of indoor plants were excluded). Exposure to, or experience with, nature can be divided into indirect, incidental, and intentional interactions with nature [79]. All types of nature experiences were included in the review, both intentional and incidental. For indirect interactions, viewing representations of nature, as well as viewing nature through a window were included. However, we distinguished between direct and indirect exposure to green spaces. Studies looking at rural exposure to green space were also included in the review, as not all studies provide clear information on where the study is conducted (i.e., in a rural or urban area) and they could also still be informative concerning the mental health benefits of these types of green space and their characteristics. Studies conducted in Europe qualify by definition. Studies conducted in other regions may still be relevant, depending on the region and theme of the study. Studies that are for instance, very specific for tropical locations/regions are less likely to be relevant for a European context.

Comparison

The focus of the systematic review is on planning and design strategies, operationalised in terms of types and /or characteristics of green space. Therefore, the comparison or reference environment was ideally another type of green space (though other comparisons with for instance the built environment or blue space would also be included), or the same type with other characteristics, e.g.,

a comparison between different plant species. Eligible studies could also be looking at the different spatial configuration of green spaces (controlling for the total amount). Studies comparing the amount of green between different areas were not eligible, unless they also included a comparison between types or characteristics of those spaces. Studies investigating a single environment, but with a pre-post measurement were also eligible. As we were interested in distinguishing between different types of green spaces, studies employing a compound measure of green space (e.g., treating grassland and forest as one category) were not included. To make sure that the types or characteristics of the green space were directly linked to the observed differences in mental health or wellbeing, other aspects had to remain as similar as possible.

Outcome

A wide range of mental health and wellbeing outcomes were included in the review, ranging from momentary mood to suicide rates. Included categories encompassed: general mental health (i.e., quality of life, satisfaction with life, subjective wellbeing); acute and direct effects on momentary mood, stress, and mental fatigue; retrospective reporting of momentary mood (i.e., recalled restoration); prevalence and severity of mental health problems; and specific correlates of mental health (e.g., loneliness, sleep, and pain). The World Health Organization ICD-10 mental health classification system [80] was adhered to: affective disorders, stress-related diseases; schizophrenia, psychosis, paranoia; personality disorders; disorders of psychological development; cognitive dysfunction; neurodegenerative disease; problem behaviour. Studies looking only at preference ratings, perceived restorativeness, expected restorative effects, physical health correlates of mental health (such as physical activity without looking directly at mental health outcomes) were excluded. Studies looking at psychological states directly linked with mental health (such as loneliness) were included in the review.

Qualitative studies were searched for using the same inclusion and exclusion criteria. These studies were included to identify in-depth insights into peoples' experiences of engaging with green spaces and the meanings people ascribed to these experiences.

Record selection

Obviously ineligible records were excluded by a single reviewer screening the records. The remaining potentially eligible records were then loaded into a systematic review management system (Covidence), where the titles and abstracts were screened in detail against the eligibility criteria. Each record was screened by two reviewers and any disagreements were discussed and solved. A conservative approach was taken, whereby any paper that was not obviously ineligible was retained. Subsequently, the records were screened at full text in Covidence. Two main reviewers each screened half of the records. The Expert Working Group members screened each record independently for the second time. In case of disagreement, the main reviewer that had not yet screened that record would look at the full text to resolve the conflict.

2.2 Meta-data extraction

An extensive set of descriptive data was extracted from each eligible paper. If a paper included two or more separate eligible studies with independent data, then each study resulted in a record in the meta-data database. Data were gathered across four different categories: general study information, methodology, green space, and mental health (Table 1). Responses were coded based on a coding

scheme that was developed beforehand by four of the authors of the report. A complete coding scheme can be found in Appendix C (only available online version).

Table 1. Overview of the information extracted during the meta-data phase (when available)

General	Methodology	Green space under study	Mental health and mental wellbeing
First author	Type of data (quantitative, qualitative)	Type or characteristic of green space	Typology of outcome measure
Year of publication	Study category (experimental, etc.)	Type of green space exposure (direct versus indirect)	Measurement instruments used *(quantitative studies)*
Paper title	Hypothesis testing versus exploratory study *(quantitative studies)*	Description of green space	Unit of observation (aggregate or individual) *(quantitative studies)*
Journal name	Study design	Environmental assessment (e.g., residential area)	Covariates and confounding variables *(quantitative studies)*
Country in which the study took place in	Type of within participants design *(within / mixed studies)*	Activities performed in the green space	Results
Location in which the study took place	Presence of a control group		
Season in which the study took place in	Data collection method		
	Health of population (general, clinical, at-risk)		
	Population type		
	Sample size (number of participants)		
	Sample age (mean and standard deviation)		
	Sample age (range)		
	Sample percentage female		
	Inclusion and exclusion criteria for participation		

General	Methodology	Green space under study	Mental health and mental wellbeing
	Study duration		
	Study Frequency		
	Duration and frequency visit report		

2.3 Critical Appraisal

During the critical appraisal phase, the risk of bias due to systematic error for each study was assessed for each of the three types of study separately. The criteria were developed specifically for this systematic review, but based on existing critical appraisal tools, namely the Cochrane Collaboration Tool [78] and the Quality in Prognostic Studies tool [81]. One custom item was added for the quantitative categories, assessing risk of bias related to the green space manipulation. Criteria for the critical appraisal of experimental, cross-sectional and longitudinal studies, and qualitative studies are detailed below.

A three-level scoring ('high', 'moderate' and 'low' confidence of no bias) was used, with a fourth 'not applicable' category. For each scoring option, the criteria were defined at the onset of the critical appraisal process. Each paper was assessed independently by two or three members of the expert working group. An overall classification of the papers was based on their overall scores during the critical appraisal phase; low quality, moderate quality, and good quality (in a relative sense, i.e., by no means perfect). Studies that had a 'low' score (i.e., a 'low' score in the critical appraisal) for more than half of the critical appraisal items were labelled 'low' quality. Thus, low quality studies are those with more than six, four, or three 'low' scores in, respectively, the experimental, cross-sectional and longitudinal, and qualitative category. Studies with good quality scored 'high' for more than half of the categories. For the experimental studies, this operationalized as a 'high' score on 6 or more items. For the cross-sectional and longitudinal studies four of the seven criteria had to score 'high' (or a 'not applicable' score on the items sample description and random selection as these could also be considered a high score). For the qualitative studies, studies were labelled as being of good quality when they scored a 'high' score on three or more items. All other studies were labelled as being of moderate quality.

Experimental studies

Risk of bias in the experimental studies was assessed on the basis of seven different categories (see Appendix D, Table D1 - only available online version): selection, performance, attrition, detection, manipulation, reporting, and covariates. These categories investigated potential bias during every stage of the study procedure, starting with the selection of the participants and how they related to the true population (selection bias). Performance bias was targeted in the allocation of participants to experimental conditions and the blinding of participants for the manipulations. Attrition was included as dropouts during the experiment, which may cause bias in the outcomes. Detection bias investigated whether there was direct contact between the researcher and the participants. Unique to the type of studies assessed in this systematic review are the environmental manipulations related to the green space type or characteristics. A separate category therefore assessed whether any

potential bias could have been introduced to the studies by the choice and execution of green space manipulations. Specifically, the duration and frequency of green space exposure were taken as a measure of potential bias as longer and more frequent exposure may provide better or more consistent results. The two last categories tested for bias in the analysis phase of the study; specifically looking at whether the authors of the study reported all outcomes (including non-significant outcomes) and had identified and accounted for covariates in the analysis.

Cross-sectional and longitudinal studies

Six categories (selection bias, attrition bias, detection bias, manipulation, reporting bias, covariates) were employed to assess the risk of bias for the cross-sectional and longitudinal studies (Appendix E, Table E2 - only available online version). These categories were very similar to those used for the experimental studies, except that no assessment was made of the performance bias as it is irrelevant for cross-sectional and longitudinal studies which typically do not contain experimental manipulations.

Qualitative studies

The bias assessment of the qualitative studies varied from the two quantitative categories, due to the difference in study characteristics and objectives. Five items were considered in two categories (selection bias and qualitative methods) (Appendix F, Table F3 - only available online version). The assessment focused on clarity in the description of the sampling used and recruitment of participants. In addition, the qualitative method was assessed on whether: independent raters and coders were used in the analysis; stakeholders were involved during the analysis; triangulation of methods was implemented.

2.4 Synthesis

After completion of the critical appraisal, a descriptive synthesis was performed followed by a narrative synthesis. Studies with a low quality were not included in the synthesis. The narrative synthesis consisted of four consecutive steps: revisiting the theory of change, performing a preliminary synthesis (for both the descriptive and narrative synthesis), exploring relationships within and between studies in the narrative synthesis, and assessing the robustness of the synthesis [82].

The theory of change, or the conceptual framework, summarized the expected underlying mechanisms of the benefits of green space on mental health. Its purpose was to guide the selection of studies, the categorization of studies, as well as performing the synthesis. The theory of change has already been described in the theoretical background of this report (section 1.4).

During the preliminary synthesis, study outcomes were grouped and tabulated per study type (experimental, cross-sectional and longitudinal, qualitative) and green space type or green space characteristic, divided into ten categories. Seven categories were used to divide the papers according to green space types and included: Urban Green Space; Park; Garden; Forest and Woodland; Grassland and Meadows; Trees and other plants; Other Green Space Types (miscellaneous category). Two categories included papers looking into green space characteristics: Biodiversity; Other Green Space Characteristic (miscellaneous category), (See Table 2 for an overview of the study categories). One study could represent several categories (e.g., forest and grassland) and could therefore be included in more than one category. As the main purpose of the review was to look at differential effects between green space types and characteristics, all studies comparing different green space

types or characteristics were gathered for each category and treated separately. A descriptive and narrative synthesis was performed for each category.

Grouping and tabulations were also made per health outcome measure, divided into fourteen categories: mental health, subjective wellbeing, affect, vitality, restorative outcomes, severity mental disorder, prevalence mental disorder, perceived stress, physiological stress, satisfaction with life, quality of life, problem behaviour, brain activity, and miscellaneous. See Table 3 for more information of the health outcome categories.

Table 2. Green space categories used for the descriptive and narrative synthesis

Green space category	Description	Examples
Urban green space	Urban land covered by vegetation, which does not fall (solely) in one of the other categories such as parks or gardens	Street trees, green vegetation coverage in the city, informal green spaces
Park	An area of vegetation used for recreation	Urban park, district park, neighbourhood park
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
Forest and woodland	An area mainly covered with trees and undergrowth cover	Deciduous, coniferous, mixed forest
Grassland and meadows	An area mainly covered with grass	Mowed lawn, improved grassland (used for grazing), semi-natural grassland
Trees and other plants	Studies with a specific focus on plants, shrubs, or vegetation cover	Tree canopy cover, vegetation cover shrubs
Biodiversity	Studies focusing on the diversity in plants and animals	Flora richness, fauna richness

For each study, the population type was also noted. A distinction was made between 18 different population types:

Local residents (people living in the proximity of the target green space)
National residents (respondents were part of a national survey or national panel)
Urban residents (a study targeting specifically those living in the city)
Rural residents (a study targeting specifically those living in rural areas)
Green space visitors
Patients with a mental disorder
Patients with a physical disorder
Employees
Students
Schoolchildren
Pupils
Adolescents
Elderly
Hikers / Athletes
Online panel members (without being nationally representative)
Conservation volunteers
University visitors
Volunteers (people who volunteered to participate in the study)
Young mothers

For the experimental category, a distinction was made between studies with direct exposure versus those with indirect representations of green space (e.g., videos and Virtual Reality) within the experimental study category. No indirect exposure was present in the cross-sectional and longitudinal studies and qualitative studies.

After these overviews were created, results were further analysed by looking at differences in possible mediators, such as type of activity, the study design, the sample, as well as the risk of bias (outcomes from the critical appraisal), to understand the observed heterogeneity in outcomes. Conceptual maps were created to reveal patterns in the outcomes and to further explain heterogeneity. Triangulation was also assessed, both in terms of methodology used and background of the researchers.

The fourth, and final, step in the synthesis was to investigate the strengths and weaknesses of the systematic review process and, subsequently, the robustness of the outcomes. This was done by critically reflecting upon the synthesis phase, and by looking at the generalisability – or relevance – of the synthesis product to the general population. The outcomes of this assessment are reported in the discussion.

Table 3. Mental health categories used for the descriptive and narrative synthesis

Mental health category	Description	Example measurement
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 [82]
Severity mental disorder	Severity of a specific mental disorder, expressed in level of symptoms or use of medication	CES-D (depression) [89]
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 [91]
Quality of life	Quality of life is the general wellbeing of an individual and can encompass multiple factors such as mental health, physical health, social health	World Health Organization Quality-of-Life Assessment short version [92]
Subjective wellbeing	Subjective ratings of wellbeing, encompassing different aspects of wellbeing such as happiness, life satisfaction, and psychological functioning	Warwick-Edinburgh Mental Wellbeing Scale [84]
Affect	Momentary measurements of mood and affective state, including for instance positive and negative affect but also state anxiety	Positive And Negative Affect Schedule [86]
Vitality	Positive energy available to the self	Vitality subscale of the Short Form-36 [87]
Restorative outcomes	Measures focused on the restorative effects of nature, including psychological benefits such as relaxation and forgetting worries. Does not included perceived restorativeness	Restorative Outcomes Scale [88]
Perceived stress	The amount of stress a person perceives they are under either right now or over a period of time	Perceived Stress Scale [90]
Physiological stress	Physiological responses to stress, or activity of the autonomic nervous system	Heart Rate Variability
Problem behaviour	Disruptive behaviour such as hyperactivity or agitation.	Strengths and Difficulties Questionnaire [93]
Brain activity	Brain activity measured with (mobile) EEG or fMRI	(mobile) EEG
Miscellaneous	Sleep quality, self-image, social contacts, and suicide rate	E.g., National suicide rate data

3. Outcomes

3.1 Search outcomes

The MEDLINE and Scopus searches were undertaken on 28 June 2019, and they identified 14,305 records (Table 4). The second search of Scopus was undertaken on 23 August 2019 and retrieved 4,033 records. Seven test-list records that were not identified by the searches were added to the Endnote library: these records were loaded to Covidence. Two records were identified from the blue space review, both also included green space. Following deduplication, 16,581 records were assessed for relevance.

Table 4. Literature search results

Resource	Number of records identified
Ovid MEDLINE ALL	8481
Scopus search 1	5824
Scopus search 2	4033
Test set records (not retrieved by the searches)	8
Records identified from other sources	2
Total number of records retrieved	18,348
Total number of records after deduplication	**16,581**

After deduplication, 15,247 records were rejected based on an assessment of the title and abstract.

The search was challenging because of the multiple meanings of some of the search terms so the result set had records about a great variety of topics, many of which were clearly not relevant to the review topic. Many records were not really about green spaces or were not about human health.

1,334 records were loaded to Covidence for title and abstract screening. 655 records were rejected on the basis of information in the title and abstract. Two hand-selected articles (from the blue space systematic review) were also included in the set. The remaining 679 records were assessed based on the full text of which 526 records were excluded, leaving a total of 134 papers. Fifty-five of these studies had a cross-sectional or longitudinal design, 67 papers (68 studies) had an experimental design, and 12 qualitative studies were included (see Figure 2). The included studies are summarized in Tables 5, 6, and 7. Please consult the list of abbreviations for the acronyms used in the table (especially with regards to physiological outcomes).

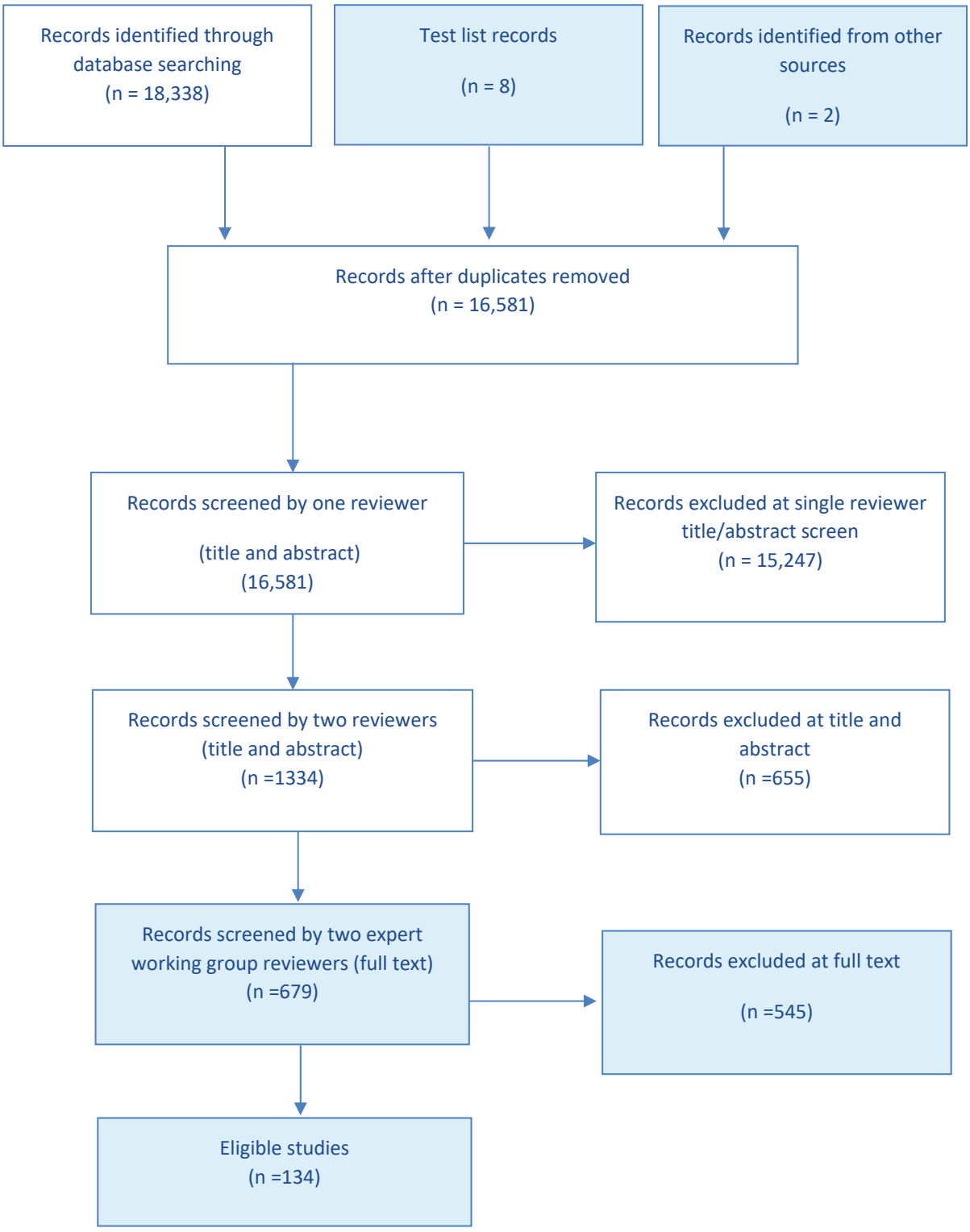

Figure 2. PRISMA Flowchart of study inclusion

Table 5. Overview of the included studies arranged by green space category; experimental studies

Article	Country	Green space category / char.	Green space description	Type Char	Participants	General / Clinical	Health outcome	Results
Sianoja 2018 [90]	Finland	Urban green space	Urban green space close to participants' work versus relaxation exercises (control group)	Type	Employees	General	Psychological stress	Strain was significantly lower in the afternoon on days when participants did their lunchtime walks in urban green space (and also for those doing the relaxation exercises). Fatigue was unaffected by the walk (but lower in the afternoon when relaxation exercises were done).
Neale 2017 [91]	UK	Urban green space	Three walking routes: urban green, urban busy, urban quiet (all participants walked 2 of 3 routes)	Type	Elderly	General	Affect	Excitement was lower in urban green than in urban busy, and frustration was higher in urban green than in urban quiet. Engagement was higher in urban green than in the other two urban areas.
Aspinall 2015 [92]	UK	Urban green space	Green space (bordering lawns, playing fields with trees), vs busy shopping street and busy commercial district	Type	Students	General	Brain activity	(no significance testing) Frustration, engagement or alertness, and long term excitement were lower and meditation higher in green space than in shopping street.
Coventry 2019 [93]	UK	Urban green space	1) mosaic of fenland, meadow and woodland; 2) community green space, a mix of grassland and wood-land; 3) large green field with surrounding woodland adjacent to a semi-urban housing development	Type	conservation volunteers	General	Perceived stress, affect	Decrease in stress over all locations (pre-post). No difference between the 3 locations. Magnitude of effect may be largest in community green space. An increase in hedonic tone and a decrease in arousal was found over all locations (pre-post). No difference between the 3 locations.

Article	Country	Green space category / char.	Green space description	Type Char	Participants	General / Clinical	Health outcome	Results
Yoshida 2015 [94]	Japan	Urban green space	Different locations on campus differing in greenness, ground cover, tree canopy. Open space vs tree canopy, in relation with temperature	Type & Char	Students	General	Affect	Anxiety-hostility, fatigue, and total mood disturbance scores were better under the tree canopy than in the sunny open space (no effect on the other subdimensions).
Carrus 2015 [95]	Italy	Urban green space, park, forest, biodiversity	Low vs high biodiversity in urban vs peri-urban green space (low, urban: urban square with trees; urban, high: urban park; peri-urban, low: pinewood forest plantation; peri-urban, high: protected reserve)	Type & Char	Green space visitors	General	Subjective wellbeing	Better scores for peri-urban green areas than for urban areas on wellbeing and higher scores for high biodiversity green areas than for low biodiversity green areas. Reading, talking, and socializing in the green setting scored significantly lower than contemplating the setting and walking, exercising, No difference in wellbeing score between contemplating and walking. Greater wellbeing scores with longer visits
Chang 2019 [96]	USA	Park, other green space type	Park vs wilderness type setting vs fitness and recreation facility	Type	Green space visitors	General	Physiological stress, perceived stress	Salivary cortisol decreased significantly after the wilderness setting. Decrease in demands and worries and increase in joy at all three sites. Stronger increase in joy at the wilderness setting.
Orsega-Smith 2004 [97]	USA	Park	Frequency and duration of park use and level of physical activity	Type	Elderly	General	Perceived stress, physiological stress, mental health	People with high stress levels stayed in the park longer than those with low stress levels. Visitors that stayed in the park longer than one hour had lower blood pressure after the visit. No relation between stress levels and visit frequency. No effect was found on mental health.

Article	Country	Green space category / char.	Green space description	Type Char	Participants	General / Clinical	Health outcome	Results
Hull 1995 [98]	USA	Park	Time spent in the park	Type	Green space visitors	General	Affect	A longer stay in the park resulted in lower anxiety. Effects were more pronounced for high-stress individuals. Tiredness also increased with longer time in the park, no difference found for high vs low stress individuals here. No effect of park visit on calm and energy.
Li 2019 [99]	China	Park	15 different parks; time spent on hard surface, lawn, under tree cover, in water, on the trail, in children's play areas, fitness area, total steps	Type	Elderly	General	Affect	Lower anxiety, depression, higher relaxation and contentment after the park visit. Active park lingerers had higher relaxation and more contentment than active walkers. No difference anxiety and depression, nor with a third group of elderly; passive scanner.
Grazulevicie ne 2016 [100]	Lithuania	Park	Pine park versus busy urban street	Type	Patients physical disorder	Clinical	Affect, physiological stress	Cortisol decreased after the walk in the park on day 1, but not for the urban area. After 7 days, blood pressure was lower for the park but not the urban group. Positive affect increased and negative affect decreased after the walk in the park on day 1, but not for the urban area. For urban walks negative affect increased.
Gidlow 2016 [101]	UK	Park	Park vs footpath along a canal vs urban residential street	Type	Local residents	General	Affect, perceived stress, restorative effect	Mood improved in all three environments, restorative effect was higher in the urban park (and along the canal) than in the urban environment. Cortisol levels decreased in all three environments.

Article	Country	Green space category / char.	Green space description	Type Char	Participants	General / Clinical	Health outcome	Results
Mokhtar 2018 [102]	Malaysia	Park	Urban park versus city area	Type	Students	General	Affect, physiological stress, restorative effect	Cortisol levels were lower in the urban park than in the urban area. Cortisol increased over time in the urban, but not in the urban green area. Systolic blood pressure and pulse rate were lower in the urban green space after the experiment, and were lower at the end of the afternoon than in the urban area. No effect found on diastolic blood pressure. All six subscales of the POMS were better for the urban park after the experiment than for the urban area. Tension and confusion decreased in the urban park, whereas tension, depression, anger, fatigue, and confusion increased in the urban area. Higher restorative outcomes for the urban park than for the urban area.
Wang 2016* [103]	China	Park	Videos of urban parks differing in openness, vs urban road	Type & Char	Students	General	Affect, physiological stress	Anxiety decreased while viewing all urban parks compared to the urban roadway. Skin conductance reduced when viewing lawn (with and without people), a small lake and a walkway. Heart rate was lower after viewing a small lake and the walkway. No effects on skin conductance were found for plaza and urban roadway, no effect found on HR for lawn, plaza, and urban roadway.
Yuen 2019 [104]	USA	Park	Three different parks	Type	Green space visitors	General	Affect, satisfaction with life	Affect increased after the park visit, satisfaction with life also increased after the park visit. Time spent in the park was related with satisfaction outcomes (10,5 min visit predicted the highest improvement)

** Indirect green space manipulation (i.e., using a representation of nature rather than real exposure, such as a video, image or Virtual Reality)*

Article	Country	Green space category/ char.	Green space description	Type Char	Participants	General / Clinical	Health outcome	Results
Guéguen 2016 [105]	France	Park	Historic park	Type	Green space visitors	General	Affect	Affect was significantly better for those that were asked after their park visit (as opposed to those that reported their affect before the park visit)
Wallner 2018 [106]	Austria	Park, forest	Lunch breaks in busy, small urban park with few trees vs larger park with tree clumps, larger broadleaved forest with meadows	Type & Char	Adolescents, pupils	General	Subjective wellbeing	The decline in wellbeing (readiness for action, readiness for exertion, state of mood, tension / relaxation) after return in the classroom was larger after visiting the two parks than after visiting the forest. No difference was found between the two parks.
McAllister 2017* [107]	Australia	Park, forest	video of wild forest vs urban park vs urban environment	Type	Local residents, members online panel, sports club members	General	Affect	Positive affect was the same for the video of the urban park and the urban environment, but higher for the wild forest. Negative affect for the urban park video was the same as for the wild forest, and both scored lower on negative affect than the urban environment.
Zhang 2019 [108]	China	Park, other green space characteristic	Two parks: greenness, sound level, sky visibility	Type & Char	Students	General	Affect	No effect of greenness or sky visibility in either park on affect. LAeq, loudness, and roughness were negatively correlated with affect in one park, no effects in the other park. Acoustic and visual comfort positively affected cheerfulness, relaxation, and energy
Benfield 2018* [109]	USA	Park, other green space characteristic	Light pollution in three different parks	Type & Char	Students	General	Affect	Arcadia park scored lower than the other two parks. Lower light pollution was associated with better scores on overall mood and arousal

** Indirect green space manipulation (i.e., using a representation of nature rather than real exposure, such as a video, image or Virtual Reality)*

Article	Country	Green space category / char.	Green space description	Type Char	Participants	General / Clinical	Health outcome	Results
Song 2013 [110]	Japan	Park	Urban park versus city area	Type	Students, males	General	Affect, physiological stress	Better scores after the park walk (than city walk) for comfortable, natural, and relaxed, anxiety, total mood disturbance, tension-anxiety, vigour. HR, ln(HF). No effect on was found on fatigue, anger-hostility, confusion, depression, or HF/LF ratio.
Song 2014 [111]	Japan	Park	Urban park versus city area	Type	Students, males	General	Affect, physiological stress	Better scores after the park walk (than city walk) for comfortable, natural, relaxed, anxiety, tension-anxiety, fatigue, vigour, HR, ln(HF), LF/HF ratio. No effect on depression, anger-hostility and confusion.
Song 2015 [112]	Japan	Park	Urban park versus city area	Type	Students	General	Affect, physiological stress	Better scores after the park walk (than city walk) for comfortable, natural, relaxed, anxiety, tension-anxiety, fatigue, confusion, anger-hostility, vigour, HR, ln(HF), LF/HF ratio. No effect on depression.
Song 2019 [113]	Japan	Park	Urban park versus city area	Type	Visitors green space	General	Affect, physiological stress	Better scores after the park walk (than city walk) for comfortable, natural, relaxed, anxiety, tension-anxiety, fatigue, confusion, anger-hostility, vigour.
Tyrväinen 2014 [114]	Finland	Park, forest	Urban park and urban woodland, versus built-up area	Type	Employees	General	Affect, vitality, physiological stress, restorative effect	Higher positive affect, vitality, restorative outcomes, and lower negative affect in urban park and woodland than in built-up area. No difference urban park and forest on positive affect. Fewer negative emotions in forest as compared to park. No effects found on cortisol levels

Article	Country	Green space category / char.	Green space description	Type Char	Participants	General / Clinical	Health outcome	Results
Ojala 2019 [115]	Finland	Park, forest	Urban park and urban woodland, versus built-up area	Type	Employees	General	Vitality, physiological stress, restorative effect	Both forest and park scored higher on restorative outcomes and vitality than the city. No effect found on blood pressure.
Lanki 2017 [116]	Finland	Park, forest	Urban forest vs urban park vs built-up city centre	Type	Employees	General	Physiological stress	Heart rate was lower in forest and park versus city, in an uncontrolled model and when controlled for either air pollution or noise. Compared to the city, SDNN was higher in the forest, but not in the park, higher HF in forest and park versus the city during the walking period. In the viewing only period: lower systolic blood pressure for forest, not park (and not for forest when controlling for air pollution). Lower heart rate for forest and park (not for park when controlling for air pollution) versus city. SDNN lower for forest (only main model). RMSSD lower for park and forest (not when controlling for air pollution). HF higher for park and forest compared to the city. No effects found on RMSSD or blood pressure.
Ewert 2018 [117]	USA	Park, forest	wilderness type forest, park, and built environment	Type	Green space visitors	General	Perceived stress, physiological stress	Demands and worries decreased after visiting all three sites. Joy increased after the park and forest visit (not after urban visit), with higher joy after visiting the forest than the park or urban area. Cortisol levels decreased after visiting the forest, but not the park or urban area. A-amylase increased after visiting the urban area, no effect found for the park or forest. No effect found of environment on demand, worries, tension.

Article	Country	Green space category / char.	Green space description	Type Char	Participants	General / Clinical	Health outcome	Results
Detweiler 2009 [118]	USA	Garden	Wander garden in a closed dementia facility	Type	elderly, dementia patients	Clinical	Severity mental disorder	Secondary anti-depressants dosages and antipsychotic drug prescriptions decreased after implementing the wander garden. Both medications were only prescribed to low users of the garden. Primary dosage levels of anti-depressants increased after implementation. No effects on anxiolytics or hypnotic drugs.
Detweiler 2008 [119]	USA	Garden	Wander garden in a closed dementia facility	Type	elderly, dementia patients	Clinical	Problem behaviour	Lower scores on agitation after implementing the garden and with longer stays in the garden. Most patients required less medication. Increase in level 4 incidents (causing physical harm) after implementation of the garden.
Cordoza 2018 [120]	USA	Garden	Hospital garden	Type	Employees, nurses	General	Affect, severity mental disorder	Positive effect of taking breaks in the garden on emotional exhaustion and depersonalization, not on personal accomplishment. Positive effects on anger, tiredness, and total score but only when taking scores above 10 % from zero.
Zhang 2018 [121]	China	Garden	Unstructured versus Japanese garden	Char	Students	General	Physiological stress	HR increased and GSR mean and SD higher and BVA lower in unstructured than in the Japanese garden. No effect on HRV.
Lee 2017* [122]	Korea	Garden	Pictures of a garden versus urban (distant, medium, near distance)	Type	Adolescents	General	Affect, physiological stress, brain activity	Pictures of the garden scored lower on anxiety and in the negative mood states than the urban pictures, and higher on the semantic differential scale. No effect on blood pressure or pulse rate, nor on vigour. Activity in the left and right prefrontal cortices decreased for the garden pictures, and increased for the city.

** Indirect green space manipulation (i.e., using a representation of nature rather than real exposure, such as a video, image or Virtual Reality)*

Article	Country	Green space category / char.	Green space description	Type Char	Participants	General / Clinical	Health outcome	Results
Korn 2018 [123]	Peru	Garden	Constructing a garden vs not	Type	Local residents	General	Perceived stress, physiological stress, quality of life, problem behaviour	Having constructed a garden resulted in lower stress scores, more parent empathy after 6 and 12 months, and higher quality of life after 12 months. No effect on partner empathy or blood pressure.
Goto 2018 [124]	Japan	Garden	Japanese garden on rooftop / terrace of healthcare facility	Type	Elderly, dementia patients	Clinical	Physiological stress, problem behaviour	After installing the Japanese garden, pulse rates and heart rate were significantly lower and more positive comments about behaviour were made. (note: in separate analysis, only the terrace had a significant effect)
Elsadek 2019 [125]	Canada	Garden	Landscape (botanical) garden vs Japanese garden vs architectural (rose) garden	Type and char	Students	General	Affect, physiological stress	Feeling of garden atmosphere (relaxing, comfortable): Japanese better than landscape, and Japanese and landscape better than architectural. Feeling of garden design (cheerful, colourful): Japanese better than architectural and Japanese and architectural better than landscape. No difference of garden styles on HRV.
Lee 2009 [126]	Japan	Forest	forest versus urban environment	Type	Students	General	Affect, physiological stress	Refreshment and comfortability better after viewing forest than after viewing urban, also in the evening. Soothing scores better after viewing forest than after urban. Lower diastolic pressure, pulse rate after viewing forest than after viewing urban environment. Cortisol level lower before and after viewing forest than urban. No effect on systolic blood pressure and no effect of environment on physiology in the evening.

Article	Country	Green space category / char.	Green space description	Type Char	Participants	General / Clinical	Health outcome	Results
Joung 2015 [127]	Korea	Forest	Forest vs urban, viewed from roof top	Type	Students	General	Affect, brain activity	Comfortable, natural and soothed were significantly higher in forest than in urban. Anger & hostility, fatigue, and total mood disturbances were lower and vigour was higher in forest than in urban. No differences between tension & anxiety, depression, and confusion. Change in Hb and oxy-Hb was lower in forest than in urban condition, indicating greater stability in the prefrontal cortices.
Takayama 2014 [128]	Japan	Forest	Four different forests (two artificial with Japanese cedar, other two deciduous bread-leaved such as oak) urban areas (downtown major traffic areas), viewing and walking	Type & Char	Students	General	Affect, vitality, restorative effect	Significant interaction of environment and activity for tension and anxiety, vigour, fatigue, confusion, vitality, and restorative outcomes. Greater benefits forest (vs urban) when walking (vs viewing) on vitality and restorative outcomes. Combined effect of viewing and walking: tension and anxiety, fatigue, confusion, vigour, vitality, positive affect, negative effect, restorative outcomes were better after the forest than the urban environment. No interaction effect was found for the PANAS. No combined effect on POMS anger and hostility, depression.
Morita 2007 [129]	Japan	Forest	Forest bathing compared to a control day	Type	Volunteers	General	Affect	Interaction of environment and time: forest scores significantly improved over time compared to the control day on hostility, depression, liveliness, and anxiety, but also boredom increased. More beneficial effects were found for higher stressed individuals.

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Article	Country	Green space category / char.	Green space description	Type Char	Participants	General / Clinical	Health outcome	Results
Moyle 2018* [130]	Australia	Forest	Virtual reality of forest	Type	Elderly, dementia patients	Clinical	Affect	The scores were compared to norm scores. Patients expressed more pleasure and alertness during the forest VR, but some also showed more anxiety. No effect was found on anger or sadness.
Lee 2011 [131]	Japan	Forest	forest (broad-leaved deciduous trees) versus urban commercial area	Type	Students	General	Affect, physiological stress	Better scores for comfortable, soothed, refreshed, tension-anxiety, vigour, fatigue, and confusion, and total mood disturbance in forest compared to urban. Before and after comparison showed better scores for comfortable, soothed, refreshed, vigour, tension, fatigue and confusion after forest compared to before (tension-anxiety and anger-hostility increased after urban walk). Better HRV and LF/HF ratio for forest in the beginning of the viewing period. No effect of environment on cortisol levels or blood pressure.
Tsunetsugu 2013 [132]	Japan	Forest	Conifer and deciduous trees forest vs urban	Type	Students	General	Affect, physiological stress	The forest was more comfortable, soothing, natural and more refreshing than the urban environment. Over time, only negative effects of urban were found on mood outcomes. Diastolic blood pressure was lower and HRV higher, LF/HF ratio was lower, and pulse rate was lower in forest than in urban. No effect on systolic blood pressure.
Martens 2011 [133]	Switzerland	Forest	Wild versus tended forest	Type & Char	Students, employees, elderly	General	Affect	A stronger increase in positive affect and a stronger decrease in negative affect was found for the tended versus the wild forest, there was no difference between arousal and activation.

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Article	Country	Green space category / char.	Green space description	Type Char	Participants	General / Clinical	Health outcome	Results
Takayama 2017 [134]	Japan	Forest	Thinned versus unthinned forest	Type & Char	Students, employees	General	Affect, restorative effect	In both thinned and unthinned forest, a reduction was found in tension-anxiety, depression, confusion. In the unthinned condition, fatigue also reduced. In the thinned condition, anger-hostility reduced. Restorative outcomes were better in the unthinned forest. No difference was found for positive and negative affect.
Tsutsumi 2017* [135]	Japan	Forest	Video of forest (preferred or not) vs sea, with sounds	Type	Students	General	Affect, physiological stress	Those that preferred a sea video reported a decrease in vigour and confusion after viewing the forest video. No effect on blood pressure, Behavioural Inhibition System higher for sea than for forest.
Yu 2018* [136]	Taiwan	Forest	Virtual reality of forest vs shopping street	Type	Volunteers	General	Affect, physiological stress	The forest environment significantly decreased the negative mood components (confusion, fatigue, anger-hostility, tension, and depression), and increased vigour. No effect of environment on heart rate, a-amylase, or blood pressure
Song 2015 [137]	Japan	Forest	Forest with many Japanese cypress trees, versus urban area	Type	Patients with a physical disorder	Clinical, at-risk	Affect, physiological stress	Comfortable, natural, and relaxed scored better in park than in city. Better scores after park - than city- walk for tension-anxiety, fatigue, anger-hostility, confusion, vigour, and depression. HR lower and ln(HF) higher during park than city walk, no effect on LF/HF ratio.
Song 2018 [138]	Japan	Forest	52 different Japanese forests vs city areas	Type	Students	General	Affect	Scores for tension-anxiety, fatigue, anger-hostility, confusion, vigour, and depression were better after the forest walk than after the city walk. Participants with higher anxiety levels showed greater decreases in depression.

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Article	Country	Green space category / char.	Green space description	Type Char	Participants	General / Clinical	Health outcome	Results
Stigsdotter 2017 [139]	Denmark	Forest	Health forest versus urban downtown area	Type	Students	General	Affect, physiological stress	After the forest walk a decrease in fatigue and total mood disturbances were found compared to before the walk. Before walking in the environment (but while already being there), tension-aggression, depression-dejection, ager-hostility, and confusion-bewilderments scored better in the forest than in the urban environment. No difference in blood pressure and HRV was found after the walk in the forest as compared to the city area.
Sonntag-Ostrom 2014 [140]	Sweden	Forest, other green space type	Forest by the lake, rock outcrop, spruce forest (vs city)	Type	Patients mental disorder	Clinical	Affect, physiological stress	Higher scores were found on all natural environment (vs city) for: relaxed, happy, harmonious, peaceful, clearheaded). Participants reported feeling more relaxed, harmonious, and peaceful in the forest by the lake than in the rock outcrop. No effect found on energy. Heart rate was significantly lower in all natural environments (vs city). Heart rate was lower in the forest by the lake than in the rock outcrop and spruce forest. Blood pressure lower in forest by the lake and spruce forest (vs city). No difference blood pressure or heart rate recovery.
Jo 2019* [141]	Japan	Forest	Forest sounds vs urban sounds	Type	Students	General	Affect, physiological stress	Forest sounds scored higher on comfortability, relaxation, and naturalness. Forest sounds scored lower on tension - anxiety, depression, anger-hostility, fatigue, confusion, and total mood disturbance, and higher on vigour than urban sounds. Mean Oxy-Hb concentrations in left and right prefrontal cortex was lower for forest sounds than for urban sounds. HRV was better and HR lower during forest sounds vs urban sounds.

** Indirect green space manipulation (i.e., using a representation of nature rather than real exposure, such as a video, image or Virtual Reality)*

Article	Country	Green space category / char.	Green space description	Type Char	Participants	General / Clinical	Health outcome	Results
Chiang 2017* [142]	Taiwan	Forest, Trees and other plants	Location in the forest: interior vs edge vs exterior. High vs low density vegetation	Type and char	Students	General	Affect, brain activity	Interior images resulted in a more positive mood, less negative mood, and less mood disturbances than edge and exterior. Higher EEG-Alpha activity was found for the interior images compared to the edge images (signalling more relaxation in the edge group). High and medium density vegetation resulted in a significantly better positive mood than low-density vegetation. No effect of vegetation level on negative mood and total mood disturbance, nor on EEG-alpha activity.
Toda 2013 [143]	Japan	Forest	walking up a mountain path through the forest versus sitting at the office	Type	Elderly	General	Affect, perceived stress, physiological stress	Feeling uplifted was higher directly after, 20 min, and 40 min after the walk than before the walk. Feeling tired was lower directly after the walk and feeling stressed was significantly lower 40 min after the walk than before the walk. CgA was significantly higher after the walk than before the walk and significantly lower 40 min after the walk than before the walk. Blood pressure was lower after the walk than before the walk. No effect on cortisol levels.
Greenwood 2016 [144]	UK	grass	on a grass plane outside the building (vs inside) with or without a friend, or with a phone	Type	Adolescents	General	Physiological stress	Heart rate decreased after being on the grass (but: also decreased indoors), blood pressure decreased in all conditions (irrespective of environment). Positive affect increased on the grass (compared to indoors).

* *Indirect green space manipulation (i.e., using a representation of nature rather than real exposure, such as a video, image or Virtual Reality)*

Article	Country	Green space category / char.	Green space description	Type Char	Participants	General / Clinical	Health outcome	Results
Rogerson 2016 [145]	UK	Grass	Grassland vs heritage park, beach, riverside	Type	Runners	General	Affect, perceived stress, self-esteem	Decrease in stress, tension, depression, anger, confusion and an increase in vigour, self-esteem, and fatigue after the run. No difference between the environments was found.
Arnberger 2018 [146]	Austria, Switzerland	Grass	Managed versus tended meadow, versus urban, versus river (urban, mountain)	Type & Char	Students, employees	General	Perceived stress, subjective wellbeing, physiological stress	No difference was found between managed and tended meadows on perceived stress, subjective wellbeing or any of the physiological outcomes.
Ho 2016 [147]	Taiwan	Plants and trees	Short-term (spinach and lettuce) versus long-term life (tomato, string beans) cycle plants	Char	Patients physical disorder	Clinical	Quality of Life	Participants tending short-term plants demonstrated more improvements in social role than those tending long-term plants, an effect that was more pronounced for females. More improvement in family role was found for participants tending long-term plants, which was more pronounced for males, and patients in stage 2.
Paraskevopoulou 2018* [148]	Greece	Plants and trees	Still images of shrubs or a tree displaying seasonal changes vs no seasonal changes	Char	Patients mental disorder	Clinical	Affect	Facial expression tracking displayed that positive time percent was greater for image depicting a tree in autumn colour compared to a tree with green foliage, flowered shrub, and a green shrub. Joy time percent was greater for green shrub planting than for a tree in green or autumn foliage and flowered shrub. No effects on anger, and negative effect.

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Article	Country	Green space category / char.	Green space description	Type Char	Participants	General / Clinical	Health outcome	Results
Elsadek 2019 [149]	China	Plants and trees	Three different roadside trees: Sakura trees, the London plane, Metasequoia versus a control road (surrounded by buildings)	Char	Students, university visitors	General	Affect, vitality, restorative effect	Compared to the control road, participants reported lower values on tension - anxiety, depression, anger-hostility, fatigue, confusion, anxiety and total mood disturbance, and higher scores for vigour, vitality, and restorative effect on all three roads with trees. No significant difference between the three roadside trees.
Gathright 2006 [150]	Japan	Plants and trees	Climbing in a real tree versus artificial structure	Type	Climbers	General	Affect, restorative effect, physiological stress	Tension, fatigue, and confusion were lower while climbing the tree versus the tower, while vitality and restorative effect was higher. HRV was also higher while climbing the tree compared to the tower.
Marselle 2016 [151]	UK	Biodiversity	Perceived bird, butterfly, and plant/tree biodiversity	Char	Walkers, elderly	General	Affect	None of the biodiversity outcomes influenced post-walk affect directly
Chang 2016 [152]	Taiwan	Biodiversity	Biodiversity in green urban space, farmland, mountain	Type & Char	Volunteers	General	Physiological stress	Setting with more evenness in biodiversity resulted in lower heart rate. No other effects were found.
Kondo 2015 [153]	USA	Other green space type	Green stormwater infrastructure	Type	Local residents	General	Perceived stress, physiological stress	No effect of green stormwater infrastructure on high blood pressure or high stress.

Article	Country	Green space category / char.	Green space description	Type Char	Participants	General / Clinical	Health outcome	Results
Martensson 2009 [154]	Sweden	Other green space characteristic	OPEC: proportion containing shrubs, trees, hills; degree of integration be-tween vegetation, open area, and play structures, sky view factor	Char	Schoolchildren	General	Severity mental disorder	Higher OPEC scores related to better outcomes on inattention, no effect on hyperactivity / impulsivity (effect turned significant after deleted outdoor schools). No effect of sky view factor on inattention or hyperactivity.
Olszewska-Guizzo 2018* [155]	Portugal	Other green space characteristic	Contemplative (e.g., long vistas, lush seemingly-wild vegetation, presence of symbolic elements, smooth landforms)	Char	Students and employees	General	Brain activity	Greater temporal beta asymmetry when viewing contemplative versus non-contemplative and versus baseline. No effect on prefrontal alpha asymmetry, associated with positive affect.
Gaterslebe n 2013* [156]	UK	Other green space characteristic	Real walk vs video of the walk, high prospect, low refuge walk vs low prospect, high refuge walk	Char	Students	General	Affect, physiological stress	Anger/aggression, fear, and sadness decreased whereas attentiveness and positive affect increased for high prospect, low refuge, increased for low prospect, high refuse, with a greater reduction in the field. Effect on positive affect and sadness was stronger in the laboratory than in the field.

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Table 6. Overview of the included studies arranged by green space category; cross-sectional and longitudinal studies

Article	Country	Green space category/ char.	Green space description	Type Char	Participants	General / Clinical	Health outcome	Results
Van Dillen 2012 [157]	The Netherlands	Urban green space	Quantity and quality of street greenery and green areas	Type & Char.	Urban residents	General	Mental health	Better mental health with more and better-quality street greenery. No relation between the quality of green areas and mental health.
Coldwell 2018 [158]	UK	Urban green space, countryside	Visits to urban green space and countryside	Type	Urban residents	General	Subjective wellbeing, Quality of life, Affect	Mental wellbeing and quality of life increased with more visits per year to the countryside and urban green space. Yearly urban green space visits were also positively related to momentary anxiety. Little to no relations for visits over the past two weeks.
Wyles 2019 [159]	UK	Urban green space, rural green space	Recent visits to urban & rural green space, protected vs non-protected areas	Type	National residents	General	Recalled psychological restoration	No difference in recalled restoration between rural and urban green areas, better recalled restoration for protected versus non-protected areas.
Ma 2018 [160]	China	Urban green space, park	Frequency visits to city park, country park, community / square green spaces	Type	Green space visitors	General	Subjective wellbeing	Higher frequency of visits to city parks and community / square green spaces was related with better mental well-being. Distance to the park had a U-shaped relation to wellbeing.
Hadavi 2017 [161]	USA	Urban green space	Distance to open lawn with trees and green / social spaces	Type	Local residents	General	Subjective wellbeing	Better mental wellbeing when living in closer proximity of open lawn with trees and green / social spaces. Worse wellbeing when living close to building-dominated space.
Krekel 2016 [162]	Germany	Urban green space, forest	Distance and coverage of urban green space and forest (and abandoned areas and water)	Type	National residents	General	Satisfaction with life	Higher satisfaction with live when living closer to urban green space and with more green space in the residential area. No relations for forest (or water). Negative relation for abandoned areas.

Article	Country	Green space category/ char.	Green space description	Type Char	Participants	General / Clinical	Health outcome	Results
Kim 2016 [163]	USA	Urban green space, forest	Urban natural environments, trees / forests: patches and characteristics of the patches	Type, Char	Schoolchildren	General	Quality of life	Higher quality of life when more trees / forests patches, larger sizes, and more distance between forest patches. No relation for mean patch size and mean shape.
Marselle 2013 [164]	UK	Urban green space, green corridor, farmland	Walking through urban green space, green corridor, natural and semi-natural farmland (coastal)	Type	Walkers	General	Subjective wellbeing, affect, severity depression, perceived stress	Walking in urban green space / natural and semi-natural did not affect subjective wellbeing, affect, depression, or perceived stress. Walking in green corridor and farmland improved wellbeing, and lowered negative affect and perceived stress but had no relation for depression. No relation for coast was found.
Korpela 2010 [165]	Finland	Urban green space	Managed natural areas as favourite places	Type	Local residents	General	Restorative effect	Restorative outcomes were better for managed natural areas (and waterside and activity / hobby areas) than for indoor and outdoor urban areas and built green spaces.
White 2013 [166]	UK	Urban green space, forest, other green space type	Recent visits to urban green space, countryside, farmland, forest, hill / moor / mountain	Type	Green space visitors	General	Restorative effect	Recalled restoration was similar for different types of urban green space (town park, open space, allotment, playground), and a lower score for playing field compared to countryside visits. Scores were better for rural nature compared to countryside visits: farmland, woodland/forest, hill/moor/mountain; and aquatic space: beach and coast, not for river / lake / canal. In the general categories urban green space yielded lower restoration outcomes than rural green space and the coast

Article	Country	Green space category/ char.	Green space description	Type / Char	Participants	General / Clinical	Health outcome	Results
Saw 2015 [167]	Singapore	Park, other green space type	Regional parks, neighbourhood parks, park connector, nature reserve	Type	Students	General	Affect, perceived stress, subjective wellbeing, satisfaction with life	None of the green space variables affected affect, perceived stress, subjective wellbeing, or satisfaction with life.
Dadvand 2019 [33]	Iran	Park, forest, garden, other green space type	Urban parks, nature reserves, forests and other natural green spaces, and garden and agricultural field	Type	Adolescents	General	Self-image, social contacts	Better self-satisfaction and social contacts with increased time spent in urban parks and gardens, more social contacts with increased time spent in forest, lower self-satisfaction with increased time spent in forest.
Wood 2017 [168]	Australia	Park	Park area, number of parks, type of parks, and park functions	Type	Local residents	General	Subjective wellbeing	Wellbeing increased for (all, small, district, regional) parks but not for (local, neighbourhood) parks. More pronounced associations found for larger parks and total park area.
Tillman 2018 [75]	Canada	Park, grass, Trees and other plants	Park, grass / shrubbery, dense vegetation	Type	Schoolchildren	General	Quality of Life	Quality of life positively related with percentage of park space, no relation with percentage of dense vegetation and urbanicity, and a negative relation with percentage of grass and water. These associations were only found for urban and suburban regions.
Balseviciene 2014 [169]	Lithuania	Park	Distance to parks	Type	Young mothers, children	General	Children's problem behaviour	Only associations for low-education mothers were found, with less problem behaviour of the children with closer residential proximity to the parks

Article	Country	Green space category/ char.	Green space description	Type Char	Participants	General / Clinical	Health outcome	Results
Zhang 2019 [170]	China	Park	Park area, number of parks, trees, activities, amenities in park	Type & Char	Elderly	General	Quality of Life	No association for park area, number of amenities and paths, aesthetics, and visibility on quality of life, positive association for (number of trees in the park) on social quality of life. Negative association between number of parks and activity types. Positive association for entertainment density and negative effect of signs of crime on psychological quality of life.
Bojorquez 2018 [171]	Mexico	Park	Distance to park, vegetation cover, park qualities	Type & Char	National residents	General	Mental health	Positive association for park coverage on mental health, no effect of vegetation cover, and park qualities on mental health.
Larson 2016 [172]	USA	Park	Park quantity and quality (amenities)	Type & Char	National residents	General	Subjective wellbeing	Better wellbeing scores with more park coverage and better park quality.
Benita 2019 [173]	Singapore	Park	Parks visited (versus urban areas)	Type	Schoolchildren, adolescents	General	Affect	The odds of experiencing happy moments was greater in park environments than in commercial spaces.
Sugiyama 2016 [174]	Australia	Park	Park area, mean / highest attractiveness, of the park, size park	Type & Char	National residents	General	Mental health	No association for the park variables on mental health. Higher odds of being in the high distress groups for those with residential exposure to more attractive parks within the 800 and 1200 m buffer.
Hansmann 2007 [175]	Switzerland	Park, forest	Visits to a park, forest inside, and forest edge	Type	Green space visitors	General	Perceived stress, subjective wellbeing	Lower stress and higher wellbeing scores after visiting all three sites, no differences were found between the sites.
Mitchell 2013 [43]	UK	Park, forest, garden, other green space type	Open space / parks, forest / woods, outdoor / courts, home /garden, and beach / waterside	Type	National residents	General	Mental health, Subjective wellbeing	Mental health: use of park and forest at least once a week was related to higher odds of good mental health. No association for sports pitch, garden, or beach. Wellbeing: positive association for irregular use of parks, regular use of sports pitch. No association for forest, garden, beach.

Article	Country	Green space category/ char.	Green space description	Type / Char	Participants	General / Clinical	Health outcome	Results
Scott 2018 [176]	USA	Park, Trees and other plants	Park access, impervious surface and tree canopy coverage in home and school environment	Type	Schoolchildren	At-risk	Problem behaviour	No association for park access on problem behaviour, only one positive effect on the subcomponent initiative. For tree canopy, some subcomponents scored better with more tree canopy around the house and home, not all.
Zhang 2019 [177]	Singapore	Park, Trees and other plants	Park area, tree canopy cover, vegetation cover (circular, nested, network (distance to road))	Type & Char	National residents	General	Mental health	Positive relation between park area (network buffer), canopy cover (circular, nested, network buffer), and vegetation cover (circular, nested, network buffer) on mental health
Ayala-Azcárraga 2019 [178]	Mexico	Park, biodiversity, other green space characteristic	Urban park; tree abundance, height of tree, greenness, naturalness, biodiversity, bird song, noxious fauna	Type & Char	Green space visitors	General	Subjective wellbeing	Canonical correlations with wellbeing were positive for bird song, naturalness degree, park area, walking trails, and safety. Negative correlations were found with the height of trees and distance to the park.
Henderson-Wilson 2017 [179]	Australia	Park	Urban (fringe) park use	Type	Green space visitors	General	Mental health, perceived stress	Park users reported lower mental health but also lower stress levels than the general population in the UK.
Burton 2015 [180]	United Kingdom	Garden	Personal/shared: back, front garden, yard, patio, balcony, courtyard, nr. of trees, greenness outdoor space	Type & Char	Elderly	General	Subjective wellbeing	No association on wellbeing of number of trees in view, having a front/back garden, balcony, courtyard. Positive association for a greener view, having a personal patio. Having a personal yard resulted in lower subjective wellbeing.

Article	Country	Green space category/ char.	Green space description	Type Char	Participants	General / Clinical	Health outcome	Results
Kohlleppel 2002 [181]	USA	Garden	Botanical garden	Type	Green space visitors	General	Perceived stress	Stress levels were lower after visiting the botanical garden (than before the visit)
Tsai 2018 [182]	USA	Forest, Trees and other plants	Forest, shrubland, herbaceous land (% cover, patch area & density, edge density & contrast index, Euclidean distance patches, patch cohesion index)	Type & Char	National residents	General	Mental health	Adjusted model (not all predictors were entered): No association for forest %, shrubland patch area & edge contrast, herbaceous % & patch density on odds of frequent mental distress. Positive association for forest edge contrast index and negative association for more connected shrubland.
Van Aart 2018 [183]	Belgium	Forest, other green space type	Forest / semi-natural areas and agricultural area	Type	National residents, adolescents	General	Affect, problem behaviour, physiological stress	Positive association for forest / semi-natural area on affect, while no association were found for problem behaviour or cortisol levels. No association for agricultural land on affect and cortisol levels. Lower hyperactivity levels with more agricultural land. No effects of industrial area on affect or cortisol levels. Higher hyperactivity related with built-up area.
Wu 2017 [184]	USA	Forest, grassland, Trees and other plants	Average and near-road tree canopy, % forest, % grassland, versus % urban land	Type	Schoolchildren	Clinical	Prevalence mental disorder	Lower autism prevalence for school districts with more: tree canopy, near-street tree canopy, forest area, and higher prevalence with more urban land but only in districts with high road density. For all districts, there was a lower autism prevalence with more grassland.
Song 2019 [185]	Korea	Forest	Per district, forest: area, volume, area per capita, volume per capita	Type	National residents	General	Severity mental disorder	Positive associations for forest area and volume (both total and per capita) on the rate of depressive symptoms. Lowest rates were found in the highest quartile (or third quartile for forest area)

Article	Country	Green space category/ char.	Green space description	Type Char	Participants	General / Clinical	Health outcome	Results
MacKerron 2013 [186]	UK	Forest, grassland, other green space type	Forest, semi-natural grassland, mountain / moors / heathland, enclosed farmland, inland bare ground (coast and freshwater)	Type	National residents	General	Affect	Compared to urban areas, more positive affect was reported in forest, grassland, mountain / moors / heathland, and in enclosed farmland. No association for inland bare ground. Positive association for coast (most pronounced of all) and freshwater.
Gilchrist 2015 [187]	UK	Forest, grassland, Trees and other plants, other green space type	Office view: trees / woodland, lawn / mown grass, bushes / flowering plants, meadow / rough grass, fields / distant countryside	Type	Employees	General	Subjective wellbeing	Better wellbeing with more trees / woodland, lawn / mown grass, bushes / flowering plants in the view. No association for meadow / rough grass, fields / distant countryside.
Alcock 2015 [188]	UK	Forest, grassland, other green space type	Broadleaved & coniferous wood-land, arable, improved & semi-natural grassland, mountain, heath & bog, (salt/fresh water)	Type & Char	National residents	General	Mental health	No association for amount of green space between individuals, within individuals (people that moved) positive association for improved grassland, and mountain, heath, bog (and coastal, negative for saltwater)
Astell-Burt 2019 [189]	Australia	Grassland, Trees and other plants	Percentage of grass, percentage tree canopy	Type	Urban residents	General	Prevalence mental disorder, mental health	Higher percentage of tree canopy was related with a lower incidence of psychological distress, whereas a higher percentage of grass was associated with higher odds of psychological distress. No associations were found on the prevalence of depression / anxiety.

Article	Country	Green space category/ char.	Green space description	Type Char	Participants	General / Clinical	Health outcome	Results
Taylor 2015 [190]	UK	Trees and other plants	Street tree density	Type	Urban residents	General	Prevalence mental disorder	Boroughs with lower street tree density had higher anti-depressant prescription rates.
Tomao 2018 [191]	Italy	Trees and other plants	Stand density and tree size in pine wood forests	Type	Green space visitors	General	Restorative effect	The basal area of understory trees and shrubs (stand density) was negatively associated with perceived psychological benefits. No association for stem size was found.
Browning 2018 [192]	USA	Trees and other plants	Tree coverage (mean of 30 meter percent tree canopy)	Type	National residents	General	Mental health	No relation was found between tree coverage and mental health.
Browning 2019 [193]	USA	Trees and other plants	Tree canopy coverage in different buffers (0 – 3000 m)	Type	Elderly (residents nursing home)	Clinical	Prevalence mental disorder	The percentage of long-term stay residents with depressive symptoms was lower with more tree canopy coverage, effects were most pronounced for the nearest buffers.
Johnson 2018 [194]	USA	Trees and other plants	Tree canopy coverage	Type	National residents	General	Sleep quality	A tree canopy of 10% or more was associated with lower odds of weekday (not weekend) short sleep duration.
Beyer 2014 [195]	USA	Trees and other plants	Tree canopy coverage, 10 % census blocks	Type	National residents	General	Severity mental disorder	Higher proportion of tree canopy coverage was related with lower levels of stress, anxiety, and depression.
Larson 2018 [196]	USA	Trees and other plants	Percentage tree canopy in zip code area (and impervious surface)	Type	Schoolchildren, patients mental disorder	General and clinical	Severity mental disorder	More impervious surface (grey surface) and more tree canopy coverage were both associated with higher odds of moderate to high levels of anxiety for children with autism, similar relations were not found for typical youth or children with other diagnoses.

Article	Country	Green space category/ char.	Green space description	Type Char	Participants	General / Clinical	Health outcome	Results
Dzhambov 2018 [197]	Bulgaria	Trees and other plants	Tree canopy coverage in 100, 300, 500 m buffers	Type	Students	General	Mental health	Tree canopy coverage was not found to be related to mental health.
Mavoa 2019 [198]	Australia	Biodiversity	Flora and fauna richness	Char	Urban residents	General	Subjective wellbeing	Flora and fauna species richness were both positively related with subjective wellbeing.
Adjei 2015 [199]	UK	Biodiversity	Total plant diversity, diversity of: native plants, introduced plants. in park, garden, green path, woods, nature reserve	Char	Green space visitors	General	Affect	Positive relation between total plant diversity, diversity of native species, and diversity of introduced species and happiness. More pronounced associations for introduced species.
Hoyle 2017 [200]	UK	Biodiversity	Wood / shrub / herbaceous, biodiversity: perceived different / UK native plant species. Perceived value of planting for insects / native UK insects.	Type & Char	Green space visitors	General	Restorative effect	Woodland: no association for biodiversity on self-reported restorative effect. Shrubland: A higher restorative effect when the perceived number of different plant species was higher. Herbaceous: A higher restorative effect when the perceived value of planting for insects was higher.
Southon 2018 [201]	UK	Biodiversity	Meadows, perceived plant species richness	Char	Green space visitors	General	Subjective wellbeing	No associations found for perceived plant species richness on mental wellbeing.
Rantakokko 2018 [202]	Finland	Biodiversity	Nature diversity	Char	Elderly	General	Quality of life, severity mental disorder	Higher nature diversity resulted in higher quality of life, no associations for depressive symptoms.
Speldewinde 2009 [203]	Australia	Other green space characteristic	Dryland salinity	Char	Rural residents	General	Prevalence mental disorder	An elevated risk of hospitalisations for depression was associated with residence in areas proportionately more affected by dryland salinity.

Article	Country	Green space category/ char.	Green space description	Type Char	Participants	General / Clinical	Health outcome	Results
Speldewinde 2011 [204]	Australia	Other green space characteristic	Dryland salinity	Char	Patients mental disorder	Clinical	Suicide rate	Positive association between salinity and suicide rate, higher suicide rates in more saline areas, especially females. Depression associated with salinity.
Björk 2008 [205]	Sweden	Other green space characteristic	Wild, lush, serene, spacious, culture area within 100 / 300 m of the home	Char	Rural and suburban residents	General	Vitality	Vitality increased when the number of recreational characteristics increased within 300 m for females. No association was found for men.
Annerstedt 2012 [206]	Sweden	Other green space characteristic	Serene, wild, lush, spacious, culture presence within 300m, amount within 300 m, accessibility	Char	Rural residents	General	Mental health	No association for environmental quality on mental health, only for advanced activity access to serene and spacious nature improved mental health for females.
Van den Bosch 2015 [207]	Sweden	Other green space characteristic	Area of 5 different natural characteristics: serene, wild, lush, spacious, culture within 300 m buffer	Type	National residents	General	Mental health	Better mental health after moving to an area with more serene nature within a 300 m buffer (females only). No association for the other nature qualities.

Table 7. Overview of the included studies arranged by green space category; Qualitative studies

Article	Country	Green space category/ char.	Green space description	Type Char	Participants	General / Clinical	Health outcome	Results
Henderson -Wilson 2017 [179]	Australia	Park	Two urban parks, one urban fringe park	Type	Green space visitors	General	Mental health	Respondents highlighted the importance of urban parks for mental health.
Windhorst 2015 [208]	Canada	Park, garden, other green space type	Local nature trail, garden, conservation area, park	Type	Students	General	Mental health	Most common feeling in the natural places were calm, relaxation, and peace.
Liao 2018 [209]	USA	Garden	Garden at nine dementia facilities	Type	Elderly, dementia patients	Clinical	Subjective wellbeing	Nurses expressed that garden visits made patients feel independent and happier and stress was relieved by looking at and talking about garden, and experiencing sunshine. Garden elements provided topics and gave memories to talk about, increasing social interaction. Two nurses reported that for some patients the garden visits increased anxiety and agitation, because they could not leave the facility and because the garden was overwhelming / confusing.
Pálsdóttir 2018 [210]	Sweden	Garden	Rehabilitation garden	Type	Patients mental disorder	Clinical	Affect	The rehabilitation garden consisted of different areas, differing in for instance level of cultivation, seclusion, indoors (glass houses). Each area provided benefits for different emotional states (e.g., outer meadows were used for dealing with strong emotions, benches were used when feeling better and up to social contact). Areas also represented memories and metaphors.

Article	Country	Green space category/ char.	Green space description	Type Char	Participants	General / Clinical	Health outcome	Results
Packer 2013 [211]	Australia	Garden	Botanical garden and historic museum	Type	Green space visitors	General	Restorative effect	Similar to museum visits, the botanical gardens provided restorative experiences through e.g., peace and quiet, aesthetic qualities, and spaciousness.
Rostami 2014 [212]	Iran	Garden	Historical Persian garden	Type	Green space visitors	General	Subjective wellbeing	Respondents indicated that visiting the garden was beneficial for their wellbeing, observations indicated the importance of the natural features such as shady trees, grass plane, and water feature.
Moyle 2018* [130]	Australia	Forest	Virtual Reality of a forest environment	Type	Elderly, dementia patients	Clinical	Affect	Six patients liked being in the virtual forest and it reminded two patients of their childhood, some mentioned elements such as leaves. Some patients did not like the VR experience, or felt it did not affect them. Some family members noted an improvement in mood. Nurses all saw an improvement in mood and calming effect in most (not all) patients.
Cook 2019 [213]	United Kingdom	Forest	Urban woodland activity program	Type	Elderly, dementia patients	Clinical	Subjective wellbeing	For some participants, the urban woodlands brought back happy memories and gave a sense of escape.
Foo 2016 [214]	Malaysia	Forest	Community forest, forest, forest park	Type	Green space visitors	General	Restorative effect	Each different forest space offers different affordances to different types of visitors.
O'Brien 2014 [215]	United Kingdom	Forest	Peri-urban woodlands	Type	Green space visitors, patients physical disorder	General, clinical	Subjective wellbeing	Urban woodlands can improve subjective wellbeing, elements are discussed in terms of being away, memories, but also a differing need for facilities for different users and the optimal level of challenge is necessary for people with a disability.

** Indirect green space manipulation (i.e., using a representation of nature rather than real exposure, such as a video, image or Virtual Reality)*

Article	Country	Green space category/ char.	Green space description	Type Char	Participants	General / Clinical	Health outcome	Results
Hoyle 2017 [200]	United Kingdom	Trees and other plants	Vegetation in full bloom (spring) versus green (summer)	Char	Green space visitors	General	Restorative effect	Participants preferred green plant over flowering plant for relaxation.
Thomas 2015 [216]	Denmark	Other green space characteristic	General nature features	Char	Women	General	Restorative effect	The interviews revealed that specific natural features enabled restorative benefits, sometimes acting as a metaphor or by evoking memories. The actual features differed between individuals.

3.2 Critical Appraisal

The following describes the results from the critical appraisal. A three-level scoring ('high', 'moderate' and 'low' confidence of no bias) was used, with a fourth 'not applicable' category. A score of 'high' is therefore good in that there is relatively high confidence of no bias in the study for that particular component. Conversely, a score of 'low' is not good, as this signals a low confidence of no bias for that particular component.

Experimental studies

The confidence of no bias for the experimental studies was rather low, indicating a relatively low quality of the studies see Figure 3 and Table 8. Only thirteen of the sixty-eight studies (19 %) scored 'high' on six items (half of the items). No study scored more than 6 'high' scores. Most improvement could be made in terms of representative sampling and blinding of both the participants and the outcome assessment. The experimental studies scored relatively well on the items concerning selective reporting, treatment similarity, and the definition of the manipulation. No studies had to be deleted due to low quality, i.e., scoring 'low' on 7 or more items.

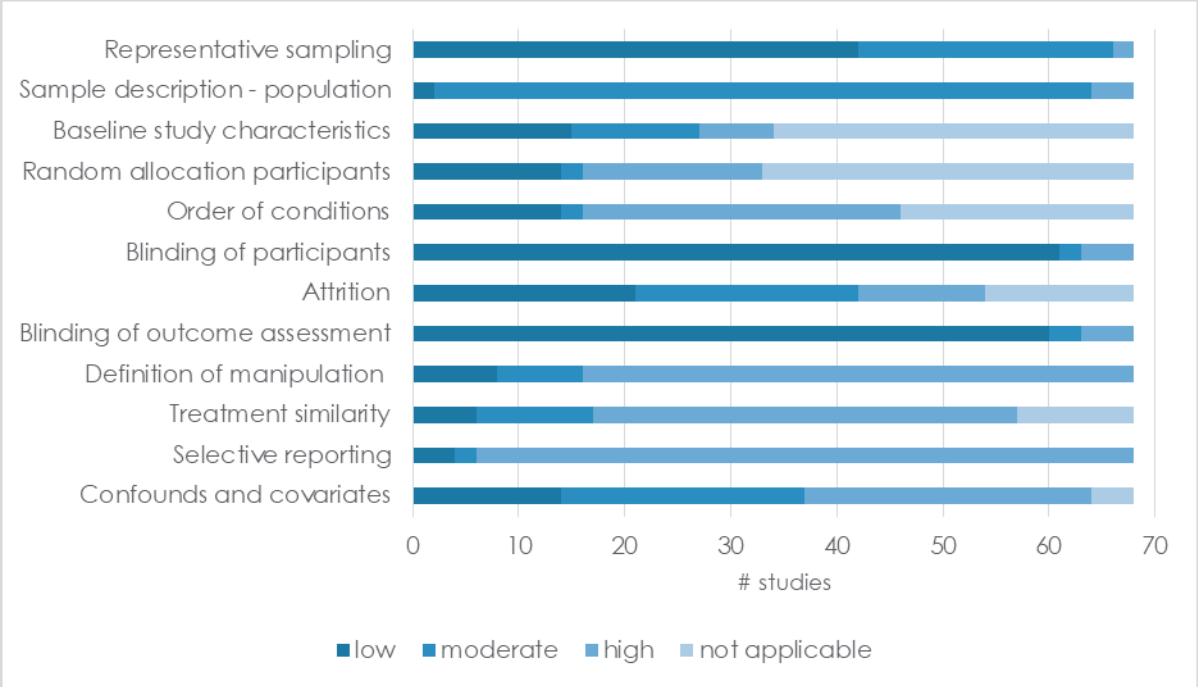

Figure 3. Overall score (confidence of no bias) per item on the critical appraisal for the experimental studies

Table 8. Confidence of no bias for the individual experimental studies

	Representative sampling	Sample description - population	Baseline study characteristics	Random allocation participants	Order of conditions	Blinding of participants	Attrition	Blinding of outcome assessment	Definition of manipulation	Treatment similarity	Selective reporting	Confounds and covariates
Arnberger 2018 [150]	-	□	-	n/a	n/a	-	-	-	+	+	+	+
Aspinall 2015 [96]	-	□	n/a	n/a	-	-	n/a	□	+	□	-	-
Benfield 2018 [113]	□	□	-	+	+	-	-	-	□	+	+	+
Carrus 2015 [99]	-	□	-	-	n/a	-	□	-	□	-	+	□
Chang 2016 [156]	-	□	n/a	n/a	-	-	n/a	-	+	+	+	-
Chang 2019 [100]	-	□	□	n/a	n/a	-	-	-	-	+	+	□
Chiang 2017[1] [146]	-	□	□	+	+	-	n/a	-	+	+	+	+
Cordoza 2018 [124]	-	□	n/a	n/a	+	-	□	-	+	+	+	□
Coventry 2019 [97]	-	□	□	-	n/a	-	-	-	□	□	+	-
Detweiler 2008 [123]	-	□	n/a	n/a	n/a	+	□	-	□	n/a	+	+
Detweiler 2009[1] [122]	-	+	n/a	n/a	-	+	+	+	+	n/a	+	-
Elsadek 2019a [129]	-	□	-	n/a	+	-	-	-	+	+	+	+
Elsadek 2019b [153]	□	□	-	-	+	-	-	-	+	+	+	+
Ewert 2018 [121]	□	+	□	n/a	n/a	-	-	-	+	-	+	□
Gatersleben 2013 S1[1] [160]	-	□	+	□	+	-	n/a	+	+	+	+	-
Gatersleben 2013 S2 [160]	-	□	-	-	n/a	-	n/a	-	+	+	+	-
Gathright 2006 [210]	□	+	n/a	n/a	-	-	□	-	-	-	+	-
Gidlow 2016 [105]	□	□	n/a	n/a	+	-	□	-	+	+	+	+
Goto 2018 [129]	□	□	□	n/a	-	-	□	-	+	+	+	□
Grazuleviciene 2016 [104]	□	□	+	+	n/a	-	-	-	+	+	+	□
Greenwood 2016[1] [148]	-	□	+	+	-	-	+	-	+	+	+	□
Guéguen 2016 Study 2 [109]	-	□	n/a	n/a	n/a	+	n/a	-	□	+	+	□

[1] *good quality, high scores on six or more items (all other studies were of moderate quality)*

+ = high confidence of no bias, □ = moderate confidence of no bias, - = low confidence of no bias, n/a = not applicable

	Representative sampling	Sample description - population	Baseline study characteristics	Random allocation participants	Order of conditions	Blinding of participants	Attrition	Blinding of outcome assessment	Definition of manipulation	Treatment similarity	Selective reporting	Confounds and covariates
Ho 2016[1] [151]	□	□	□	+	+	-	+	+	+	+	□	□
Hull 1995 Study 2 [102]	□	□	n/a	n/a	n/a	-	□	-	-	-	+	-
Jo 2019 [145]	□	□	n/a	n/a	+	-	n/a	-	+	+	+	□
Joung 2015 [131]	-	□	n/a	n/a	-	-	□	-	+	n/a	+	-
Kondo 2015[1] [157]	+	□	-	-	n/a	+	+	+	-	-	+	+
Korn 2018 [127]	□	□	+	n/a	-	-	+	-	-	n/a	+	□
Lanki 2017[1] [120]	-	□	n/a	+	+	-	□	-	+	+	+	+
Lee 2009 [130]	-	□	n/a	n/a	+	-	□	-	+	+	+	□
Lee 2011[1] [135]	□	□	n/a	+	+	-	+	-	+	+	+	-
Lee 2017[1] [126]	-	□	+	n/a	+	-	n/a	-	+	+	+	+
Li 2019 [103]	□	□	n/a	n/a	n/a	-	□	-	□	n/a	+	+
Marselle 2016 [155]	+	□	□	□	n/a	-	+	-	+	□	+	□
Martens 2011 [137]	-	□	+	+	n/a	-	□	-	+	□	+	+
Martensson 2009 [158]	□	+	n/a	n/a	n/a	-	□	-	□	□	+	+
McAllister 2017 [111]	-	□	□	+	n/a	-	□	-	+	□	+	+
Mokhtar 2018 [106]	-	□	□	-	n/a	-	-	-	□	+	+	□
Morita 2007 [133]	-	□	□	-	□	-	-	-	+	□	+	+
Moyle 2018 [134]	□	□	n/a	n/a	n/a	+	n/a	-	+	+	+	□
Neale 2017 [95]	□	□	n/a	n/a	-	-	-	-	+	□	+	-
Ojala 2019 [119]	-	□	+	-	+	□	□	-	+	□	+	+
Olszewska-Guizzo 2018 [159]	-	□	n/a	n/a	-	-	n/a	-	+	n/a	-	-
Orsega-Smith 2004 [101]	-	□	-	-	n/a	-	+	+	-	-	+	+
Paraskevopoulou 2018 [152]	□	□	n/a	n/a	+	-	□	-	+	n/a	-	+

[1] *good quality, high scores on six or more items*

+ = high confidence of no bias, □ = moderate confidence of no bias, - = low confidence of no bias, n/a = not applicable

	Representative sampling	Sample description - population	Baseline study characteristics	Random allocation participants	Order of conditions	Blinding of participants	Attrition	Blinding of outcome assessment	Definition of manipulation	Treatment similarity	Selective reporting	Confounds and covariates
Rogerson 2016 [149]	-	□	-	-	n/a	-	-	-	+	□	+	+
Sianoja 2018[1] [94]	□	□	-	+	+	□	+	-	+	□	+	+
Song 2013 [114]	-	□	n/a	n/a	+	-	-	-	+	n/a	+	n/a
Song 2014 [115]	-	□	n/a	n/a	+	-	+	-	+	+	+	n/a
Song 2015a [116]	-	□	n/a	n/a	+	-	□	-	+	+	+	n/a
Song 2015b[1] [141]	-	□	n/a	+	+	-	□	-	+	+	+	+
Song 2018 [142]	-	□	-	+	+	-	-	□	-	+	+	□
Song 2019 [117]	-	□	-	+	+	-	-	□	-	+	+	+
Sonntag-Öström 2014 [144]	□	□	n/a	n/a	+	-	□	-	+	+	+	-
Stigsdotter 2017 [143]	□	□	n/a	n/a	+	-	□	-	+	+	+	n/a
Takayama 2014[1] [132]	-	□	n/a	+	+	-	-	-	+	+	+	+
Takayama 2017[1] [138]	□	□	□	+	+	-	-	-	+	+	+	+
Toda 2013 [147]	-	□	n/a	n/a	-	-	+	-	+	n/a	+	□
Tsunetsugu 2013 [136]	-	-	-	-	+	-	+	-	+	+	+	□
Tsutsumi 2017 [139]	-	□	n/a	n/a	-	-	-	-	+	+	+	□
Tyrväinen 2014 [118]	□	□	-	-	+	-	-	-	+	+	+	+
Wallner 2018 [110]	-	□	n/a	n/a	□	-	□	-	+	+	+	□
Wang 2016 [107]	-	□	□	+	n/a	-	n/a	-	+	+	+	□
Yoshida 2015 [98]	-	□	-	-	+	-	n/a	-	+	+	□	+
Yu 2018 [140]	□	□	n/a	+	+	-	-	-	+	+	+	□
Yuen 2019 [108]	□	-	n/a	-	n/a	-	n/a	-	+	+	+	+
Zhang 2018 [125]	-	□	n/a	n/a	-	-	-	-	+	n/a	-	□

[1] *good quality, high scores on six or more items*

+ = high confidence of no bias, □ = moderate confidence of no bias, - = low confidence of no bias, n/a = not applicable

	Representative sampling	Sample description - population	Baseline study characteristics	Random allocation participants	Order of conditions	Blinding of participants	Attrition	Blinding of outcome assessment	Definition of manipulation	Treatment similarity	Selective reporting	Confounds and covariates
Zhang 2019 [112]	-	□	n/a	n/a	-	-	n/a	-	+	n/a	+	-

[1] *good quality, high scores on six or more items*

+ = high confidence of no bias, □ = moderate confidence of no bias, - = low confidence of no bias, n/a = not applicable

Cross-sectional and longitudinal studies

The confidence of no bias of cross-sectional and longitudinal studies appeared better than that of the experimental studies, although there is much room for improvement (Figure 4; Table 9). Thirty-two of the fifty-five cross-sectional and longitudinal studies (58 %) scored relatively well, with 'high' ratings on more than four of the seven criteria (including eight studies looking at census data, which scored n/a on sample description and random selection by definition). In contrast to the experimental studies, the cross-sectional and longitudinal studies generally scored better on the blinding of participants, but low on the description of the green space manipulation. The description of the sample in relation to the population could also be improved. In line with the experimental studies, no evidence of selective reporting was found. One study was excluded due to low quality, i.e., scoring 'low' on four or more items.

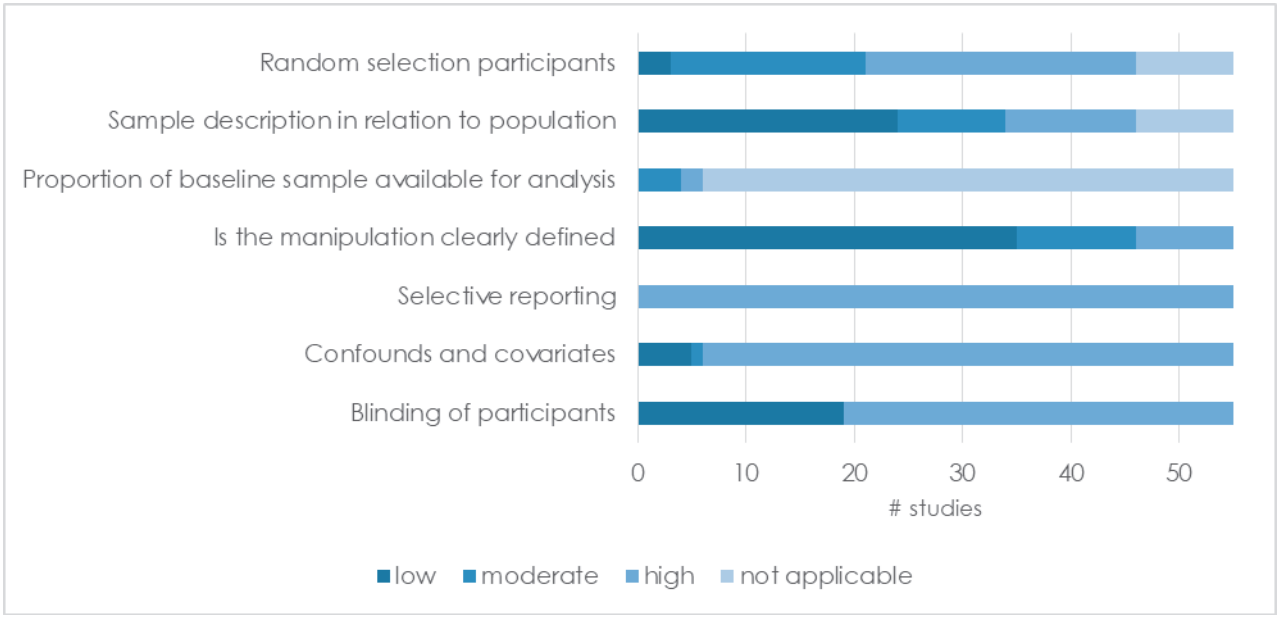

Figure 4. Overall score (confidence of no bias) per item on the critical appraisal for the cross-sectional and longitudinal studies

Table 9. Confidence of no bias for the individual cross-sectional and longitudinal studies

	Random selection participants	Sample description in relation to population	Proportion of baseline sample available for analysis	Is the manipulation clearly defined	Selective reporting	Confounds and covariates	Blinding of participants
Adjei 2015 [203]	□	-	n/a	-	+	+	-
Alcock 2015[1] [221]	+	□	+	-	+	+	+
Annerstedt 2012[1] [210]	+	□	n/a	-	+	+	+
Astell-Burt 2019[1] [57]	+	+	□	-	+	+	+
Ayala-Azcárraga 2019 [182]	□	-	n/a	+	+	□	-
Balseviciene 2014 [173]	-	-	n/a	-	+	+	+
Benita 2019[1] [177]	+	-	□	□	+	+	+
Beyer 2014[1] [199]	+	+	n/a	□	+	+	-
Björk 2008[1] [209]	n/a	n/a	n/a	-	+	+	+
Bojorquez 2018[1] [175]	+	+	n/a	□	+	+	+
Browning 2018[1] [196]	+	+	n/a	-	+	+	+
Browning 2019[1] [197]	n/a	n/a	n/a	-	+	+	+
Burton 2015[1] [184]	+	□	n/a	-	+	+	+
Coldwell 2018 [162]	+	□	n/a	-	+	+	-
Dadvand 2019[1] [33]	+	-	n/a	+	+	+	-
Dzhambov 2018 study 1 [201]	□	-	n/a	-	+	+	-
Dzhambov 2018 study 2 [201]	□	-	n/a	+	+	+	-
Gilchrist 2015[1] [191]	□	-	n/a	+	+	+	+
Hadavi 2017 [165]	□	□	n/a	□	+	-	-
Hansmann 2007 [179]	□	-	n/a	□	+	-	-
Henderson-Wilson 2017 [183]	+	-	n/a	+	+	-	-

** low quality: low scores on four or more items; not included in synthesis, [1] good quality, high scores on four or more items*

+ = high confidence of no bias, □ = moderate confidence of no bias, - = low confidence of no bias, n/a = not applicable

	Random selection participants	Sample description in relation to population	Proportion of baseline sample available for analysis	Is the manipulation clearly defined	Selective reporting	Confounds and covariates	Blinding of participants
Hoyle 2017 [200]	□	-	n/a	+	+	+	-
Johnson 2018[1] [198]	+	+	n/a	-	+	+	+
Kim 2016 [167]	□	-	n/a	-	+	+	-
Kohlleppel 2002* [181]	□	-	n/a	-	+	-	-
Korpela 2010[1] [169]	+	□	n/a	□	+	+	+
Krekel 2016[1] [166]	+	+	n/a	-	+	+	+
Larson 2016[1] [176]	n/a	n/a	n/a	-	+	+	+
Larson 2018[1] [200]	+	+	n/a	-	+	+	+
Ma 2018 [164]	+	-	n/a	□	+	+	-
MacKerron 2013 [190]	□	□	□	-	+	+	+
Marselle 2013[1] [168]	□	-	n/a	+	+	+	+
Mavoa 2019 [202]	-	-	n/a	□	+	+	+
Mitchell 2013[1] [43]	+	+	n/a	□	+	+	+
Rantakokko 2018 [206]	-	-	n/a	-	+	+	+
Saw 2015 [171]	□	-	n/a	+	+	+	-
Scott 2018[1] [180]	n/a	n/a	n/a	-	+	+	+
Song 2019[1] [189]	+	+	n/a	-	+	+	+
Southon 2018 [205]	□	-	n/a	+	+	+	-
Speldewinde 2009[1] [207]	n/a	n/a	n/a	-	+	-	+
Speldewinde 2011[1] [208]	n/a	n/a	n/a	-	+	+	+
Sugiyama 2016[1] [180]	+	+	n/a	-	+	+	+
Taylor 2015[1] [194]	n/a	n/a	n/a	-	+	+	+

** low quality: low scores on four or more items; not included in synthesis, [1] good quality, high scores on four or more items*

+ = high confidence of no bias, □ = moderate confidence of no bias, - = low confidence of no bias, n/a = not applicable

	Random selection participants	Sample description in relation to population	Proportion of baseline sample available for analysis	Is the manipulation clearly defined	Selective reporting	Confounds and covariates	Blinding of participants
Tillmann 2018 [75]	□	-	n/a	-	+	+	+
Tomao 2018 [195]	+	-	n/a	-	+	+	-
Tsai 2018[1] [186]	n/a	n/a	n/a	-	+	+	+
Van Aart 2018 [187]	□	-	□	-	+	+	-
Van den Bosch 2015[1] [211]	+	□	+	-	+	+	+
Van Dillen 2012[1] [161]	+	□	n/a	-	+	+	+
White 2013[1] [170]	+	+	n/a	-	+	+	+
Wood 2017 [172]	□	-	n/a	-	+	+	+
Wu 2017[1] [191]	n/a	n/a	n/a	-	+	+	+
Wyles 2019[1] [164]	+	□	n/a	□	+	+	+
Zhang 2019 a [174]	□	-	n/a	-	+	+	-
Zhang 2019 b[1] [181]	+	+	n/a	□	+	+	+

[*] *low quality: low scores on four or more items; not included in synthesis,* [1] *good quality, high scores on four or more items*

+ = high confidence of no bias, □ = moderate confidence of no bias, - = low confidence of no bias, n/a = not applicable

Qualitative studies

The confidence of no bias for the qualitative studies was reasonable (see Table 10 and Figure 5). Seven of the twelve qualitative studies scored relatively well with at least three 'high' scores out of the five items (58 %). The studies scored well on the description of the source of the target population and the application of triangulation in the studies. However, all studies scored low on stakeholder involvement. Furthermore, there was also room for improvement in terms of the involvement of independent coders and raters. The studies scored well on the description of the source of the target population and the application of triangulation in the studies. One study was excluded due to low quality; having four 'low' scores.

Table 10. Confidence of no bias for the individual qualitative studies

	Source of target population	Recruitment description	Independent raters	stakeholder involvement in the research process	Triangulation
Rostami 2014[1] [216]	+	+	-	-	+
Windhorst 2015 [212]	+	+	□	-	□
Thomas 2015[1] [220]	+	+	-	-	+
Henderson-Wilson 2017[1] [179]	+	+	+	-	+
Pálsdóttir 2018 [214]	+	+	□	-	-
Packer 2013* [215]	-	□	-	-	-
Foo 2016 [218]	+	□	-	-	+
O'Brien 2014[1] [219]	+	+	+	-	+
Liao 2018[1] [213]	+	+	□	-	+
Moyle 2018 [130]	+	□	□	-	+
Cook 2019[1] [217]	+	+	□	-	+
Hoyle 2017[1] [200]	+	+	□	-	+

** low quality: low scores on four or more items; not included in synthesis, [1] good quality, high scores on four or more items*

+ = high confidence of no bias, □ = moderate confidence of no bias, - = low confidence of no bias, n/a = not applicable

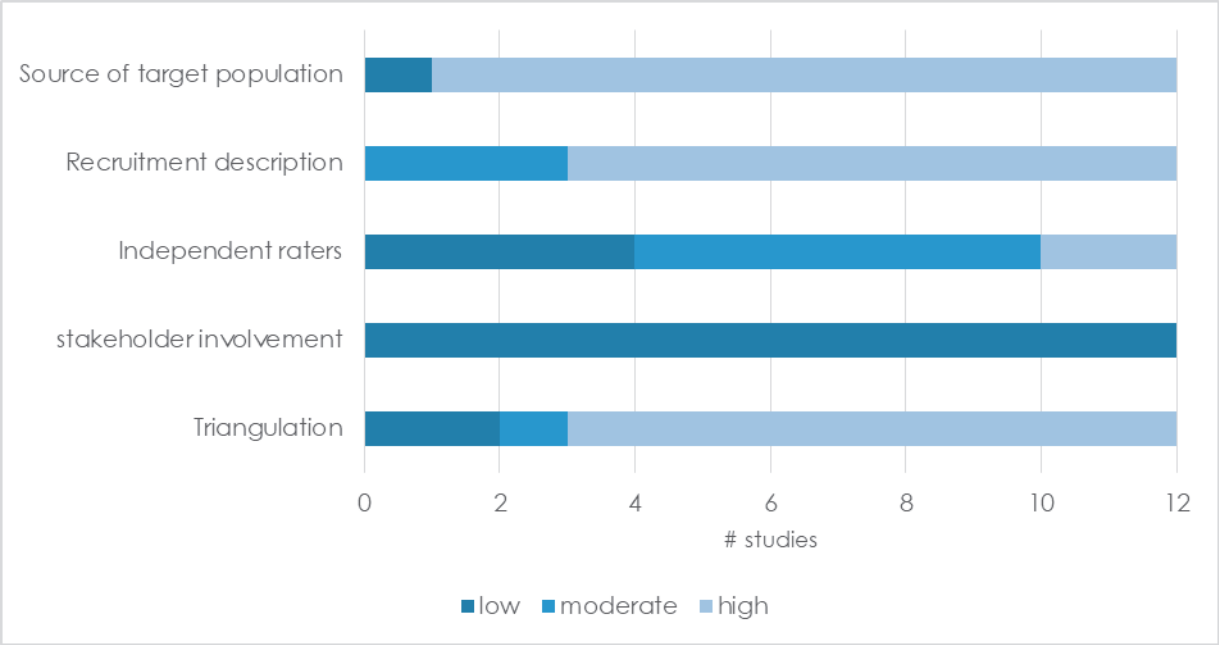

Figure 5. Overall score (confidence of no bias) per item on the critical appraisal for the qualitative studies

3.3 Synthesis

3.3.1 Descriptive synthesis

The descriptive synthesis included six different factors: the country in which the study was conducted; whether the sample was drawn from a general, at-risk, or clinical population; the type of population; the type of health outcomes; the assessment environment; the design of the study (cross-sectional versus longitudinal, or within- between- mixed- subjects design or pre-post design). The narrative synthesis was performed for all papers, except for those with low quality, as rated in the critical appraisal phase, and for the nine green space types / characteristics subcategories. Each of the following section will focus on one subcategory of green space types or characteristics, beginning with the subset of papers that directly compared green space types and characteristics, followed by the papers focusing on green space characteristics and finishing with the outcomes of the specific green space type.

Experimental

Overall

The sixty-eight studies were conducted in twenty different countries. About one-third of the studies (twenty-four studies) were conducted in Europe. The largest proportion of studies were conducted in Japan (seventeen studies), followed by the USA with ten studies, the UK with eight studies, China with five studies, and Taiwan and Finland with 4 studies each. Austria, Australia, Korea, Switzerland, and Sweden all contributed with two studies. All other countries contributed only one study, see Table 11.

Fifteen different types of populations were studied and most often a convenience sample consisting of students was used in the experiments (twenty-nine studies), followed by the elderly people in ten studies, employees in nine studies, green space visitors and patients with a mental disorder in six studies. Local residents and hikers / athletes were each included in four studies, volunteers and adolescents in three studies, and patients with a physical disorder in two studies. All other population types were included in one study, see Table 12.

The majority of studies (fifty-nine) included the general population, whereas nine studies included a clinical population [104, 122, 123, 128, 134, 141, 144, 151, 152], of which one study also including an at-risk population [137]. Thirteen different mental health outcomes were studied of which affect received the most attention, in forty-five studies. Physiological stress was also included as outcome measure relatively often, in thirty-four studies. Perceived stress was studied in twelve studies, the restorative effect in eight studies, brain activity in five studies, vitality in four studies, and subjective wellbeing, severity of a mental disorder, and problem behaviour in three studies. Quality of life was targeted in two studies, and all other mental health outcomes were investigated in one study, see Table 13.

Table 11. Overview of the countries for the included experimental studies

Country	#	References
Japan	17	[98, 114, 115, 117, 128, 130, 132, 133, 135, 136, 138, 139, 141, 142, 145, 147, 154]
USA	10	[100-102, 108, 113, 121, 122-124, 157]
UK	8	[95-97, 105, 148, 149, 155, 160]
China	5	[103, 107, 112, 125, 153]
Taiwan	4	[140, 146, 151, 156]
Finland	4	[94, 118-120]
Austria	2	[110, 150]
Australia	2	[111, 134]
Korea	2	[126, 131]
Switzerland	2	[137, 151]
Sweden	2	[144, 158]
Malaysia	1	[106]
France	1	[109]
Peru	1	[127]
Canada	1	[129]
Lithuania	1	[104]
Denmark	1	[143]
Greece	1	[152]
Portugal	1	[159]
Italy	1	[99]

Table 12. Overview of the population types for the included experimental studies

Population	#	References
Students	29	[96, 98, 106, 107, 112-115, 117, 141] [125, 129-132, 135-139, 141-143, 149, 150, 159, 160]
Elderly	10	[95, 101, 103, 122, 123, 128, 134, 137, 147, 155]
Employees	9	[94, 118-120, 124, 137, 138, 146, 159]
Green space visitors	6	[99, 100, 102, 108, 109, 121]
Patients mental disorder	6	[122, 123, 128, 134, 144, 152]
Local residents	4	[105, 111, 127, 157]
Hikers / Athletes	4	[111, 149, 154, 155]
Volunteers	3	[133, 140, 156]
Adolescents	3	[110, 126, 148]
Patients physical disorder	2	[104, 151]
Conservation volunteers	1	[97]
Pupils	1	[110]
Online panel members	1	[111]
University visitors	1	[153]
Schoolchildren	1	[158]

Table 13. Overview of the mental health outcomes for the included experimental studies

Mental health outcome	#	References
Affect	45	[95, 97, 98, 102-109, 111-115, 117, 118, 126, 129-147, 149, 152-155, 160]
Physiological stress	34	[100, 101, 104, 106, 107, 114, 115, 117-130, 135, 136, 139-145, 147, 148, 150, 154, 156, 157, 160]
Perceived stress	12	[94, 97, 100, 101, 105, 121, 124, 127, 147, 149, 150, 157]
Restorative effect	8	[105, 106, 118, 119, 132, 138, 153, 154]
Brain activity	5	[96, 126, 131, 146, 159]
Vitality	4	[118, 119, 132, 153]
Subjective wellbeing	3	[99, 111, 151]
Problem behaviour	3	[123, 127, 128]
Severity mental disorder	3	[122, 124, 158]
Quality of life	2	[127, 151]
Self-esteem	1	[149]
Mental health	1	[101]
Satisfaction with life	1	[108]

Thirteen studies included indirect contact with green spaces [107, 111, 113, 126, 128, 134, 139, 140] [145, 146, 152, 159, 160], these studies all investigated the effects of viewing green space (as

environmental assessment), with one exception that focused on sound rather than viewing [145]. A health care environment was the focus in five studies [122-124, 128, 151]. The residential area [157] and the school environment [158] were both targeted in one study. All other studies focused on effects of a green space visit. The oldest paper dated from 1995 [102] and the sample sizes ranged from 7 to 585. The majority of studies (forty-four) had a pre-post design, ten studies had a within-subjects design (without pre-post measurements) [96, 119, 125-127, 131, 139, 144, 145, 159], nine studies had a between-subjects design [99, 101, 109, 111-113, 146, 157, 158], and five studies used a mixed design [95, 98, 122, 151, 152].

Comparison

A total of twenty-two experimental studies compared two or more green space types or green space characteristics, see Table 14. Most studies compared different green space types, but characteristics of green space were included in ten studies [99, 110, 125, 137, 138, 146, 150-153]. These experimental studies, investigating a comparison, were conducted in thirteen different countries, with three studies in the UK and Finland, and two studies in Taiwan, Switzerland, China, the USA, Austria, and Japan. All other countries represented a single study, see Table 14.

The majority of studies (eighteen) focused on the general population, only four studies included a clinical population [128, 144, 151, 152]. Students participated in seven studies and employees in six studies. Patients with a mental disorder and green space visitors were each recruited in three studies and elderly and local residents in two studies. All other population types were sampled in a single study, see Table 14.

Regarding mental health outcomes investigated in the 22 experimental comparison studies, affect received most attention, in fourteen studies, followed by physiological stress in nine studies. Other mental health outcomes targeted were restorative effect (four studies), perceived stress (four studies), subjective wellbeing (2 studies), and vitality (2 studies). Single studies included other mental health outcomes, see Table 14.

The majority of studies looked at actual exposure, whereas four studies studied indirect exposure [111, 146, 152]. The studies focused mostly on a visit to a green space (fifteen studies [97, 99, 100, 105, 119-121, 125, 129, 137, 138, 144, 149, 153]), while two studies looked at either the health care environment [128, 151] or at effects of viewing green space [146, 152].

The majority of studies employed a pre-post design (fourteen studies) [97, 100, 105, 110, 118, 120, 121, 128, 129, 137, 138, 149, 150, 153], a between-subjects design was opted for in three studies [99, 111, 146], a within-subjects design was also employed in three studies [119, 125, 144], and two studies used a mixed design [151, 152].

Table 14. Summary for studies with a comparison for the experimental studies

Country	#	References
UK	3	[97, 105, 149]
Finland	3	[118-120]
Taiwan	2	[146, 151]
Switzerland	2	[137, 150]
China	2	[125, 153]
USA	2	[100, 121]
Austria	2	[110, 150]
Japan	2	[128, 138]
Australia	1	[111]
Greece	1	[152]
Canada	1	[129]
Sweden	1	[144]
Italy	1	[99]
Population		
Students	7	[125, 129, 137, 138, 146, 150, 153]
Employees	6	[120-124, 137, 138, 150]
Patients mental disorder	3	[128, 144, 152]
Green space visitors	3	[99, 100, 121]
Hikers / athletes	2	[111, 149]
Elderly	2	[128, 137]
Local residents	2	[105, 111]
Pupils	1	[110]
Adolescents	1	[110]
Members online panel	1	[111]
Conservation volunteers	1	[97]
Patients physical disorder	1	[151]
University visitors	1	[153]
Mental health outcome		
Affect	14	[97, 100, 105, 111, 118, 121, 129, 137, 138, 144, 146, 149, 152, 153]
Physiological stress	9	[100, 118, 120, 121, 125, 129, 144, 146, 150]
Restorative effect	4	[99, 118, 119, 138]
Perceived stress	4	[97, 121, 149, 150]
Subjective wellbeing	2	[110, 150]
Vitality	2	[118, 119]
Quality of life	1	[151]
Self-image	1	[149]
Brain activity	1	[146]
Problem behaviour	1	[128]
Urban Green Space		

Six experimental studies, conducted in four different countries investigated effects of urban green space on wellbeing. Five of these studies were conducted in Europe, see Table 15. Four different population types were included; students (2 studies), elderly, employees, and green space visitors. All experiments included members of the general population and the manipulations used were all direct contact with green space. Four different mental health outcomes were included; affect (four studies), perceived stress (two studies), brain activity, and subjective wellbeing. All six studies investigated effects of visiting green spaces. Two studies employed a pre-post design [94, 97], two studies a mixed design [95, 98], and a within-subjects design [96] and between-subjects design [99] were used in one study each.

Table 15. Summary for studies included in the urban green space category of the experimental studies

Country	**#**	**References**
UK	2	[95-97]
Japan	1	[98]
Finland	1	[94]
Italy	1	[99]
Population		
Students	2	[96, 98]
Elderly	1	[95]
Employees	1	[94]
Green space visitors	1	[99]
Mental health outcome		
Affect	3	[95, 97, 99]
Perceived stress	2	[94, 97]
Brain activity	1	[96]
Subjective wellbeing	1	[99]

Park

A total of twenty-two studies investigated effects of park environments on mental health, divided over eleven countries. The majority of studies were performed outside Europe (thirteen studies outside Europe), with most studies in the USA (six), followed by China, Japan, and Finland with three studies. All other countries were represented in a single study, see Table 16.

Table 16. Summary for studies included in the park category of the experimental studies

Country	#	References
USA	6	[100-102, 108, 113, 121]
China	3	[103, 107, 112]
Japan	3	[114, 115, 141]
Finland	3	[118-120]
Lithuania	1	[104]
UK	1	[105]
Malaysia	1	[106]
France	1	[109]
Austria	1	[110]
Australia	1	[111]
Italy	1	[99]
Population		
Green space visitors	7	[99, 100, 102, 103, 108, 109, 121]
Students	7	[106, 107, 112-115, 141]
Employees	3	[118-120]
Local residents	2	[105, 111]
Patients mental disorder	1	[104]
Elderly	1	[101]
Adolescents	1	[110]
Pupils	1	[110]
Members online panel	1	[111]
Hikers / athletes	1	[111]
Mental health outcome		
Affect	15	[102-109, 111-115, 119, 141]
Physiological stress	11	[100, 101, 104, 106, 107, 114, 115, 118-121, 141]
Perceived stress	4	[100, 101, 105, 121]
Restorative effect	4	[105, 107, 118, 119]
Vitality	2	[118, 119]
Subjective wellbeing	2	[99, 110]
Mental health	1	[101]
Satisfaction with life	1	[108]

Green space visitors and students were included most often, both in seven studies. Employees participated in three studies and local residents in two studies, all other population types were included only once, see Table 16. The majority of studies included members from the general population, whereas one study included a clinical population [104]. Eight different mental health outcomes were targeted, with most emphasis on affect (fifteen studies) and physiological stress (eleven studies), followed by perceived stress and restorative effects, both investigated in four

studies. Three studies included vitality and subjective wellbeing as outcomes, whereas the other two mental health outcomes were only targeted in a single study, see Table 17. The majority of the studies investigated direct effects of park exposure during green space visits, whereas three studies investigated an indirect exposure of park environments and investigated the effects of viewing a park rather than visiting it [107, 111, 113]. A pre-post design was employed most often (sixteen studies), five studies had a between-subjects design [101, 109, 111-113] and one study had a within-subjects design [119].

Garden

In the garden category, experimental studies investigated public and private gardens. The eight studies in this category were conducted in five different countries, with three of them in the USA. All other studies were conducted in a single country, see Table 17.

Table 17. Summary for studies included in the garden category of the experimental studies

Country	**#**	**References**
USA	3	[122-124]
China	1	[125]
Korea	1	[126]
Peru	1	[127]
Japan	1	[128]
Canada	1	[129]
Population		
Elderly	3	[122, 123, 127]
Patients mental disorder	3	[122, 123, 127]
Students	2	[125, 129]
Employees	1	[124]
Adolescents	1	[126]
Local residents	1	[127]
Mental health outcome		
Physiological stress	5	[125-129]
Problem behaviour	3	[123, 127, 128]
Affect	3	[124, 126, 129]
Severity mental disorder	2	[122, 124]
Brain activity	1	[126]
Perceived stress	1	[127]
Quality of life	1	[127]

Three studies targeted elderly patients with a mental disorder. These three studies were also the only studies targeting a clinical sample [122, 123, 128]. Students participated in two studies. The other population types were only included once, see Table 17. Seven different mental health outcomes were investigated, mostly physiological stress (five studies), followed by problem behaviour and affect (three studies), and the severity of a mental disorder in two studies. The other

three mental health outcomes were only investigated once, see Table 17. Four studies investigated the effects of a garden in a healthcare facility [122-124, 128], two studies investigated the effects of visiting a garden [127, 129], and two studies investigated effects of viewing a garden [125, 126]. One study used indirect exposure to green space [126]. Half of the studies used a within-subjects design [126, 122, 125, 127], whereas the other half employed a pre-post design [123, 124, 128, 129].

Forest / woodland

The forest category is dominated by Asian studies. Of the twenty-five experimental studies, thirteen were conducted in Asia and nine in Europe. After Japan with ten studies, Finland contributed three studies and Australia and Taiwan both two studies. Single studies were conducted in all other countries, see Table 18. Three studies used a clinical population [134, 141, 144], of which one study also included at-risk participants [141]. All other experiments used members of the general population. A total of eleven different population types were included. Most experiments did convenience sampling by recruiting students (thirteen studies), followed by employees (four studies), and elderly, green space visitors, adolescents, volunteers, and patients with a mental disorder (all with two studies). All other population types were sampled only once, see Table 18. Seven different mental health outcomes were investigated. Most emphasis was on affect (twenty studies), often combined with measures of physiological stress (fifteen studies). The other mental health outcomes received far less attention; restorative effect was targeted in four studies, vitality in three studies, and subjective wellbeing, brain activity, and perceived stress in two studies. The majority of studies investigated effects of a visit to the forest (seventeen studies), five studies had a view of the forest as exposure [111, 134, 139, 140, 146], and one focused on listening to sounds of the forest [141]. These six studies all employed an indirect exposure of green space [111, 134, 139, 140, 145, 146]. The majority of studies also had a pre-post design (eighteen studies), five studies had a within-subjects design [119, 131, 139, 144, 145] and two studies a between-subjects design [111, 146].

Table 18. Summary for studies included in the forest category of the experimental studies

Country	#	References
Japan	10	[130, 132, 135, 136, 138, 139, 141, 142] [145, 147]
Finland	3	[118-120]
Australia	2	[111] [134]
Taiwan	2	[140] [146]
Austria	1	[110]
Italy	1	[99]
USA	1	[121]
Korea	1	[131]
Switzerland	1	[137]
Denmark	1	[143]
Sweden	1	[144]
UK	1	[148]
Population		
Students	13	[130-132, 135-139, 141, 142, 143, 145, 146]
Employees	4	[118-120, 138]
Elderly	3	[134, 137, 147]
Green space visitors	2	[103, 125]
Adolescents	2	[114, 152]
Volunteers	2	[133, 140]
Patients mental disorder	2	[134, 144]
Pupils	1	[110]
Local residents	1	[111]
Members online panel	1	[111]
Hikers / athletes	1	[111]
Mental health outcome		
Affect	20	[111, 118, 130-147]
Physiological stress	15	[118-121, 130, 135, 136, 139-141, 143-144, 148]
Restorative effect	4	[118, 119, 132, 138]
Vitality	3	[118, 119, 132]
Subjective wellbeing	2	[99, 110]
Perceived stress	2	[121, 147]
Brain activity	2	[131, 146]

Grassland and Meadows

Only three experimental studies looked at effects of grassland and meadows. One within-subjects study from the UK studied the effects of grassland on affect, perceived stress, and self-image for runners, focusing on a physical exercise environment [149]. A second study from the UK investigated adolescents affective responses and heart rate in a grassland environment [148]. The third study employed a pre-post design and was conducted in Austria and Switzerland. It investigated the effects of visiting a meadow on perceived stress, physiological stress, subjective wellbeing for students and employees [150]. In both studies, members of the general population participated.

Trees and other plants

Five experimental studies from four countries focused on trees and other plants. Two of these studies were conducted in Taiwan, while the other studies were conducted in a single country, see Table 19. Two studies focused on a clinical sample [151, 152], and included population types were students (two studies), patients mental disorder, patients physical disorder, university visitors, and athletes (climbers), see Table 19. Six different mental health outcomes were investigated. Affect was explored in all-but-one of the studies, followed by restorative effect in two studies. All other outcomes were studied in a single study, see Table 19.

Table 19. Summary for studies included in the trees and other plants category of the experimental studies

Country	#	References
Taiwan	2	[146, 151]
Japan	1	[154]
China	1	[153]
Greece	1	[152]
Population		
Students	2	[146, 153]
Patients physical disorder	1	[151]
Patients mental disorder	1	[152]
University visitors	1	[153]
Athletes (climbers)	1	[154]
Mental health outcome		
Affect	4	[146, 152-154]
Restorative effect	2	[153, 154]
Vitality	1	[153]
Brain activity	1	[146]
Quality of life	1	[151]
Physiological stress	1	[154]

Two studies used indirect exposure to trees and other plants [146, 152], both focusing on the effects of a view to nature. The other studies focused on a healthcare environment [151], physical activity

environment [154], and visiting a green environment [153]. Two studies had a pre-post design [153] [154], two studies a mixed design [152, 153], and one a between-subjects design [146].

Other green space type

Three experimental studies incorporated a green space type that was not captured by any of the previous categories. These green space types were a wilderness setting [100] and green stormwater infrastructure in the USA [157], and a rock outcrop in Sweden [144]. One study included participants from a clinical population, which were patients with a mental disorder [144]. This study employed a within-subjects design and investigated effects of visiting green space on affect, and physiological stress. In a second study, students were recruited and effects of a visit to the wilderness on perceived and physiological stress was measured in a pre-post design. The third study investigated effects within the residential area, targeting local residents, on both perceived and physiological stress in a between-subjects design [157]. All studies employed a direct exposure of the green space.

Biodiversity

Three experimental studies investigated effects of biodiversity on mental health, in Italy [99], the UK [155], and Taiwan [156]. All three studies sampled from the general population, and recruited green space visitors [99], walkers and elderly [155], and volunteers [156]. Three different mental health outcome measures were included: subjective wellbeing [99], affect [155], and physiological stress [152]. All studies looked at the effects of green space visits, either with a pre-post design [155, 156] or a between-subjects design [99].

Other green space characteristic

Three experimental studies investigated a green space characteristic that was not yet captured by the previous categories. One study in Sweden investigated the effects of schoolyard design on the severity of a mental disorder (ADHD), with schoolchildren as study subjects and employing a between-subjects design [158]. The second study, conducted in Portugal, investigated the effects of viewing contemplative space on brain activity [159], recruiting both students and employees in a within-subjects design with an indirect green space manipulation. The third and last study investigated effects of prospect and refuge with both a direct (visiting green space) and indirect (viewing green space) manipulation [160]. This study was conducted in the UK, with a pre-post design, students as participants, and affect and physiological stress as outcome measures.

Cross-sectional and longitudinal studies

Overall

All cross-sectional and longitudinal studies investigated effects of direct exposure to green spaces. Overall, fifty-three cross-sectional and longitudinal studies were included from eighteen different countries. The highest number of studies were conducted in the United Kingdom (thirteen) and the United States of America (eleven), followed by Australia with seven studies. Three studies were conducted in Singapore and Sweden, and two in China, Mexico, and Finland. All other countries contributed one study, see Table 20.

Table 20. Overview of the countries for the included cross-sectional and longitudinal studies

Country	#	References
UK	13	[47, 162, 163, 168, 170, 184, 190-192, 194, 203-204, 222]
USA	11	[165, 167, 176, 180, 186, 188, 196-200]
Australia	7	[172, 178, 183, 193, 202, 207, 208]
Singapore	3	[171, 177, 181]
Sweden	3	[209-211]
China	2	[164, 174]
Mexico	2	[175, 183]
Finland	2	[169, 206]
Canada	1	[75]
Iran	1	[33]
The Netherlands	1	[161]
Bulgaria	1	[201]
Germany	1	[166]
Belgium	1	[187]
Switzerland	1	[179]
Lithuania	1	[173]
Korea	1	[189]
Italy	1	[195]

The majority of studies regarded the general population. One study focused on an at-risk population [180], whereas four further studies included a clinical population [188, 197, 200, 208]. By far the most studies (nineteen) sampled from the entire population of a country (national residents). Other populations that were sampled relatively often were green space visitors (nine studies) and schoolchildren (six studies). Urban residents and elderly people were both sampled in four studies, whereas local and rural residents where each included in three studies, and students, adolescents, athletes / hikers, and patients with a mental disorder were the focus of two studies. All other population types were included in one study, see Table 21.

Table 21. Overview of the population types for the included cross-sectional and longitudinal studies

Population	#	References
National residents	19	[43, 163, 166, 170, 175, 176, 178, 181, 182, 186, 187, 189, 190, 192, 194, 196, 198, 199, 211]
Green space visitors	9	[164, 170, 179, 183, 183, 195, 203-204]
Schoolchildren	6	[75, 167, 177, 180, 188, 200]
Urban residents	4	[161, 152, 193, 202]
Elderly	4	[174, 184, 197, 206]
Local residents	3	[165, 169, 172]
Rural residents	3	[207, 209, 210]
Students	2	[171, 223]
Adolescents	2	[33] [177]
Hikers / athletes	2	[43, 168]
Patients mental disorder	2	[200, 208]
Young mothers	1	[173]
Employees	1	[191]

Mental health and subjective wellbeing received the most attention, respectively with fifteen and thirteen studies. Restorative effect was investigated in six studies and affect, severity of a mental disorder, and the prevalence of a mental disorder in five studies. Perceived stress, satisfaction with life, and quality of life were the focus in four studies and problem behaviour in three studies. All other mental health outcomes were targeted once, see Table 22.

The majority of the articles focused on the residential area (thirty-four studies), a green space visit was assessed in eleven studies [33, 162, 164, 170, 179, 182, 183, 195, 203-204], an environment for physical exercise [43, 168], a school environment [180, 188], and all places visited [173, 190] were all addressed in two studies. Single studies investigated favourite places [88], work environment [191], and a healthcare environment [197].

The “oldest” paper included dated from 2008 and all studies measured direct exposure (as opposed to indirect exposure through for instance images or videos) to green. The participant numbers ranged from 140 to 97,574,613. The majority of studies had a cross-sectional design (forty-one), and fewer a longitudinal design (fourteen: [75, 172, 173, 177, 180, 187, 190, 192, 193, 197, 198, 208, 209, 211]).

Table 22. Overview of the mental health outcomes for the included cross-sectional and longitudinal studies

Mental health outcome	#	References
Mental health	15	[43, 161, 175, 178, 181, 186, 192, 193, 196, 210, 211, 223]
Subjective wellbeing	13	[43, 162, 164, 165, 168, 171, 172, 176, 179, 184, 191, 202, 204]
Affect	5	[168, 171, 177, 190, 203]
Restorative effect	5	[163, 169, 170, 195, 200]
Severity mental disorder	5	[168, 189, 199, 200, 206]
Prevalence mental disorder	5	[188, 193, 194, 197, 207]
Perceived stress	4	[168, 171, 179, 183]
Satisfaction with life	4	[166, 171, 182]
Quality of life	4	[75, 167, 174, 206]
Problem behaviour	3	[173, 180, 187]
Self-image	1	[33]
Physiological stress	1	[187]
Sleep quality	1	[198]
Suicide rate	1	[208]
Vitality	1	[209]

Comparison

A total of thirty-five cross-sectional and longitudinal studies compared one or more green space types or green space characteristics, see Table 23. They were conducted in fourteen different countries. The United Kingdom had the highest share of studies (thirteen), followed by the United States of America with four studies and Sweden and Australia both with three studies. Two studies were contributed by Singapore and Mexico. The remaining countries were represented by one study, see Table 23.

Most studies in the comparison either focused on characteristics or included multiple green space types in their analyses and comparisons are (indirectly) made by comparing the separate effects of the different green space types and their direction and sometimes magnitude (positive / negative / non-significant). Some studies also included different indices for the same green space type, such as different buffer sizes (e.g., 100 metres versus 500 metres around the residence) or different characteristics of green space patches (e.g., edge contrast, patch area).

One study included a clinical sample [188], whereas all other studies included participants from a healthy, or general, population. Sixteen studies had national residents as their participants (mostly in panel studies), six studies sampled green space visitors, whereas two studies each focused on hikers / athletes, urban residents, schoolchildren, and local residents. All other population types were included in single studies see Table 23.

Table 23. Summary for country and population of studies with a comparison for the cross-sectional and longitudinal studies

Country	#	References
UK	13	[2, 3, 8, 10, 22, 32-34, 45][191, 203-204]
USA	4	[165, 176, 186, 188]
Sweden	3	[209-211]
Australia	3	[172, 178, 202]
Singapore	2	[171, 174]
Mexico	2	[175, 182]
China	1	[164]
Iran	1	[33]
Canada	1	[75]
Germany	1	[166]
Belgium	1	[187]
Switzerland	1	[179]
Finland	1	[206]
Italy	1	[195]
Population		
National residents	16	[43, 163, 166, 170, 174-176, 180, 182, 186, 187, 190, 192, 209, 211]
Green space visitors	6	[164, 179, 195, 203-204]
Hikers / athletes	2	[43, 168]
Urban residents	2	[162, 202]
Schoolchildren	2	[75, 188]
Local residents	2	[165, 173]
Students	1	[171]
Adolescents	1	[33]
Employees	1	[191]
Rural residents	1	[210]
Elderly	1	[206]

Thirteen different mental health outcomes were studied (see Table 24). Subjective wellbeing received most attention, in twelve studies, followed by mental health with seven studies, and affect and restorative effect each with four studies. Three studies focused on perceived stress, satisfaction with life, and the severity of a mental disorder, whereas quality of life was targeted in two studies. All other outcomes were included in single studies, see Table 24.

Most studies (nineteen) looked at either the residential area [75, 163, 164, 166, 171, 172, 174-176, 180, 182, 186, 187, 192, 202, 206, 209-211] or at green space visits (eleven) [33, 162, 164, 170, 179, 182, 195, 203-204]. Two studies looked at an environment for physical activity [43, 168]. Single studies looked at the school environment [188], work environment [191], and all places visited [190].

Twenty-eight studies had a cross-sectional design, six studies used a longitudinal design [75, 172, 190, 192, 209, 211], and one study contained both a cross-sectional and a longitudinal design [187].

Table 24. Summary for mental health outcomes studies with a comparison for the cross-sectional and longitudinal studies

Mental health outcome	#	References
Subjective wellbeing	12	[43, 162, 164, 165, 168, 171, 172, 176, 179, 191, 202, 204]
Mental health	7	[43, 174, 178, 186, 192, 210, 211]
Affect	4	[168, 171, 190, 203]
Restorative effect	4	[163, 170, 195, 200]
Perceived stress	3	[168, 171, 179]
Satisfaction with life	3	[166, 171, 182]
Severity mental disorder	3	[168, 175, 206]
Quality of life	2	[75, 162]
Self-satisfaction	1	[33]
Prevalence mental disorder	1	[188]
Problem behaviour	1	[187]
Physiological stress	1	[187]
Vitality	1	[209]

Urban Green Space

Eleven cross-sectional papers investigated the effects of urban green space from six different countries (see Table 25). The majority of these studies were conducted in Europe (seven out of eleven), with most studies (four) conducted in the United Kingdom; the other European studies were conducted in the Netherlands, Germany, and Finland. Outside Europe, three studies were conducted in the United States of America, and one in China.

Most studies investigated green space types; only two studies looked at characteristics of green space [161, 167]. The majority of the studies used a general population; only one study [188] included a clinical sample. Seven different samples were included in the urban green space category. Three studies included national residents, whereas urban residents and local residents were both sampled in two studies. Two studies looked at the effects of urban green space on schoolchildren. Patients with a mental disorder, green space visitors, and walkers / athletes were recruited in single studies.

Effects of green space on nine mental health outcomes were investigated. Again, subjective wellbeing received the most attention, in four studies. Three studies investigated restorative effect, whereas satisfaction with life, quality of life, affect, severity of a mental disorder, perceived stress, mental health, and prevalence of a mental disorder were all targeted in a single study.

Six studies focused on the residential area [161, 163, 165-167, 170], green space visits were investigated twice [162, 164], whereas school environment [188], an environment for physical exercise [168], and favourite places [169] were all included once. All studies had a cross-sectional design.

Table 25. Summary for studies included in the urban green space category of the cross-sectional and longitudinal studies

Country	#	References
UK	4	[162, 163, 168, 170]
USA	3	[165, 167, 188]
The Netherlands	1	[161]
Germany	1	[166]
Finland	1	[169]
China	1	[164]
Population		
National residents	3	[163, 166, 170]
Urban residents	2	[161, 162]
Local residents	2	[165, 169]
Schoolchildren	2	[167, 188]
Patients (mental disorder)	1	[188]
Green space visitors	1	[164]
Walkers / athletes	1	[168]
Mental health outcome		
Subjective wellbeing	4	[162, 164, 165, 168]
Restorative effect	3	[163, 169, 170]
Quality of life	2	[162, 224]
Satisfaction with life	1	[166]
Affect	1	[168]
Severity mental disorder	1	[168]
Perceived stress	1	[168]
Mental health	1	[161]
Prevalence mental disorder	1	[188]

Park

Seventeen cross-sectional and longitudinal studies were included from ten different countries (see Table 26). Three studies were conducted in Singapore and Australia, followed by China, the United States of America, and Mexico with two studies. One study was conducted in Iran and Canada. Relatively few studies (three out of eleven) were conducted in Europe; one in Lithuania, one in Switzerland, and one in the United Kingdom.

Sixteen studies investigated effects of the green space type park. Five studies also investigated the effects of park characteristics, including: park qualities [175], amenities [174, 176], park functions [172], and park attractiveness [180]. One study only looked at different characteristics of a park, such as bird song and biodiversity [182].

All studies except one focused on a general population, with the exception being a study looking at an at-risk population [180]. Eight different population types were included in the studies. National residents were included in most (six studies), followed by schoolchildren and green space visitors,

both with three studies. Adolescents participated in two studies, and single studies included students, local residents, elderly, and young mothers.

Table 26. Summary for studies included in the park category for the cross-sectional and longitudinal studies

Country	#	References
Singapore	3	[171, 177, 181]
Australia	3	[172, 178, 183]
China	2	[164, 174]
United States of America	2	[176, 180]
Mexico	2	[175, 182]
Canada	1	[72]
Iran	1	[33]
Lithuania	1	[173]
Switzerland	1	[179]
United Kingdom	1	[43]
Population		
National residents	7	[43, 175, 176, 178, 181, 182]
Schoolchildren	3	[75, 177, 180]
Green space visitors	3	[164, 179, 183]
Adolescents	2	[33, 177]
Students	1	[171]
Local residents	1	[172]
Elderly	1	[174]
Young mothers	1	[173]
Mental health outcome		
Subjective wellbeing	6	[43, 164, 171, 172, 176, 179]
Mental health	4	[43, 178, 181, 183]
Perceived stress	3	[171, 179, 183]
Affect	2	[171, 177]
Quality of life	2	[75, 174]
Problem behaviour	2	[173, 180]
Satisfaction with life	2	[171, 182]
Severity mental disorder	2	[175]
Social contacts	1	[33]
Self-image	1	[33]

Effects of park environments on ten different mental health outcomes were investigated. Six studies focused on subjective wellbeing, four on mental health, three on perceived stress, and two studies on affect, quality of life, satisfaction with life, problem behaviour, and the severity of a mental disorder. Social contacts and self-image were the outcomes of a single study.

The majority of studies (eleven) focused on the residential area [75, 171-176, 178, 180, 181, 189]. The remaining studies were aimed at visiting / visitors green space (five studies) [33, 164, 179, 182, 183], and single studies looked at all places visited [177], physical exercise environments [43], and school environments [180].

Again, most studies had a cross-sectional design and only five studies a longitudinal design [75, 172, 173, 177, 180]

Garden

Three studies looked at cross-sectional benefits of gardens, two in the United Kingdom [43, 184] and one in Iran [33].

All three studies investigated the effects of the garden as a green space type, whereas one study also looked at the characteristics of the garden, namely of view characteristics [184]. All three studies included a general population, and specifically: adolescents [33], national residents [43], and the elderly [184].

Two studies had subjective wellbeing as mental health outcome [43, 184], whereas self-image and social contacts were in focus in the third [33]. The three studies all looked at a different assessment area: visiting / visitors of green space [33], a physical activity environment [43], and the residential area [184].

Forest / Woodland

Twelve cross-sectional and longitudinal papers examined the effects of forest and woodland on mental health in seven different countries, see Table 27. The majority of studies were conducted in Europe (seven out of twelve), out of which five studies were conducted in the United Kingdom, and one study in Switzerland, Belgium, and Germany. Outside Europe, two studies were conducted in the United States of America, one in Iran, and one in Korea.

All studies investigated the effects of a forest as a green space type, and one study looked at characteristics of patches of forest in addition to that [186].

One study included a clinical population, namely children with autism [188], whereas all other studies focused on the general population. Six different population types were included. The majority of studies had national residents as respondents (eight studies), and single studies included: green space visitors, adolescents, schoolchildren, patients with a mental disorder, and employees.

Mental health outcomes where highly scattered with eleven different outcomes. Most outcomes were only included once in a study: satisfaction with life, physiological stress, problem behaviour, restorative effect, prevalence mental disorder, self-image, and social contacts. Two studies focused on subjective wellbeing and affect, and three studies on mental health.

Six studies were conducted within the residential area [166, 170, 186, 187, 189, 192] and two for green space visitors [33, 166]. Single studies were conducted in the school environment [188], work environment [191], an environment for physical activity [43], and all places visited [190].

Again, most studies had a cross-sectional design. Two studies combined a cross-sectional design with a longitudinal design [187, 192] and one study had a longitudinal design [190].

Table 27. Summary for studies included in the forest / woodland category for the cross-sectional and longitudinal studies

Country	#	References
United Kingdom	5	[43, 170, 190-192]
United States of America	2	[186, 188]
Switzerland	1	[179]
Belgium	1	[187]
Germany	1	[166]
Iran	1	[33]
Korea	1	[189]
Population		
National residents	8	[43, 166, 170, 186, 187, 189, 190, 192]
Green space visitors	1	[179]
Adolescents	1	[33]
Schoolchildren	1	[188]
Patient mental disorder	1	[188]
Employees	1	[191]
Mental health outcome		
Mental health	3	[43, 186, 192]
Subjective wellbeing	2	[43, 191]
Affect	2	[187, 190]
Perceived stress	1	[179]
Social contacts	1	[33]
Self-image	1	[33]
Prevalance mental disorder	1	[188]
Restorative effect	1	[170]
Problem behaviour	1	[187]
Physiological stress	1	[187]
Satisfaction with life	1	[166]
Severity mental disorder	1	[189]

Grassland and Meadows

Seven cross-sectional and longitudinal studies from four countries focused on grassland and meadows, with three studies in the United Kingdom [190-192], two in the United States of America [165, 188] and one in Australia [193] and Canada [75].

All studies looked at grassland and meadows as a specific green space type and none of the studies looked further at characteristics of this specific green space type. One study had a clinical population [188], the other six studies sampled from the general population. Six different population types were included: national residents (2 studies) [190, 192], urban residents [193], local residents [165], employees [191], and schoolchildren [75, 188] and patients with a mental disorder [188].

Six different mental health outcomes were the focus of the seven studies. Two studies targeted subjective wellbeing [165, 191], while the other outcomes were quality of life [75], affect [190], prevalence mental disorder [188], severity of mental disorder [193], and mental health [192].

Again, the majority of studies investigated the residential area [75, 165, 192, 193], whereas single studies looked at the work environment [191], the school environment [188], and all places visited [190].

Three studies had a longitudinal design [75, 190, 193] and one study combined a longitudinal and a cross-sectional design [192]. The remaining three studies had a cross-sectional design.

Trees and other plants

Sixteen cross-sectional and longitudinal studies investigated effects of trees and / or plants in seven different countries, see Table 28. This green space category was dominated by research from the United States of America, with eight studies. Two studies came from Bulgaria and the remaining six studies were from Australia, the United Kingdom, Italy, Singapore, Canada, and Mexico.

Again, most studies investigated trees and other plants as a specific type. Two studies looked at characteristics of trees: stand density and tree size [182, 195], and one study looked at patch characteristics of different types of vegetation [186].

The majority of studies, once more, included general participants. Three studies focused on a clinical population [188, 197, 200] and one on an at-risk population [180]. Eight different population types were included: national residents (eight studies), schoolchildren (four studies), students (two studies), patients with a mental disorder (two studies), and elderly, urban residents, green space visitors, and employees with one study each.

Nine different mental health outcomes were the dependent variables. The largest focus was on mental health, with six studies, followed by the severity of a mental disorder with three studies and the prevalence of mental disorders with two studies. Single studies targeted sleep quality, problem behaviour, subjective wellbeing, restorative effect, quality of life, satisfaction with life.

The residential area was again the most often-used area of assessment with eleven studies [75, 181, 186, 193, 194, 196, 198-201, 223]. Green space visits [180, 182] and the school environment [188, 195] were investigated twice , whereas the healthcare environment [197] and a work environment [191] both were assessed in single studies.

Five of the sixteen studies had a longitudinal design [75, 180, 193, 197, 198] and the remaining eleven studies employed a cross-sectional design.

Table 28. Summary for studies included in the trees and other plants category for the cross-sectional and longitudinal studies

Country	#	References
United States of America	8	[180, 186, 188, 196-200]
Bulgaria	2	[201, 223]
Australia	1	[193]
United Kingdom	1	[194]
Italy	1	[195]
Singapore	1	[181]
Canada	1	[75]
Mexico	1	[182]
Population		
National residents	8	[181, 182, 186, 194, 196, 198, 199]
Schoolchildren	4	[75, 180, 188, 200]
students	2	[201, 223]
Patients mental disorder	2	[188, 200]
Elderly	1	[197]
Urban residents	1	[193]
Employees	1	[191]
Green space visitors	1	[195]
Mental health outcome		
Mental health	6	[181, 186, 193, 196, 201, 223]
Severity mental disorder	3	[197, 199, 200]
Prevalence mental disorder	2	[188, 194]
Sleep quality	1	[198]
Problem behaviour	1	[180]
Subjective wellbeing	1	[191]
Restorative effect	1	[195]
Quality of life	1	[75]
Satisfaction with life	1	[182]

Other Green Space Types

Ten cross-sectional and longitudinal studies focused on other green space types, including mostly rural green spaces such as fields, distant countryside, nature reserves, rural green, farmland, but also inland bare ground, and green corridors. The studies were conducted in five countries, with the majority of studies conducted in Europe (ten) with most of them from the United Kingdom (eight) [43, 162, 163, 168, 170, 190-192], while the other European countries were Germany [166] and Belgium [187]. The remaining two studies were conducted in Singapore [171], and Iran [33].

All studies focused on a general population within four population types: national residents (seven studies) [43, 163, 166, 170, 187, 190, 192], employees [191], students [171], urban residents [162], and walkers [168].

Eight different mental health outcomes were investigated, namely: subjective wellbeing (five studies) [43, 162, 168, 171, 191], affect (four studies) [168, 171, 187, 190], perceived stress (two studies) [168, 171], satisfaction with life (two studies) [166, 171], restorative effect (two studies) [163, 170], severity of mental disorder [168], quality of life [162], problem behaviour [187], mental health [192].

Five studies focused on the residential area [163, 166, 171, 187, 192], two studies on green space visits [162, 170] and a physical exercise environment [43, 168]. Single studies looked at all places visited [190] and the work environment [191]

Three of the ten studies had a longitudinal design [187, 190, 192] and the remaining ten had a cross-sectional design.

Biodiversity

Five cross-sectional studies in three countries looked at differences in biodiversity level on mental health. Three of these studies were conducted in the United Kingdom [203-204], whereas the other two took place in Australia [202] and Finland [206].

All studies focused on the general population, with three different population types included: green space visitors [203-204], urban residents [202], and the elderly [206].

The studies covered five different mental health outcomes: subjective wellbeing [202, 204], affect [203], restorative effect [200], quality of life [206], and severity mental disorder [206].

The studies included either the residential area [202, 206], or green space visits [203-204] and all studies had a cross-sectional design.

Other Green Space Characteristics

Six cross-sectional and longitudinal studies in two countries looked at other green space characteristics. Two studies from Australia [207, 208] looked at dryland salinity, whereas three studies from Sweden [209-211] investigated effects of a specific characterisation of green space types (in e.g., 'lush', 'wild', 'serene' nature) on mental wellbeing.

One study included a clinical sample [208], whereas the other five all included a general population. Four different population types were recruited across the four studies; national residents [159, 209, 211], urban residents [210], rural residents [207], and patients mental disorder [208].

Four different mental health outcomes were investigated; mental health [210, 211], vitality [209], suicide rate [208], prevalence mental disorder [207].

All studies focused on the residential area and three of the studies had a longitudinal design [208, 209, 211].

Qualitative

Overall

A total of eleven qualitative studies were included (see Table 29), in six different categories: park (2) [183, 212]; garden (4) [212-216]; forest (4) [130, 217-219]; trees and other plants (1) [200]; other green space type (1) [212]; other green space characteristic [220].

The studies were conducted in eight different countries, three studies were performed in the UK and two in Australia, whereas all other countries contributed with a single study: the USA, Canada, Sweden, Denmark, Iran, and Malaysia.

Four studies included a clinical population [134, 213, 214, 217, 219], and six different population types were included. Five studies focused on green space visitors, four studies were on patients with a mental disorder, and three included the elderly. Single studies looked at patients with a physical disorder and women.

Four different types of mental health outcomes were investigated. Four studies had subjective wellbeing as the outcome measure and three focused on restorative effects, whereas mental health and affect were the focus of two studies each.

Table 29. Summary for the included qualitative studies

Country	**#**	**References**
United Kingdom	3	[200, 217, 219]
Australia	2	[134, 183, 215]
United States of America	1	[213]
Canada	1	[212]
Sweden	1	[214]
Denmark	1	[220]
Iran	1	[216]
Malaysia	1	[218]
Population		
Green space visitors	5	[183, 200, 215, 216, 218, 219]
Patients mental disorder	4	[134, 213, 214, 217]
Elderly	3	[134, 213, 217]
Students	1	[212]
Patients physical disorder	1	[219]
Women	1	[220]
Mental health outcome		
Subjective wellbeing	4	[213, 216, 217, 219]
Restorative effect	3	[200, 215, 218, 220]
Mental health	2	[183, 212]
Affect	2	[134, 214]

The majority of studies (eight) focused on a visit to a green space [183, 200, 212, 215-220], two studies focused on a healthcare environment [213, 214], and one on viewing green space [134].

Park

Two studies focused on the experiences in parks. One study was conducted in Australia [183], with green space visitors and the second was conducted in Canada [212] off site with students. Both studies employed a general population, had mental health as an outcome variable, and investigated a visit to a green space.

Garden

Three studies investigated the effects of a garden. One study from the USA included gardens at dementia facilities [213] and the study from Sweden investigated experiences with a rehabilitation garden [214]. Both studies included a clinical population of patients with a mental disorder and had a healthcare environment as environmental assessment area. The mental health outcomes were subjective wellbeing and affect, respectively.

The other two studies employed a healthy population and were conducted in a historical Persian garden in Iran [216] and gardens in general in Canada [212]. The population types studied were green space visitors [215, 216] and students [212]. The studies focused on subjective wellbeing [216] and mental health [212]. Both studied a visit to a green environment.

Forest

In four studies the forest was the focal point. Two studies were conducted in the UK [217, 219], one in Australia [134], and one in Malaysia [218].

Two studies focused on a clinical population [130, 217], one study included both a clinical and a general population [219], and one study included a general population [218]. Two studies focused on elderly dementia patients [134, 217], two studies on green space visitors [218, 219], and one also included patients with a physical disorder [219].

Three different mental health outcomes were studied; subjective wellbeing [217, 219], affect [134], and restorative effect [218].

Three studies investigated a visit to a green environment [217-219], and in one study it was viewing a green space [134]. This latter study also used an indirect green space exposure (Virtual Reality).

Trees and other plants

One study from the UK focused on trees and other plants, by comparing effects of plants and bushes in full bloom (spring) versus only green (summer) [200]. See Table 29 for further details.

Other green space type

One study from Canada included not only gardens and parks but also local trails and conservation areas [212]. See Table 29 for further details.

Other green space characteristic

One study from Denmark looked at the relevance of general natural features for restoration outcomes [220]. See Table 29 for further details.

Overview experimental, cross-sectional and longitudinal, and qualitative studies

The previous sections have focused on the three study types (experimental, cross-sectional and longitudinal, qualitative) separately. In this section, the outcomes of the three study types are brought together and compared in terms of composition, land of origin, and outcome.

Figure 6 shows the different green space categories across the study types. The cross-sectional and longitudinal studies had most studies that enabled comparison, followed by the experimental category, whereas none of the qualitative studies enabled comparison. All three study types had a large focus on the park and the forest, while the cross-sectional and longitudinal studies also included a relatively high number of studies on trees and other plants and urban green space.

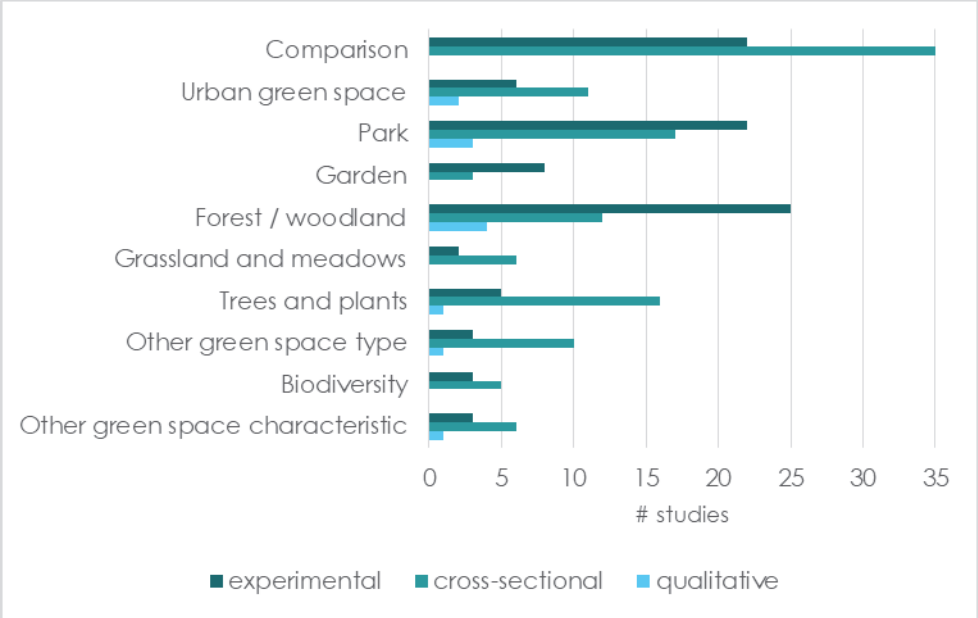

Figure 6. Overview of the green space categories division across the three study types

Figure 7 shows the land of origin for each study type. Most studies in the cross-sectional and longitudinal category and the qualitative category came from Europe, whereas most studies in the experimental category were conducted in Asia, followed by Europe. A relatively high number of studies from Australia were in the cross-sectional and longitudinal category, see Figure 7.

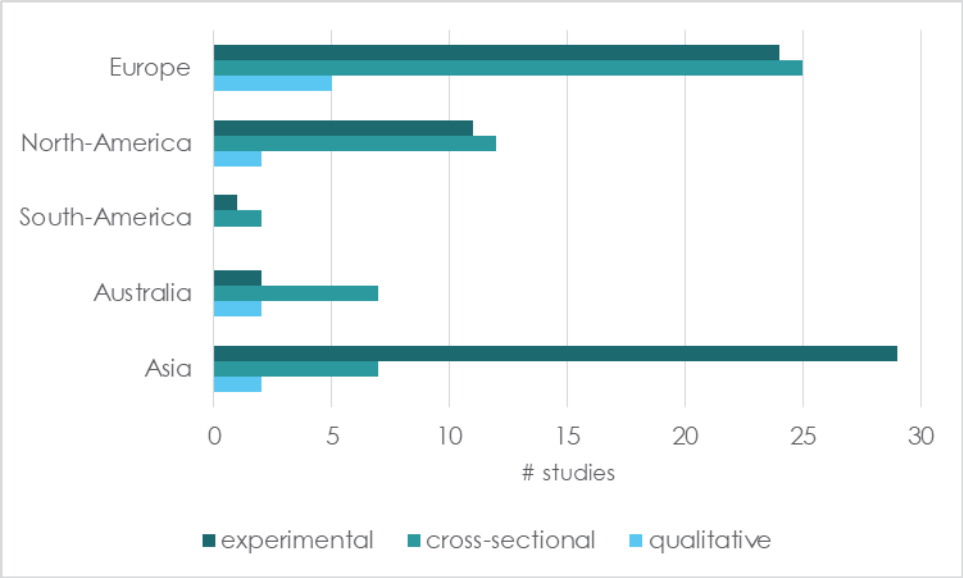

Figure 7. Overview of division of the three study types across continents

With regards to the mental health outcomes that were studied, there was a clear focus of the experimental studies on affect and physiological stress. The cross-sectional and longitudinal studies were more heterogenous in terms of mental health outcome, but most studies focused on mental health and subjective wellbeing. Perhaps logically, the experimental studies focused most on momentary measures of mental health, whereas the cross-sectional and longitudinal studies included more long-term effects of exposure to green, see Figure 8. The qualitative studies focused more on subjective wellbeing followed by restorative effect, affect and mental health.

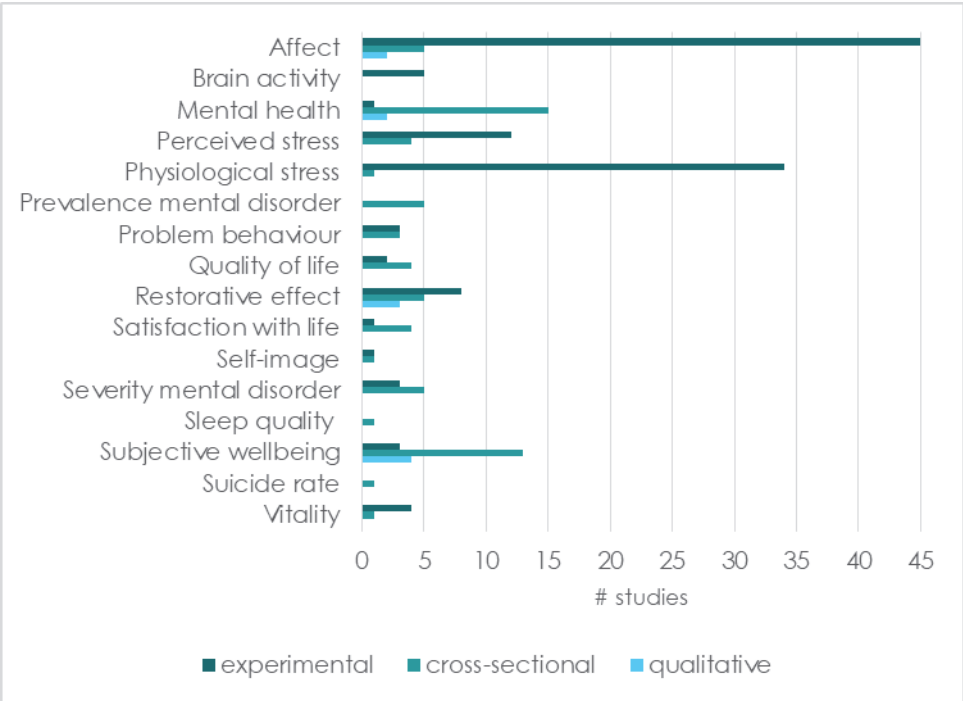

Figure 8. Overview of the health outcomes studied across the three study types

Figure 9 details the population types examined across the three study types. The majority of the experimental studies included a convenience sample of students, whereas many of the cross-sectional and longitudinal studies included nationwide sampling of respondents. The qualitative studies, on the other hand focused mainly on green space visitors. Green space visitors were also sampled frequently in the quantitative study types. Additional population types examined included the elderly and employees most frequently for the experimental studies, and schoolchildren in the cross-sectional and longitudinal studies (Figure 9).

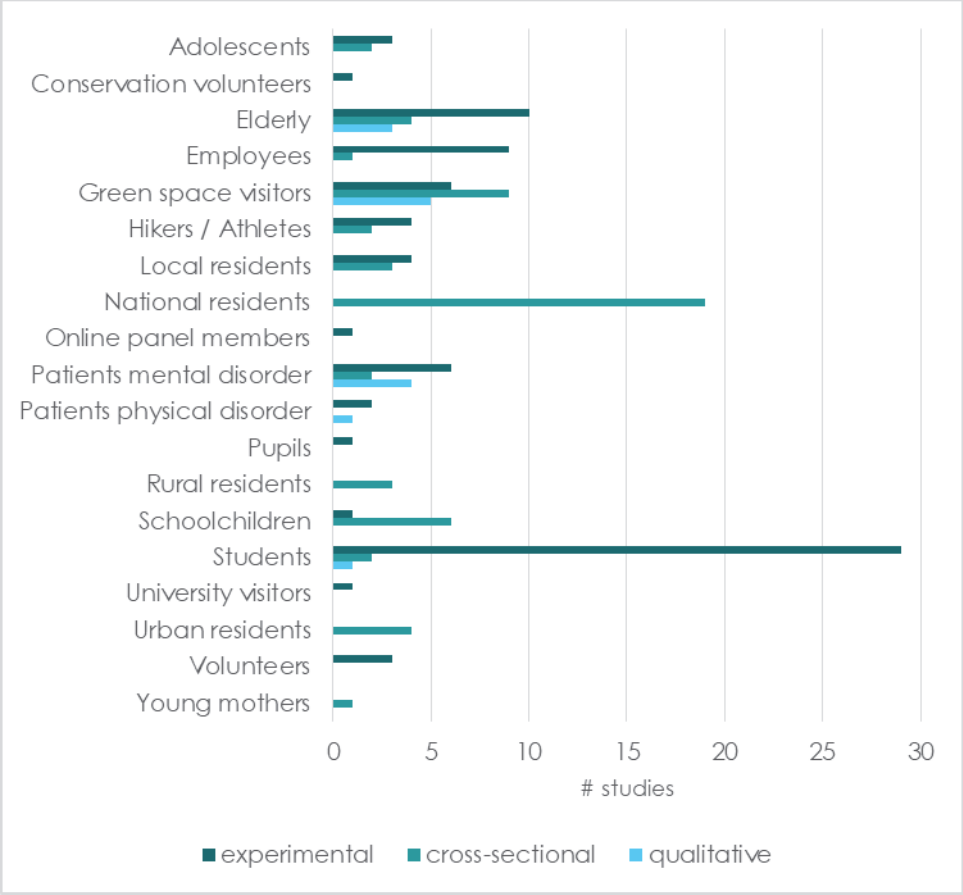

Figure 9. Overview of the population types included in the three study types

Figure 10 displays the environmental assessment area. These are the areas that were the focal point of the studies which tells something about the applicability of the results. Results for a school environment, for instance, may differ from results for a residential area. There were again two categories that stood out. For the experimental and qualitative studies, this was the green space visited, whereas a large majority of the cross-sectional and longitudinal studies focused on the residential area. Viewing green space received some attention in the experimental studies, whereas a green space visit was the second largest area of interest in the cross-sectional and longitudinal category. All other assessment areas were focused on infrequently, see Figure 10.

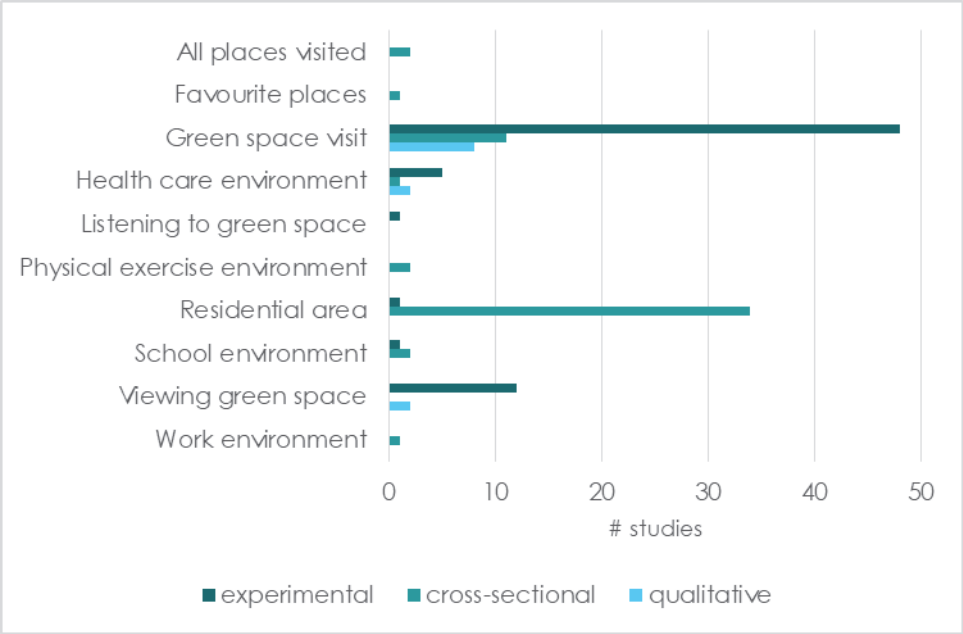

Figure 10. Overview of the division of the environmental assessment area across the three study types

The timeline of the included papers is displayed in Figure 11, which shows that most papers in all categories were from the last 5 years and, in addition, there is a steady increase in relevant papers over the past two decades.

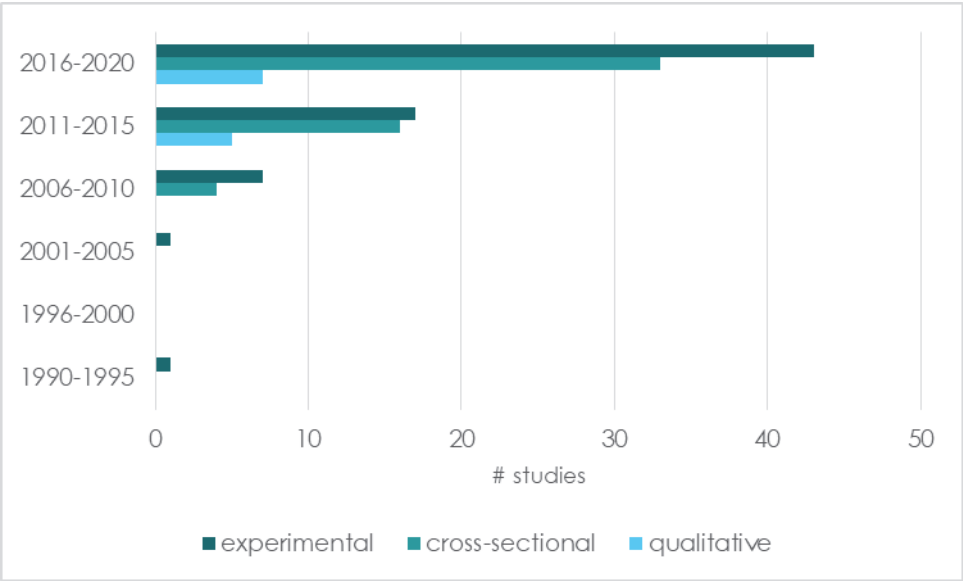

Figure 11. Timeline of the included papers across the three study types

3.3.2 Narrative synthesis

The narrative synthesis consisted of four consecutive steps: revisiting the theory of change; performing a preliminary synthesis (for both the descriptive and narrative synthesis); exploring relationships within and between studies in the narrative synthesis; and assessing the robustness of the synthesis [82]. As for the two quantitative (experimental and qualitative) categories, studies comparing different green space types and / or characteristics, either directly or indirectly, provided the most information suitable for the narrative synthesis and will therefore be discussed in the beginning of each section.

Experimental studies

The narrative synthesis of the experimental studies starts with discussing the studies that enabled a comparison between green space types and / or characteristics, either directly or indirectly. After that, the experimental studies focusing on green space characteristics is discussed, followed by experimental studies looking at pre- and post-measurements following exposure to a single green space type and then experimental studies that compare effects of green space types with urban (built-up) areas.

Urban green space

Nine experimental studies enabled a comparison. Two studies compared effects of urban green space with those of another green space type. The first study, conducted in the UK and of moderate quality, used a pre-post design to compare the effects of a visit to three different types of urban green space for conservation volunteers [97]. The results pointed at lower perceived stress for the community green space, characterized by a mix of forest and grassland than for two other green areas, one with a mosaic of fenland, meadow, and woodland and the other one with a large green field surrounding woodland near semi-urban housing. Positive affect increased the same for all three locations. A second study conducted in Italy and also of moderate quality compared restorative outcomes for visitors of urban versus peri-urban green spaces with high versus low biodiversity [99]. This study reported better restorative outcomes for visitors of peri-urban green spaces (pinewood forest and protected reserve) than for those visiting urban green spaces (urban square and park). High biodiversity (urban park and protected reserve) also scored better than the areas with low biodiversity (urban square and pinewood forest). Longer visits resulted in better outcomes. The authors also looked at the types of activities visitors were engaging in and how this affected restorative outcomes. Better outcomes were found for those that were contemplating the setting or walking / exercising than for those who were reading, talking, or socializing in the green space. One additional study looked at the characteristics of urban green space. This study from Japan and of moderate quality found better mood outcomes (less fatigue, anxiety-hostility, total mood disturbance) under the tree canopy than in sunny areas on campus [98].

Urban green space was investigated in three further studies. One good quality study from Finland found that employees who went for a walk in nearby urban green space during lunchtime experienced less strain in the afternoons after the walk, whereas fatigue remained unaffected [94]. A similar effect was found when doing relaxation exercises. The other two studies were both from the UK, of moderate quality, and both employed mobile EEG devices to measure brain activity while

visiting green spaces. The first study found that EEG-signals related to engagement were stronger for an urban green space than for a busy and quiet urban area, whereas excitement was higher in the busy urban area and frustration was lower in the urban quiet area [95]. The second study pointed at lower frustration, engagement or alertness, and long term excitement in an urban green space than in a busy urban area, whereas meditation was higher in the green urban area than in the busy urban area [96].

Park

Eight experimental studies compared mental health effects of a park with another green space type. Six studies compared the park with the forest [110, 111, 118-121]. A visit to the park was compared in five of the six studies and all five studies found superior effects of the forest over the park for some (but not all) of the indicators [110, 118-121]. An urban park and an urban forest were compared in three of these studies, all conducted in Finland with employees as participants with two studies of moderate quality [118, 119] and one study of good quality [120]. A first study found no difference between the two environments on restorative effect or vitality, but found less negative emotions in the park than in the forest [118]. A second study found better restorative outcomes and vitality after walking in the forest than after walking in the park [119]. The third study focused on physiological stress and found no difference in heart rate or blood pressure between the two environments, but a better heart rate variability in the forest than in the park [120]. A fourth study, conducted in the USA and of moderate quality, found better outcomes for cortisol and joy for visitors of the forest than for visitors of the park and no difference on perceived stress between the two environments [121]. In the fifth study, conducted in Austria, pupils were taken on lunch breaks in one of three environments: a busy, small urban park with few trees; a larger park with clusters of trees; and a larger broadleaved forest with meadows [110]. There was no difference in subjective wellbeing scores when the pupils where in the different environments, but there was a smaller decline in subjective wellbeing after returning to the classroom for the forest than for the parks. No difference in subjective wellbeing was found between the two different parks. The sixth study of moderate quality from Australia compared the effects of viewing a video of an urban park with viewing a video of a wild forest and found no difference between the two environments on negative affect, whereas more positive affect was reported when viewing the wild forest than the urban park [111].

Two other studies compared an urban park with a wilderness type setting in the USA [100], and the park with a footpath along a canal [105] in the UK. Both studies were of moderate quality. No difference was found on affect between walking in the park or walking along the canal [105], whereas the wilderness scored better on physiological stress and affect than the park [100]. The wilderness and the park both resulted in a (similar) decrease in perceived stress.

Characteristics of parks were investigated in three studies, all of moderate quality. A Chinese study compared responses of students to videos of urban parks differing in openness, and also compared to an urban road [107]. This study indicated that skin conductance reduced when viewing a lawn (with and without people), a small lake, and a walkway, indicating lower stress levels. Heart rate was lower (again related to lower stress) after viewing a small lake and a walkway, but not for the lawn. There was no effect on skin conductance or heart rate for a plaza or an urban roadway. A second Chinese study investigated effects of the greenness of the park, the soundscape of the park, and the

visibility of the sky [112] on affect. This study revealed no effect of greenness of the park or sky visibility on affect, whereas acoustic comfort was positively related with positive affect, relaxation, and energy. The third study, from the USA, used an (indirect) representation of a park at night, manipulated on the level of light pollution and found that students reported better affect when they viewed parks with lower light pollution [113].

Time spent in the park was the main focus in three studies of moderate quality, all conducted in the USA [101, 102, 108]. All three studies found a positive effect of time spent in the park on some indicators of mental health, whereas one study also found a negative relation [102]. A first study, among the elderly, found that people with higher stress levels stayed longer in the park than those with lower stress levels [101]. Longer stays were also related with lower blood pressure. No effects were found for visit frequency and stress levels and mental health. A second study looked at the relation between time spent in the park and affect, and found that longer stays were associated with lower anxiety, but also with more tiredness [102]. The effects on anxiety were more pronounced for high-stress individuals. No effects were found on relaxation or energy. The third study found that positive affect and satisfaction with life were higher after the park visit and that longer visits to the park were related to a higher satisfaction with life [108].

The remainder of the studies (six) compared the park with an urban (built-up) area. All reported at least one positive effect [104, 106, 114-116, 189], and were of moderate quality. One research group in Japan contributed four studies, all with a focus on affect and physiological stress and with students (only males or only females) as participants [114-116, 189]. These studies all found positive affect of a visit to the park compared to an urban area on affect, anxiety, and physiological stress (heart rate, heart rate variability). One study reported no effect on the mood sub-scale depression [116], and one study found no differences in blood pressure and pulse rate [189]. A study from Lithuania among patients with a coronary artery disease found that affect improved and cortisol and blood pressure decreased after the park visit, but not after the visit to the urban area [104]. A study from tropical Malaysia among students also reported beneficial effects of the park, with lower cortisol levels and blood pressure and better mood after the park visit than after the visit to the urban area [106].

Two studies of moderate quality compared pre-and post-measurements for a visit to the park and both reported positive effects of a park visit [103, 109]. In France, affect was better for those that participated after the park visit than for those that were asked before the park visit [109]. A study from China with elderly participants reported beneficial effects on anxiety, depression, contentment, and relaxation with more pronounced effects for the active park lingerers than for walkers [103].

Garden

Two experimental studies compared different types of public gardens [125, 129], both studies were of moderate quality. One study from China compared an unstructured garden with a Japanese garden and found increases in physiological stress when viewing the unstructured garden in terms of heart rate and skin conductance but not for heart rate variability [225]. The second study, from Canada compared three different garden styles; botanical garden, Japanese garden, and architectural garden. No difference in physiological stress were found between the three gardens but affect was generally better for the Japanese garden than for the other two gardens [129].

Four studies were conducted in a healthcare environment, three studies in a (closed) dementia ward [122-124, 128] and one study focused on a hospital garden. Three studies were conducted in the USA [122-124], one study was conducted in Japan [128] and one of these studies was of good quality [122]. This latter study found that dosage levels for primary antidepressants increased whereas antipsychotic medication prescription decreased for dementia patients after implementing a wander garden. On the other hand, it was found that the secondary antidepressant dosages (patients requiring a second medicine against depression) decreased. Frequent users of the wander garden needed less antidepressant medication and also less antipsychotic medication than low users. A second study from this research group [123] also reported lower medication use after the implementation of a wander garden, as well as lower levels of perceived agitation. On the other hand, an increase in incidents involving personal harm was reported after the implementation. A third study using dementia patients compared a Japanese with a non-Japanese garden and found lower pulse rates after installing the Japanese garden and more positive comments about behaviour after installing both gardens [128]. The fourth study, focusing on lunchbreaks for nurses, found that going outdoors in the garden resulted in better scores on two of the three indicators of burnout (emotional exhaustion and depersonalization, not on personal accomplishment), and positive effects were found on affect but only when the lowest 10 % of the scores were taken out of the analysis [124].

One study from Korea of good quality compared viewing pictures of a traditional Korean garden versus an urban environment [126]. The images of the garden scored better on affect and anxiety than the urban images, whereas no difference was found on vigour. There were also differences in brain activity, with lower activation in the prefrontal cortex when viewing the garden images.

The last study was conducted in Peru and of moderate quality, comparing participants that had created a garden versus those that did not create a garden. Those that had created a garden had lower perceived stress after six and twelve months after the garden creation and reported a higher quality of life twelve months after garden creation. No effect was found on blood pressure.

Forest and woodlands

In the park section, six experimental studies have already been reported in which the forest was compared to the park [110, 111, 118-121]. In general, the forest scored better on mental health outcomes than the park in these studies. One further study compared forests with a different green space type; visits to two types of forest (forest by the lake and spruce forest) were compared to a visit to rock outcrop for persons suffering from exhaustion disorder in a Swedish study of moderate quality [144]. A visit to the forest by the lake resulted in a lower heart rate than a visit to a spruce forest or to a rock outcrop, whereas both forest environments scored better on blood pressure than the rock outcrop.

Three studies investigated specific characteristics of the forest [137, 138, 146], of which two were of good quality [138, 146]. One study of moderate quality from Switzerland compared a visit to a wild versus to a tended forest for students and employees [137]. This study found better effects for the tended forest than for the wild forest on positive and negative affect, but no difference on arousal or activation. A study in Japan compared a thinned forest with an unthinned forest [138]. No effect on

affect was found, but a better restorative effect was reported for the unthinned forest versus the thinned forest. A Taiwanese study among students tested effects of viewing images taken at different location within the forest (the interior, the edge, or the exterior) and found that brain activity signalled more relaxation in the interior of the forest than on the edge. Students also reported better mood when the images displayed the interior of the forest than when the images displayed the edge or exterior of the forest [146].

Ten studies compared the forest with an urban (built-up) environment [130-132, 135, 136, 140-143, 145]. The majority of these studies were of moderate quality (six) [130, 131, 136, 142, 143, 145], and three of good quality [132, 135, 141]. A visit to the forest versus an urban environment was the focus in eight of these studies, of which six studies looked at affect and physiological stress [130, 131, 135, 136, 141, 143]. All studies were conducted in Asia except one Danish study [143]. This Danish study on people with exhaustion disease found an improvement in affect after the forest walk, but reported no effect on physiological stress (measured with blood pressure and heart rate variability). Quite similar results were reported in the Asian studies for affect; better outcomes in (at least one parameter of) affect in the forest environment as compared to the urban environment were reported in almost all studies [131, 132, 135, 136). Better physiological stress outcomes (on at least one parameter) in the forest than in the urban built-up environments were, however, also reported in all these Asian studies. These effects were found for students [130, 142] and people with hypertension [141].

Affect was measured with the Profile of Mood States (POMS) scale in six studies [226], this scale is composed of six dimensions: tension / anxiety, anger / hostility, vigour / activity, fatigue / inertia, depression / dejection, confusion / bewilderment. Tension / anxiety was overall lower in the forest than in the urban environment in three studies [132, 141, 142], while one study found no effect [131]. No effects of a forest environment on tension / anxiety or anger / hostility were found in one further study, but this study did report an increase over time in tension / anxiety as well as anger / hostility for the urban environment [135]. Anger / hostility was lower in the forest in three studies [131, 141, 142], whereas another study did not find an effect [132]. Vigour increased and fatigue was lower in the forest in five studies [131, 132, 135, 141, 142]. Depression was lower in the forest in two studies [141, 142], with one study reporting more pronounced effects for people scoring high on anxiety [142], and three studies found no effect of the forest versus an urban environment on depression [141, 142, 135]. The sixth dimension, confusion, was lower in the forest for four studies [132, 135, 141, 142], and no effect was found in one study [131]. One study only reported negative effects over time of the urban environment and no positive effects of the forest on affect [136].

Heart rate was lower in three studies [130, 136, 141] in the forest compared to the urban environment, while heart rate variability improved in two studies [135, 136] and mixed results for heart rate variability (improved for only one of the two indicators) were found in yet another [141]. Diastolic blood pressure was lower in the forest in two studies, whereas no effect was found on systolic blood pressure in the same studies [130, 136] and one study found no effect on blood pressure at all [135]. Cortisol levels were lower in the forest than in the urban environment in one study [130], and another study found no difference in cortisol levels [135]. Brain activity was tested in

one study, which revealed greater stability in the prefrontal cortices for the forest than for the urban environment [131].

One of the studies also investigated the role of activity on the beneficial outcomes of a forest visit and included restorative outcomes and vitality as outcome variables [132]. This Japanese study found that better restorative effects occurred and vitality was higher when participants were walking as opposed to viewing the forest. Besides actual visits to a forest versus an urban environment, there was one study that employed a Virtual Reality representation of the forest versus a commercial shopping street [140]. This study revealed no effect on physiological stress (heart rate, α-amalyse, blood pressure) but less negative affect (anger/hostility, tension, fatigue, confusion, depression) and more vigour in the forest. One study from Japan investigated the sound of a brook in the forest [145] compared to a busy intersection. This study reported better scores for tension / anxiety, anger / hostility, vigour, fatigue, depression and confusion for the forest sounds. In addition, lower heart rate and better heart rate variability were reported and more activity in the left and right prefrontal cortex.

Effects of the forest were investigated with pre- and post-measurements without a comparison environment in four studies of moderate quality [133, 134, 139, 147]. A visit to the forest was investigated in two studies from Japan [133, 147]. The first study revealed positive effects of the forest visit on affect and anxiety for volunteers [133], but also an increase in boredom in the forest over time. The second study revealed better affect, lower perceived stress, and lower blood pressure after the forest visit [147]. At the same time, Chromogranin A (a marker for mental stress, with higher levels signalling more mental stress) was higher directly after the walk but lower forty minutes after the walk than before the walk. Viewing the forest in videos or in Virtual Reality was the focus in two further studies, from Japan [139] and Australia [134]. A pilot study investigated the effects of viewing a video of the forest (versus the sea) [139] and found that vigour and confusion decreased while watching the forest video for those that preferred watching the sea. A study among dementia patients employed a forest in Virtual Reality and found that patients expressed more pleasure and alertness, but also more anxiety while viewing the virtual forest. No effects were found on negative affect [134].

Grassland and meadows

Two of the three experimental studies within the grassland category enabled a comparison, both of moderate quality. The first study, from the UK compared running in different environments: grassland, a heritage park, beach, and the riverside [149]. The study reported better outcomes for self-image, stress level, and affect after the run (as well as an increase in fatigue), but no differences were found between the environments. The second study compared a visit to a managed versus an unmanaged meadow in Austria and Switzerland and found no difference between the two environments on perceived stress or subjective wellbeing [150]. Furthermore, the three meadows were also compared to a riverside and two different urban environments. Heart rate was highest at the river, while the lowest heart rate was found in one of the urban areas and one of the meadows. Perceived stress was lowest and wellbeing was highest at the riverside and for the most remote meadow.

The third study, of good quality, was conducted in the UK and among adolescents and investigated effects of being on a grassy plain outside a building. Heart rate and blood pressure decreased after being on the grass, whereas no effect was found of spending time on the grass on affect (affect was overall better compared to an indoor environment) [148].

Trees and other plants

Two of the four experimental studies within the trees and other plants category enabled a comparison. A study from Taiwan of good quality compared the effects for tending short-term plants (spinach and lettuce) versus long-term plants (tomato and spring beans) on the quality of life for stroke patients [151]. Tending short-term plants resulted in a better social role than tending long-term plants, which was more pronounced for females. An exact opposite pattern occurred for another component of quality of life; family role. Here, tending long-term plants resulted in better outcomes, and this effect was more pronounced for males. The second study stemmed from Greece and was of moderate quality [152]. The effects of viewing trees or plants during different seasons on patients suffering from psychosis were investigated using biometric measures. The time percentage of joy was greater for green shrubs than for flowering shrubs, a green tree, and a tree in autumn foliage. The time percentage of positive emotions was greater for the tree in autumn colour than for the green and flowering shrubs, and the green tree.

The two other studies in this category were both of moderate quality and from Asia, namely China [153] and Japan [154]. In China, the effect of walking on streets surrounded by different types of roadside trees (Sakura, London plane, Metasequoia) versus a control road with no trees was investigated [153]. The participating students reported better affect (lower tension / anxiety, anger / hostility, fatigue / inertia, depression / dejection, confusion / bewilderment, higher vigour / activity), lower anxiety, and greater vitality on the roads with trees compared to the control road. No differences were found between the three different tree types. Climbing in an artificial tower versus a real tree was tested in the Japanese study [154]. While climbing the tree, vitality was higher and tension, fatigue, and confusion were lower than while climbing the tower. The climbers also reported better restorative outcomes. Physiological measures pointed at higher activation of the autonomic nervous system after climbing the tree, but also a worse heart rate variability while climbing the tree compared to the tower.

Other green space type

One experimental study from the USA of good quality looked at green stormwater infrastructure and implemented multiple different interventions at different locations to create green stormwater infrastructure versus a control group (waiting list) [157]. No effects were found of the interventions on high blood pressure or high stress.

Biodiversity

Three experimental studies of moderate quality from the UK [154], Italy [99], and Taiwan [156] tested for effects of biodiversity on mental health. No influence was found for elderly participants of perceived bird, butterfly, and plant/tree biodiversity on affect after going for a walk [155]. In Italy, urban and peri-urban areas with higher biodiversity resulted in better restorative outcomes than

urban and peri-urban areas with low biodiversity [99]. The Taiwanese study included the biodiversity parameters of richness, abundance, and diversity in a range of different green space types: green urban space, farmland, and mountains [156]. No effect was found on EMG, heart rate, or blood volume pulse, whereas settings with more homogeneity in biodiversity resulted in a lower heart rate.

Other green space characteristic

Three experimental studies looked at a diverse set of other green space characteristics [158-160]. A study in Portugal with moderate quality among students and employees investigated the effects of three-dimensional videos of contemplative versus non-contemplative spaces [159], with contemplative being characterised by long vistas, lush seemingly-wild vegetation, presence of symbolic elements, and smooth landforms. No effect was found on prefrontal alpha asymmetry, associated with positive affect. A study among schoolchildren in Sweden investigated the school environment in terms of a number of factors (OPEC: accessibility; proportion containing shrubs, trees, hills; degree of integration between vegetation, open area, and play structures) as well as sky visibility [158]. No effects were found for sky visibility on hyperactivity / impulsivity or inattention. Higher scores on the OPEC measurement were found related to less inattention. Less hyperactivity / impulsivity was also found for higher scores, but only after deleting three outdoor schools. The third study was of good quality and was conducted in the UK among students [160]. A real walk in areas differing in the level of prospect and refuge was compared to a video of the same walk. Environments high in prospect and low in refuge resulted in an increase in positive affect and a decrease in negative affect and heart rate compared to environments low in prospect and high in refuge, and all effects were more pronounced in the laboratory than during the real walk.

See Table 30 for a summary of the narrative synthesis, displaying the outcomes (positive, neutral, and negative) per mental health outcome and per green space category.

Table 30. Summary table for the positive, neutral, and negative outcomes per green space category and mental health outcomes for the experimental studies.

	Mental health			Severity mental disorder			Prevalence mental disorder			Satisfaction with life			Quality of life			Subjective wellbeing			Affect			Vitality			Restorative outcomes			Perceived stress			Physiological stress			Problem behaviour			Brain activity		
	+	□	-	+	□	-	+	□	-	+	□	-	+	□	-	+	□	-	+	□	-	+	□	-	+	□	-	+	□	-	+	□	-	+	□	-	+	□	-
UGS																			4	2	1				1	1		2											
Park		1		4						1						1	1			2		2			4			3	2		8	11							
Garden				4	2	1							1						2	2								1			3	3		3	1	1		1	
Forest				1																8	3	4			4			2	1			12	1						
Grassland																	1		2		1							1	1			2							
Trees & p				1									1						3	1		1			2						1		1						
Biodiversity																				1					1	1					1	1							

Cross-sectional and longitudinal studies

For the cross-sectional and longitudinal category, again, each section starts with comparisons between different green space types and characteristics. After that, studies looking at availability and / or proximity studies of green space types are discussed, followed by studies into green space visits. A distinction is made between actual exposure to green spaces and studies using availability and proximity as proxies for actual exposure.

Urban Green Space

A total of seven studies enabled a comparison. Six studies compared visits to urban green space with other green space types, namely with a green corridor and farmland [168], countryside visits [162], open lawn with trees [165], the forest [166], rural green and coast [170], and rural green space [163]. Four studies investigated actual exposure to urban green space, and all four studies were conducted in the UK [162, 163, 168, 170]. Two studies found an inferior result for urban green space, both were of good quality [168, 170]. The first study compared walking in different environment types [168]. Stronger associations were reported for walking in farmland and green corridors than walking in urban green space on subjective wellbeing, affect, and perceived stress. The second study compared restorative outcomes of recent visits to a variety of green spaces [170]. Visits to urban green spaces produced less recalled restoration than visits to rural green and coastal areas. Looking at specific types within these broad categories, most urban green space environments (town park, open space, allotment, playground) had similar relations as visits to the countryside, one urban green space type – playing fields – had negative associations. Of the rural environments, a village and a country park also had similar correlations with recalled restoration, but other rural green environments – farmland, the forest, and hill / moor / mountain – produced better recalled restoration. The coast, but not river / lake / canal also produced better results in restoration than countryside visits. Two studies found similar relations of urban green space to that of rural green, but weaker relations for the coast, on restorative effect [163] and subjective wellbeing [162]. These studies were of relatively good and moderate quality, respectively.

Two studies used availability or proximity to urban green space as a proxy for actual exposure. A superior result of urban green space on satisfaction with life was reported, compared to the forest [166]. This study of good quality was conducted in Germany and found a positive association for urban green space and no association for the forest. The third study, from the USA and of moderate quality found equal correlations of urban green space and open lawn with trees on subjective wellbeing [165].

The seventh study investigated both the quantity and the quality of street greenery and green spaces [161]. Quality of street greenery was defined on five items (maintenance level, variation, clear arrangement, absence of litter, general impression), whereas the quality of green areas was defined on ten items (maintenance level, variation, clear arrangement, absence of litter, general impression, accessibility, naturalness, colourfulness, shelter, safety). This Dutch study of good quality indicated that both the quantity and quality of street greenery were positively related with mental health, whereas no relation was found between quality of green areas and mental health.

Four studies did not directly allow for comparisons [164, 167, 188, 227]. Two of these studies investigated actual exposure [164, 227]. A study from Finland of good quality indicated that restorative outcomes were higher for favourite places in waterside environments, extensively managed nature areas and exercise and activity / hobby areas (of which 80 % were nature trails) than

in indoor and outdoor urban areas and built green spaces [227]. The second study, of moderate quality and from China, found that increased frequency of visits to community / green squares was positively related with subjective wellbeing [164].

One study used availability as a proxy for exposure and was conducted in the USA [167]. This moderate quality study reported both a positive and a non-significant association [167]. Both larger forest patches and a greater number of forest patches within the city were related to a better quality of life, but no associations were found for mean patch size or the irregularity of the shape of the patches.

Park

Twelve studies enabled a comparison involving parks. Five of these studies compared parks with other types of green spaces [33, 43, 75, 164, 179]. Three of these studies reported superior results for parks [33, 43, 75], three of these studies were conducted outside Europe [33, 75, 160], two of them were of good quality and both looked at actual exposure [33, 43]. Eight studies either compared different park types or qualities within the park [164, 171, 172, 174-176, 178, 182], of which one study also enabled a comparison of green space type [164].

Four studies investigated actual exposure to green space [33, 43, 179, 164], two studies were of good quality [33, 43] and two of moderate quality [164, 179]. In Iran, it was found that spending time in parks for adolescents was better for self-image than spending time in the forest, whereas similar results were reported for the park and the private garden [33]. All three environments had an equal and positive relation with the number of social contacts and time spent with friends. A study conducted in the United Kingdom [43] found that engaging in physical exercise in parks (and sport pitches) resulted in better subjective wellbeing than for physical exercise in forests, garden, and the beach. The same study also reported better outcomes on mental health for parks (as well as in the forest) than physical exercise at home or in the garden, at sport pitches, and at the beach. A study from Switzerland found positive relations between a park visit and subjective wellbeing and stress, but this association was equal to a visit to a forest [179]. A Chinese study included both a park and urban green space [164]. In this study, it was found that visits to community / green squares and city parks had a positive relation with subjective wellbeing, whereas no association was found for the larger country parks.

One study of moderate quality included either availability or proximity measures as proxy for actual exposure [75]. A better quality of life was reported for schoolchildren in Canada living with a higher percentage of park space around the residence area, whereas a negative association was found with the percentage of grass and shrubbery [75].

Eight studies investigated specific types or qualities of the park [164, 171, 172, 174-176, 178, 182]. Three studies were of good quality and conducted in Mexico [175], Australia [178], and the USA [176]. The first good quality study [176] only found positive associations, with inhabitants of cities with more park coverage as well as more park amenities scoring higher on subjective wellbeing. The second study [175] also found that a larger park coverage was related with lower depression scores for women, but found no interaction of park coverage and park quality (e.g., bathrooms, lighting, playground). The third study [178] investigated park coverage together with attractiveness of the parks, operationalized as an weighted mean of nine variables; lawn irrigation, walking paths, shade along the paths, sporting facilities, being close to the beach or river, water features, bird life, surrounding roads, and lighting. This study reported no association of park coverage or the number

of parks bigger than 0.3 hectare around the residence with psychological distress, but found a negative association for mean attractiveness with higher attractiveness of the parks associated with higher odds for being in the high psychological distress group.

The other five studies were of moderate quality [164, 171, 172, 174, 182]. The moderate quality studies also reported mixed results. A study conducted in Singapore found no significant relation between park connectors, neighbourhood parks, or regional parks on subjective wellbeing [171]. An Australian study did find positive associations, which also differed between park types [172]. Small (< 0,4 ha), district (5-20 ha), and regional (> 20 ha) parks were significantly related with better mental health, whereas no such relation was found for local (0,4-1 ha) and neighbourhood (1-5 ha) parks. Larger parks appeared to have stronger associations, whereas the study also pointed at stronger associations for the presence of sports amenities than for nature. One study from Mexico of moderate quality looked at relationships between different components within a park environment during a park visit and wellbeing [182]. Bird song, naturalness degree, park area, the presence of walking trails, and safety had a positive relation with wellbeing, whereas the height of trees and distance had a negative association. The other two studies were conducted in China. These studies found positive association between the number of trees in the park on quality of life of the elderly [174], whereas no relation was reported for park area, amenities, aesthetics, paths and visibility and paths in the park and a negative effect for the number of parks and the number of activities in the park. In the second study, a positive association of the number of visits to city parks, but no relation for the number of visits to country parks, was found with subjective wellbeing [164].

Five studies did not allow for a direct comparison but still provided information about the relation between mental health and parks [173, 177, 180, 181, 183]. Two studies looked at associations of park visits with mental health [177, 183]. One of these studies, from Singapore, was of good quality. This study found greater odds of experiencing happy moments in parks, while momentary happiness was not affected by park visits [177]. A moderate quality study from Australia found both a positive and a negative association with park visits [183], comparing outcomes from the Australian park visitors to the general score on the scales in the UK. Australia park users scored lower on stress levels, but reported poorer mental health then the general population from the UK. Three of these studies only looked at availability [173, 180, 181]. Two of these studies were of good quality [180, 181], and conducted in Singapore [181] and the USA [180]. These studies reported no association of park space with problem behaviour of schoolchildren [180] and a positive relation of residential park area with mental health for the general population, with no relation with distance to parks [181]. One study was of moderate quality and conducted in Lithuania [173]. This study investigated associations of park availability on schoolchildren, with positive relations found on problem behaviour for children whose mothers had a low educational background (no relations for children of mothers with a high education) [173].

Garden

A garden was only compared to other environments in two studies, which have previously been discussed in the park section [33, 43], with lower benefits of exercising in the garden compared to the park or forest on mental health, and compared to the park and sports pitches on subjective wellbeing [43]. Self-image was better with increased time spent in the private garden (and the park) than in the forest [33].

One good quality study from the UK investigated the availability of gardens [184]. This study found that having a personal patio increased subjective wellbeing, whereas no associations were found

with having a personal or shared back garden, front garden, balcony, or courtyard. A greener view outdoors was also related to better subjective wellbeing, but the number of trees in the view did not affect subjective wellbeing.

Forest / Woodland

Eleven studies compared associations of the forest with other green space types. Five of these studies have already been discussed at the park or green space comparison section [33, 43, 166, 170, 179]. These five studies found mixed results; inferior results of the forest compared to either time spent in the park or the private garden on self-image [33] and compared to exposure to urban green space on satisfaction with life [166]; superior results of the forest compared to urban green space and countryside visits on restorative effects of recent visits [170] as well as compared to the garden, sports pitches, and the beach as a physical exercise environment for mental health [43]; and positive, but equal, relations of a visit to the forest and to a park [179]. Besides superior results, the forest as a physical exercise environment scored worse than parks and sport pitches on subjective wellbeing.

The remaining seven studies also show a mixed pattern of results. Two studies from the UK looked at actual exposure to the forest [191, 228]. The first study, of good quality, found that trees and woodland in view from the office, together with lawn/ mowed grass, bushes and flowering plants, grassland, and heathland had a better associations with subjective wellbeing than meadows / rough grass and a distant field / countryside [191]. The second study, of moderate quality, found positive associations between a large range of natural settings, including the forest, grassland, enclosed farmland, and heathland and affect as compared to inland bare ground [228].

Five studies used availability or proximity as a proxy for the actual exposure [186-189, 192]. Two studies of good quality reported positive relations of mental health with the forest. A study from the USA reported positive associations for the percentage of forest and mental health, whereas no association was found with herbaceous plants and a negative association for shrubland [186]. A Korean study found that higher scores on forest area and forest volume per capita and per district were related with lower rates of depressive symptoms [189]. Two studies found inferior results for the forest, both were of good quality and were from the USA [184] and the UK [192]. No relation between the prevalence of autism and percentage of forest was found, whereas more grassland was associated with a lower prevalence of autism [188]. Moving to an area with more broadleaved or coniferous forest did not improve mental health and neither did moving to an area with more arable land or semi-natural grass. On the other hand, an improvement in mental health was reported for moving to an area with more mountain / heath / bog and with more improved grassland [192]. A Belgium study of moderate quality [187] reported mixed results. On the one hand, a positive relation between forest and affect, compared to no association for agricultural land. At the same time, the study also reported an opposite pattern for problem behaviour; no associations were found for the forest whereas agricultural land lowered hyperactivity levels of schoolchildren.

Grassland and Meadows

Six studies have compared grass or grassland with other types of green spaces. These studies have all been discussed in the previous sections, but generally show a mixed pattern. Only grass, and not forest, lowered autism prevalence [188], but grassland taken together with shrubland had a negative association with schoolchildren's quality of life compared to park space [75]. An open lawn was found

to have similar results on subjective wellbeing as social green space [165]. Two studies also compared different types of grassland (as well as with other green space types). These studies found superior results of lawn / mowed grass over rough grass on subjective wellbeing [191], while the other found better outcomes on mental health for moving to an areas with more improved grassland than for moving to areas with more semi-natural grass [192]. A sixth study compared relationships between being in a large range of natural settings, including the forest, grassland, enclosed farmland, and heathland and affect as compared to inland bare ground [228].

One study did not allow for comparison [193]. This Australian study of good quality reported that the percentage of grass around the residence was not related to depression, anxiety, or mental health.

Trees and other plants

The majority of the studies in this category looked at relationships of tree canopy coverage or street tree density with wellbeing. Eleven studies focused on tree canopy, of which seven studies were conducted in the USA and all studies used proximity or availability as a proxy for actual exposure. Beneficial associations of tree canopy with mental health were reported in nine of the eleven studies, all of good quality, on mental health [181, 193, 196], prevalence of a mental disorder [188, 194], the severity of a mental disorder [197, 199], sleep quality [198], and problem behaviour [180]. Two of these studies [188, 196] only found positive relations in sub-analyses. One study reported lower prevalence of autism with a higher percent of tree canopy, but only for the areas with the highest traffic density [188], while another study reported a positive relation between tree canopy and mental health, but only in cities with a majority of non-Hispanic Black inhabitants [196]. Two further studies reported non-significant relations of tree canopy coverage besides positive associations. A first study found a positive relation with psychological distress, but no relation with the prevalence of depression or anxiety [193], while the second study found positive relations on problem behaviour but not on all subdimensions of the scale [180]. One study of moderate quality found no relation between tree canopy coverage and mental health for students in Bulgaria [223]. Another study from the USA of good quality reported a negative relation between tree canopy coverage and the odds of moderate to high level of anxiety for children with autism. They did not find this negative relation for typical youth or children with other diagnoses [200].

Besides tree canopy, five studies also investigated plant coverage and tree characteristics. Three of these studies looked at actual exposure [182, 191, 195]. Two of these studies, both of moderate quality, investigated the influence of tree characteristics on mental health. In a study from Italy, it was found that tree stem size did not affect restorative effects, whereas a negative relation was found with stand density [195]. In Mexico, taller trees in parks were related to lower satisfaction with life for park visitors [182]. One study of good quality from the UK found a positive relation between the presence of bushes and flowering plants in view at the office and subjective wellbeing [191].

The two other studies used availability and proximity as a proxy for actual exposure [75, 186]. Both studies looked at vegetation and shrubland cover and both reported negative associations. Shrubland and dense vegetation were not positively related to mental health. A study of moderate quality from Canada reported no association of dense vegetation cover, and a negative relation between the percentage of shrubland with quality of life [75]. A study of good quality from the USA reported no relation of the size and edge contrast of shrubland patches or the percentage of herbaceous plant patches on the odds for frequent mental distress, whereas they did find a negative association of shorter distances between shrubland patches as well as of more connected shrubland patches [186]. One additional study, which also looked at tree canopy cover, did however report a positive relation

between vegetation cover and mental health [181], but in the analysis shrubs were taken together with grass.

Other Green Space Types

Four studies focused on agricultural land. Two of good quality from the UK [168, 170], and two of moderate quality from Belgium [187] and the UK [190]. Farmland scored better for recalled restoration from recent visits than countryside visits [170], had a positive relation with perceived stress and subjective wellbeing when walking through it [168], and increased happiness when visiting farmland [190]. More agricultural land in the residential area lowered hyperactivity in Belgium, but was not associated with affect [187].

Three studies looked at rural green areas; countryside [162, 191] and nature reserves [171]. The two countryside studies were both from the UK. Countryside views did not influence subjective wellbeing in a good quality study [191]. A study of moderate quality [162] indicated that countryside visits were not related with affect but were positively related to subjective wellbeing. Nature reserves in Singapore did not influence subjective wellbeing [171] in a moderate quality study.

Two studies of good quality found positive relationships of hills / mountains in the UK, with recalled restorative [170] and mental health [192]. Single studies found positive relationships of visiting heathland and affect [190], of physical activity in outdoor courts on subjective wellbeing but not mental health [43]. A greater distance to abandoned land was found to increase satisfaction with life [166] and inland bare ground was also found to negatively influence happiness [190]. Last, protected land had a higher recalled restoration score than non-protected land [163].

Biodiversity

All five studies in the biodiversity category were of moderate quality and all enabled a comparison on the characteristic biodiversity. A study from Australia [202] found a positive relation between both flora and fauna richness on subjective wellbeing. Similarly, a study from the UK found a positive relation between plant diversity and happiness, with more pronounced results for introduced species [203]. A second UK study found that a better restorative effect was reported when the perceived number of plant species was higher, but no association was found with the perceived number of native species, nor for the perceived number of (native) insects [200]. A Finnish study [206] among the elderly found a positive association between plant diversity and quality of life, but no relation for depressive symptoms. The fifth study, from the UK did not find an association with perceived species richness on subjective wellbeing [204].

Other Green Space Characteristic

One study from the UK with good quality compared protected with non-protected areas and found better restorative outcomes for the protected areas [163].

Three studies with good quality from Sweden investigated relationships of specific green space types (categorized according the same standard; wild, lush, serene, spacious, culture area) with mental health. One study reported an increase in vitality with more recreational area, but only for females and no relationship was found for the other three types [209]. A second study did not find an association of the four types with mental health, only an interaction between physical activity and access to serene and spacious areas [210]. The third study reported an improvement in mental

health for females that moved to more serene areas, but no relation was found with the other four types [211].

Two studies from Australia, both of good quality, investigated associations of dryland salinity [207, 208], with higher suicide rates in more saline areas [208] as well as an elevated risk for hospitalization with depressive symptoms [207].

See Table 31 for a summary of the narrative synthesis, displaying the outcomes (positive, neutral, and negative) per mental health outcome and per green space category.

Table 31. Summary table for the positive, neutral, and negative outcomes per green space category and mental health outcomes for the cross-sectional and longitudinal studies.

	Mental health			Severity mental disorder			Prevalence mental disorder			Satisfaction with life			Quality of life			Subjective wellbeing			Affect			Vitality			Restorative outcomes			Perceived stress			Physiological stress			Problem behaviour			Brain activity		
	+	□	-	+	□	-	+	□	-	+	□	-	+	□	-	+	□	-	+	□	-	+	□	-	+	□	-	+	□	-	+	□	-	+	□	-	+	□	-
UGS	1	1			1					1			1			3	1		1	1					1				1										
Park	3	2	2								1		1	1		5	1	1	1	1								2	1					2	2				
Garden		1															2											1											
Forest	3	2		1			1	1			1		1			2	1		2									1				1			1				
Grassland	1		2				1	1								1	1		1																				
Trees & p	2	2		1	1	1	3									1										1	1							1	1				
Biodiversity					1								1			1	1		1						1	1													

Qualitative studies

Because the separate categories (i.e., park, forest, garden, etc.) had too few studies each (four or less) to perform a thematic analysis, the analysis was performed on the entire dataset at once. However, when a specific theme or outcome applies to a specific green space type or characteristic only, this will be highlighted. The thematic analysis revealed five overarching themes: restorative experiences from natural features, social interactions, memories and symbolism, weather and seasons, and escapism.

Restorative experiences from natural features

Natural features were mentioned throughout the different qualitative studies. Trees were mentioned in relation to feeling safe, when walking under the canopy (forest: [219]). For example, someone referred to a primeval instinct to be in trees (forest: [219]), whereas another person found comfort and feelings of safety in old trees in the city (nature features: [220]). The interplay of the sun with the leaves in (tall) trees made some feel calm (garden: [216]; general greenspace: [212]), and tall trees were associated with reflection and helped put worries in perspective (forest: [219]). Trees and bushes were perceived as important elements in parks in Australia [183]. In a Persian garden in Iran, observations signalled that most activity took place under shady trees, on the grass, and along water features [216]. People talked about favouring variety and complexity in the forest landscape with some open views and clear sightlines [206].

Water features were also mentioned as calming (garden: [216]; general greenspace: [212]; nature features: [220]; garden: [214]). Sounds of water was especially perceived as relaxing. In a study in Iran [216], some interviewees indicated they would come back during the night so that they could hear the sound of the water features better. Quietness and birdsong were other “sounds” of nature that were appreciated (trees and other plants; [200]; forest: [219]). The importance of sound was also highlighted in the virtual forest [134]. Flowering plants, on the other hand, provided mixed results. For instance, they were found to be too stimulating and therefore hinder relaxation (trees and other plants; [200]), but the excitement and energy was also enjoyed and appreciated [183, 214]. Another aspect that made people feel calm was related to the senses; experiencing the ground, stepping on the leaves and sinking into the mud (park: [212]; park: [179]; garden: [214]).

A need for an experience of ‘raw nature’ was also expressed in the fact that human interference in natural settings were not always appreciated. Wild, or untended, forests were preferred (forest: [218]; [214]). In the UK, it was found that disabled persons could appreciate challenging areas in the forest and would not want all obstacles to be removed in order to facilitate their own access (forest: [219]). In the same study, it was mentioned that the preference for more wild nature may be different between life stages (e.g., a lower level of wilderness is preferred when you have children).

Social interaction

The presence of humans other than oneself in natural environments rendered mixed responses. In one study, with people visiting a rehabilitation garden, the general feeling was that people enjoyed being alone, and even explicitly searched for areas in the garden where they could be alone, at a distance from others [214] , in another study some talked about seeking solitude [206]. In a Danish study, a distinction was found between those living in shared housing, who went to the park to find personal space and to be ‘yourself’ and those living alone [220]. The social interaction with others was explicitly mentioned as a positive thing for a forest visit for dementia patients [217]. In a UK study watching others enjoying themselves in a forest could be a positive experience [206].

Memories and symbolism

Visits to the woods also brought back many childhood memories for dementia patients [217], but also for members of the general public [219, 220]. For instance, the flowers and scent of a particular tree brought back childhood memories of a family holiday [220]. Garden visits were perceived as beneficial for patients with dementia [213], whereas a Persian garden also triggered childhood memories for the general public [216]. The rehabilitation garden also helped people deal with bad memories, by facilitating reflection [214].

Reflection, contemplation, and taking psychological distance from daily hassles and worries were often mentioned as a merit of green space, for gardens [214], the forest [219], and parks [212, 220]. In this process, natural elements often took on symbolic values such as space at the waterside [220], grounding [212], or taking distance [214]. People thus often found visits to green spaces to provide a chance to escape daily hassles (garden: [214]; park: [220]; park: [183]), from the noise and distraction of the city as well as the lights and traffic (park: [220]), from technology (park: [183]), it offered a place to hide (forest: [219], garden: [214, 216]; general nature: [212]), and to help deal with new impressions (garden: [214]).

Weather, seasons, and senses

The flow of time was not only a factor when experiencing escapism, it was also reflected in the change of seasons and different weather types. Some expressed the need for warm weather to stay in a rehabilitation garden longer [214]. Sunny weather, and the interaction of sunlight with the leaves of trees were mentioned as a positive aspect as well (garden: [216]; general: [212]), whereas others indicated that they felt happy when they walked through a city park in the rain [220]. In a park in Copenhagen, respondents mentioned that it enabled the experience of changing seasons and changing light conditions, which was not always visible within the city itself [220]. In a UK study of forests changes in the seasons gave visitors a sense of connection to nature cycles and seasonal change could be linked to sensory experiences such as seeing autumn colours, crunching leaves underfoot and the smell of pines after rain [206].

4. Discussion

The aim of this report was to gain a better understanding of how different green space types and characteristics can help maintain and improve mental health. Three types of studies were included in the systematic review: experimental studies, cross-sectional and longitudinal studies, and qualitative studies. In the search, the PICO/PECO approach was adopted to capture a relevant range of studies meeting the population, intervention and exposure, comparison, and outcomes eligibility criteria. All types of human populations were deemed relevant to capture effects on all potential users of urban green space. More stringent criteria were formulated for the interventions (experimental studies) and exposure (cross-sectional and longitudinal studies), where only studies looking at one or more specific green space type or characteristic were included.

Studies that enabled a direct comparison between different types of green space or green spaces with different characteristics were prioritized, but studies that only allowed for an indirect comparison were also included – as long as they provided information on exposure to a specific green space type or characteristic (e.g., pre-post design, or a comparison with a built-up environment).

Comparisons between different types of green spaces and characteristics were possible in the experimental and cross-sectional and longitudinal study category only. Even though different green space types were also included in the qualitative studies, the reported results did not differentiate enough between the different green space types to enable a comparison. In the experimental studies, around one third of the studies enabled a comparison between different green space types and green space characteristics and these comparisons were often direct (e.g., comparing a visit to the park to a visit to the forest). In the cross-sectional and longitudinal study category, on the other hand, more studies enabled a comparison between green space types and characteristics (more than half of the included studies), but especially research into green space types did not always have the specific aim to compare different green space types. Therefore, comparisons often had to be made indirectly by looking at differences in directions of the effects or differences in the strength of the association rather than that direct comparisons were conducted and reported by the authors. Some studies were very specific and different from all other studies, such as a study comparing mental health outcomes of climbing a real versus an artificial tree [154], or looking at effects of salinity in Australia [207, 208], or the effects of a green stormwater infrastructure [157]. Overall, the majority of studies pointed at benefits of green space on mental health, but results of the comparisons between different green space types and characteristics showed mixed results.

Both measures of momentary mental health, such as affect, and measures of long-term mental health, such as the prevalence of a certain mental disorder, were included. That there is a range of mental health outcomes that can each in their own way be affected by exposure to green space has already been recognized in a recent theoretical framework linking nature and mental health from an ecosystem service perspective that was presented in the introduction section of this report [59]. Besides this range of mental health effects, the size, type, and quality of natural features was deemed of importance, as well as exposure in terms of the time spent in the environment, or – as a proxy for exposure – the proximity to or availability of (nearby) green space, and the experiences that people have in these environments. The determination of the effects of the natural features was at the core of the present systematic review, but effects were also documented in terms of the type of exposure measure (time spent in the environment, or availability / proximity, direct or indirect exposure) and factors related to the experiences people have in the environments. Especially this

latter factor of experience can be very broad, as the focus is on what the authors [59] call 'absorbed internal dosage' meaning that it is not just exposure in terms of minutes or hours that count, but that there are also individual as well as environmental factors that influence the 'absorbed dosage' of nature that people get or require. For instance, five minutes in a high-quality park environment may give a larger mental health benefit than twenty minutes in a low-quality park environment and, importantly, what is considered a 'high-quality' green environment may depend on personal experience and thus individual background, preferences, and needs.

The importance of the factors exposure and experience were highlighted in the present review as in some cases, such as the comparison between effects of the park versus the forest, contradictions were found between short term and long term mental health effects.

4.1 Urban green space, the park, and the forest

Most frequently studied, and compared, were the park, urban green space, and the forest. In the experimental studies, there was great similarity in terms of study design (going for a walk in the park versus the forest), the outcome variables (mostly affect and physiological stress), the participants (mostly students and employees), and the geographical location where the study was conducted (the majority in Asia) when comparing the park and the forest. Affect was often measured with the Profile Of Mood States [226], which has multiple subdimensions, and physiological stress was measured with multiple predictors (e.g., heart rate and blood pressure). Consistently, the forest scored better than the park on some (but not all) of these subdimensions of both affect and physiological stress. Closely related to the park-forest comparison were studies comparing the forest with an urban green space. In the experimental studies, one study compared urban green space (including a park) with peri-urban green space (including a forest) and found better outcomes for the peri-urban than for the urban green space on subjective wellbeing [99]. In another study, a wilderness type setting also scored better than a park on physiology [100].

The cross-sectional and longitudinal studies did not corroborate the experimental findings; two studies enabled direct comparison between the park and the forest and both found the opposite pattern; exercising in the park resulted in a higher subjective wellbeing than exercising in the forest [43], while spending time in the park led to a better self-image than spending time in the forest for adolescents [33]. A cross-sectional study found a positive relationship between availability of urban green space and satisfaction with life, but there was no association for the forest [166]. Another study found a positive association of both a park visit and a forest visit with subjective wellbeing, with no difference between the two environments. Thus, whereas the forest generally scored better than the park or urban green space in the experimental studies, the opposite pattern seems to appear for most of the cross-sectional and longitudinal studies.

These seemingly contradictory findings between the experimental and cross-sectional and longitudinal studies comparing park and forest environments may be due to outcomes depending on the amount of exposure. Total exposure over time is assumed to be important for long-term wellbeing benefits, with recent research indicating that at least 2-hours exposure per week is necessary to gain health-benefits, with no differentiation in outcomes between one long or many short visits (see also [229]). Differences in exposure have not been taken into account in the above comparison of the outcomes of experimental or cross-sectional and longitudinal studies. For many people, parks may be more proximate and accessible than forests, and therefore visited more often, leading to a higher total exposure to that type of environment. Research has indicated that on

average people only spend a very small percentage of their time in natural environments, around 2 percent [55, 230], and the distribution of the time spent in green spaces between different types is of yet unknown.

In the experimental studies, the participants are often taken along to a certain natural environment rather than that they choose an environment themselves. It could be, for instance, that part of the participants normally would never actually visit a park or forest. It is also often not known whether the green space was familiar to the participants, or entirely novel, or whether there was a person-environment fit. Forests may be more fascinating or more novel to participants and therefore produce better momentary effects. On the other hand, they may also be more natural or less crowded. Speculatively, there may be a difference in time spent between parks and forests in everyday life which may result in more pronounced long-term benefits of parks rather than forests, even when forests produce better momentary mental health outcomes.

Studies looking at time spent in a certain green space type may shed some light on this. Time spent in the park was found to be positively related to mental health in the three experimental studies that looked at this association, with outcomes on physiological stress, affect, and satisfaction with life, whereas one study also reported more tiredness with increased time spent in the park [101, 102, 108]. The cross-sectional and longitudinal studies showed a similar pattern, with increased frequency of visits to community / green squares related to higher subjective wellbeing and greater odds for happy moments when visiting parks [177, 183]. In line, the number of visits to city parks (but not for visits to country parks) were positively related to quality of life [164]. Potentially, city parks may be in closer proximity and therefore visited more often than country parks. Increased time spent in the forest was not investigated in any other study than the one earlier reported [33], which found a lower self-image for adolescents with increased time in the forest. As only one study focused on time spent in the forest, this outcome may not be considered representative for the general effects of spending time in the forest. One of the included cross-sectional studies investigated both visit frequency and visit duration and pointed at the complexity of the measurement of exposure dose, as small parks (< 1 ha) were visited more frequently, but shorter than large parks (> 4,6 ha) [182].

Perhaps the key to the differential findings can also be found in the studies investigating the effects of these green space types when compared to an urban built environment, or those looking at single effects of the green space types, without a comparison. These studies generally focused on short-term health outcomes and pointed at beneficial effects of the green spaces on mental health outcomes. All six experimental studies comparing a park with an urban environment showed positive effects on at least one outcome of affect or physiological stress [104, 106, 114-116, 189], as did most of the ten studies comparing the forest to an urban built environment [130-132, 135, 136, 140-143, 145], and the two studies investigating urban green spaces with urban built environments [95, 96]. A visit to the park was related to better affect and less strain [94, 103, 109], as was a visit to the forest [133, 134, 139, 147]. Trees and forest in the view from an office window generated better subjective wellbeing, people were happier in the forest, and more street greenery was generally related to better mental health [161, 191, 228].

Availability of, or proximity to, an urban green space, a park, or a forest as a proxy for exposure rendered more mixed results than studies looking actual exposure to these green space types. Total park area around the residence was not related with problem behaviour [180], or only for children coming from a lower socio-economic background [173], and no relation was found for forest area on hyperactivity [187], nor was it related to the prevalence of autism [188]. Forest availability was

associated with greater quality of life [167] while higher park availability was associated with greater quality of life for children in one study [75], yet with lower quality of life for the elderly in another study [181]. Affect was positively associated with forest availability [187], but not with park availability [171]. Both forest area and park proximity were related with less depressive symptoms [175, 189]. Forest area was also found unrelated to mental health in one study [192] and only forest-edge contrast was related in another study [186], whereas park area (but not proximity) was found positively related to mental health in one study [181], but unrelated to mental health in another study [178]. Two studies reported a positive relation between percentage of park around the residence and subjective wellbeing [172, 176], whereas another study did not confirm such an association [171].

A potential complicating factor in cross-sectional and longitudinal research using availability or proximity of one or multiple green spaces as proxy for real exposure is that different green space types may act as substitutes for each other. Systematic reviews looking at total green space exposure (not differentiating between different green space types) have pointed at better mental health [62], better emotional and behavioural functioning for children [231], and lower all-cause mortality with an increase in the quantity of surrounding greenness [232]. If other types of green space are not taken into account as covariates, and at the same time are to some extent substitutes for the type studied, the observed association may depend on the extent to which these other types are present. This presence of the substitute could be negatively associated with the presence of the green space type under study. A negative association between substitutable types could lead to a lower positive, no, or even a negative association, because of neglecting the other types. For example, if urban parks of a large city are located in the city centre, and there is a peri-urban forest surrounding the city, a study looking only at access to urban parks might produce a very low positive association with well-being, because those with limited access to urban parks are likely to have good access to the peri-urban forest (acting as a substitute). If so, studies looking at the total amount of green space, or (semi-)natural environments, might produce more consistent results than studies looking at only one type of green space, thereby ignoring other types.

Differences in short-term and long-term benefits may depend on differences in exposure, but could also reflect differences in the quality of these environments. These qualities were also investigated, but these studies showed a large extent of heterogeneity in types of characteristics investigated as well as outcomes. Higher quality street greenery (and not the quality of green areas) was found related to better mental health [161]. For urban green space, better outcomes were found for those that were contemplating or those that were being active compared to those performing passive activities or socializing [99]. For parks, beneficial effects on mental health outcomes were found for: larger parks [172]; viewing certain elements (lake, walkway, and partly for a lawn) [107], more acoustic comfort [112], less light pollution [113], more amenities [176], bird song [182], a higher degree of naturalness [182], more trees [174]. No effects were found for viewing a plaza [107]; greenness of the park [112]; the visibility of the sky [112]; park quality [175]; and the number of amenities and paths in the park, aesthetics, and visibility [174]. Three studies found a negative association between: number of parks and number of activities in the park for the elderly [174]; attractiveness of the park [178]; and taller trees [182] and mental health outcomes. In the forest, better mental health outcomes were reported for walking in the forest than for only viewing the forest [132], for the sound of a brook in the forest [145], a tended (versus wild) forest [137], unthinned versus a thinned forest [138], the interior versus the edge or exterior of the forest [146].

Four studies reported negative effects of parks on mental health outcomes [174, 178, 182, 183], and four studies found negative effects of the forest [33, 133, 134, 233]. All eight studies were conducted outside Europe: Australia [134, 178, 183], Japan [133, 233], Mexico [182], Iran [33], and China [174]. All studies that found a negative effect of the park were cross-sectional and longitudinal studies, whereas three of the four studies reporting negative effects of the forest were experimental studies [133, 134, 233].

For the park, a negative association was found between the number of parks and the number of activities in these parks for the quality of life for elderly residents in China [174]. A study in Australia found negative association between park attractiveness and mental health for adults [178]. It must be noted, though, that the attractiveness of the parks was slightly higher in areas with a lower socio-economic status, and a lower socio-economic status – in turn – also resulted in lower mental health. The study found inconclusive results for the relation between parks, mental health, and socio-economic status. The third study that found a negative association for the park, only found that taller trees were related to lower subjective wellbeing [182], whereas other indicators (such as naturalness degree) were positively related to subjective wellbeing. Last, a study compared mental health scores of Australian park users to those from the general population in the UK and found lower scores. It is questionable [183] whether these differences reflect an effect of the park on its users, or whether there were other differences between the two samples.

For the forest, the only cross-sectional study in this category found a lower self-image with increased time spent in the forest for adolescents [33]. The experimental studies found an increase in boredom over time when visiting a forest [133]. Boredom was, however, overall higher on a control day. A Japanese pilot study found that the participants that preferred watching a video of the sea reported a decrease in vigour after viewing a video of the forest, these results are based, though, on a relatively small sample size (6 students preferred the sea) [233]. The last study that found a negative effect of the forest, tested effects of a virtual forest on people with dementia [134]. As there was no control condition, however, it is not clear whether the increase in anxiety was due to the forest environment or the Virtual Reality experience.

It seems that both the forest and the park predominantly had beneficial effects on mental health in the short-term, with more pronounced effects of the forest. For long-term effects, studies often rely on availability or proximity as a proxy of real exposure. These studies generally rendered more mixed results but did point at beneficial associations between availability of both the park and the forest and mental health, with more pronounced effect of parks or urban green space in direct comparisons in three studies. Specific qualities of the environments also appear to have varying effects on mental health outcomes, and also rendered some rather unexpected outcomes with negative associations between the number of parks and attractiveness of the parks and mental health outcomes. The variety in outcomes for both availability studies and qualities might be at least partly due to the different population types, with mostly large differences between studies looking at the youth versus those including only the elderly (e.g., effects of the park on quality of life). This is in line with previous research pointing at the different functions and different uses of green space across the lifespan [57, 234]. In addition, the typologies urban green space, park, and forest are rather broad categories and the specific elements and qualities can differ substantially among them. Research looking at specific types of trees and vegetation might provide additional insights.

4.2 Lawns, trees and other vegetation

In the above section, when discussing the forest, we already noticed that in one study better outcomes were reported for a tended compared to a wild forest [137], whereas contradictory results were reported in another study with better outcomes for looking at an unthinned versus a thinned forest [138].

Similar comparisons between managed and unmanaged green spaces were made for meadows or lawns in three studies. The first study, from the experimental category, found no difference between managed and unmanaged meadows in the Alps [150], this study only reported better restorative outcomes for a more remote meadow. Two cross-sectional studies found superior results for tended grass over rough grass [191] and of improved grassland over semi-natural grassland [192]. Thus, better outcomes appeared for more managed grassland.

Other studies also pointed at specific benefits of grassland, such as a lower prevalence of autism with higher availability of grass (against no effect for the forest) [188]. One study found a negative relation concerning the percentage of grass around the residence and mental health in Australia [193]. Grassland taken together with shrubland, resulted in both a negative association [75] and a positive association with mental health outcomes [181]. In a third study the percentage of shrubland was not related with mental health outcomes, but this study reported negative associations with shorter distances between the shrubland patches and more connected shrubland [186].

Trees were also studied outside the context of the forest. Two studies compared different types of trees, and found no differences in mental health benefits [132, 153]. Roads with street trees (as compared to a control road without street trees) produced better mental health outcomes [153], which is in line with outcomes reported earlier associating higher levels of street greenery with better mental health [161]. A more general measure of tree coverage – 'tree canopy' – has received special attention in the USA. The majority of these studies reported at least one positive association between tree canopy coverage and mental health outcomes, whereas one study found that more tree canopy was related to more anxiety for children with autism [200]. Importantly, a number of studies compared different types of tree, or different types of forest, and did not find any differences between the different tree species.

In the qualitative studies, trees, and especially older trees, were given symbolic value and related to feeling safe and calm [212, 216, 219, 220]. Contradictory findings were reported in the quantitative studies. In a park environment, a negative relationship of satisfaction with life was reported for taller trees [182]. In addition, stand density (taking into account both the number of trees and their diameter) – but not stem tree size – was negatively related with restorative outcomes [195].

For people with psychosis, better mental health outcomes were found for trees and bushes showing green and autumn colours compared to flowering bushes [152]. Similarly, two qualitative studies indicated that flowering plants could be too stimulating when people were experiencing mental health problems [200, 214]. Another study, using "healthy" employees found a positive relation between flowering plants and bushes in the view from the office and subjective wellbeing. Potentially, flowering plants are appreciated more when feeling mentally healthy, a finding that was corroborated in two qualitative studies [183, 214].

It is, thus, not only specific types of green areas such as parks or forests that matter, the trees in the city can also benefit mental health. In addition, the choice of vegetation can influence the beneficial

effects of an urban green space, and this can highly depend on the target population, especially with regards to their mental health status.

4.3 Gardens

A type of green space where vegetation choice is often made very explicitly is the garden. Few studies (eleven in total) included in the review focused on effects of a garden – public or private – on mental health outcomes. Seven studies investigated the effects of public gardens, and only one tested the effects of a botanical garden on mental health outcomes by comparing it to a Japanese and an architectural garden [129]. This study found no difference in physiological responses between them, but better affective outcomes for the Japanese garden. Two other studies investigated the effects of a Japanese garden. The first compared effects of viewing a Japanese garden with an unstructured garden for the youth and found some evidence for increases in physiological stress when viewing the unstructured garden [225]. The second study tested effects of the implementation of a Japanese garden versus a non-Japanese garden for dementia patients and found lower pulse rates after installing the Japanese garden, and improvements in behaviour after implementation of both gardens with no difference between the two [128].

Two studies looked at the effects of the implementation of a wander garden for dementia patients, and found mixed results [122, 123]. Less medication had to be prescribed after the implementation, but only for secondary antidepressant medication (primary medication prescriptions increased). Less agitation was reported, but at the same time as an increase in serious incidents causing personal harm to others. A study among nurses found that lunch breaks in the hospital garden lowered burnout scores [124].

One study compared effects of viewing images of a traditional Korean garden with images of an urban built environment, and found better outcomes for the garden in terms of affect and anxiety (but not vigour) [126].

Four studies looked at effects of the private garden. Constructing a private garden in Peru led to less perceived stress a half year later and a higher quality of life a year after constructing the garden [157]. Having a garden (versus not) for elderly people in the UK was only found beneficial for a personal patio on subjective wellbeing [184], not for a back or front garden, a balcony, or a courtyard. A greener view was also found more beneficial, but not the number of trees in the view. Spending more time in the private garden for the youth resulted in a better self-image than spending time in the forest, and a similar effect was found for the private garden with spending time in the park [33]. Last, engaging in physical exercise in the garden proved less beneficial for mental health than exercising in the park or forest, and less beneficial for subjective wellbeing than exercising in the park or on sport pitches [43]. Importantly, doing housework or gardening was included in the measurement of physical exercise.

The results for private gardens pointed towards the benefits of having a private garden but once again appeared to depend on both the activity performed in the garden and the population type (especially in terms of life stage) under study. The few garden studies carefully pointed at more pronounced benefits of structured public gardens, but there were too few studies included to come to a solid conclusion. Furthermore, the studies that were included were all conducted outside Europe and often in Asian contexts. There are likely to exist different cultural associations with a range of landscapes and habitats, which hinders generalization of the results. Not only the design of the

garden can be of importance, but also the variety of vegetation types and the choice for native versus introduced species.

4.4 Biodiversity

A total of eight studies included measures of biodiversity; this could relate both to flora or fauna and be operationalized as field measurements or perceived biodiversity. Green spaces with higher biodiversity levels resulted in better restorative outcomes than those low in biodiversity in Italy [99], greater flora and fauna richness was related to better subjective wellbeing in Australia [202], between plant diversity and quality of life for the elderly [206], and positive associations between plant diversity and happiness, with more pronounced effects of introduced species [203]. Perceived biodiversity did not influence post-walk affect for the elderly in the UK [155] and did not influence subjective wellbeing [205], whereas perceived number of plant species (but not perceived number of native species or insects) was positively related with restorative effects [200]. In Taiwan, no effect was found for richness and abundance, but settings with more even biodiversity resulted in lower heart rate [156].

In a recent review on the mental health benefits of biodiversity it has been argued that there is a need to look at the effects of experienced, or perceived, biodiversity besides objectively measured biodiversity as for instance not all insects or plants may be perceived by green space visitors [235]. For the studies included in the present review, four studies with objective measures [99, 156, 202, 206] for biodiversity and two study using perceived biodiversity [203, 204] reported at least one positive associations with or positive effects on mental health, whereas two studies employing perceived biodiversity [155, 205] reported no effect of biodiversity on mental health. Thus, objective biodiversity levels may have more pronounced effects than how the green space visitors perceive the biodiversity.

4.5 Other green space types and characteristics

Green space types that received less attention were included in the miscellaneous category. Four of these studies looked at farmland [168, 170, 187, 190], and three at the countryside [162, 171, 191]. Farmland was generally related with better mental health outcomes than urban green space in two studies [168, 170], better than the forest for hyperactivity levels, but not for positive affect [187], and the fourth study reported higher happiness for a wide range of natural areas (only not for inland bare ground) [228]. Findings for countryside visits signalled that these countryside visits or views either had similar effects to urban green space [162, 170] or even inferior effects [191].

Two studies reported superior findings for mountains, in a combined category with hills and moors in one study compared to countryside visits [170], and combined with heath and bog in the second study compared to the forest (broadleaved and coniferous), arable land, semi-natural grassland, and freshwater. Three studies conducted in Sweden [209-211] investigated the relation of availability of environments divided in five pre-defined categories (based on a proposed framework) of nature characteristics: wild, lush, serene, spacious, and cultural natural areas. These three studies found only limited associations, mostly in sub-analyses such as only for females (recreational or serene nature) [209, 210] or for an interaction with physical activity (serene nature) [211]. Other green space characteristics were relevant, but only addressed in single studies and therefore more difficult to generalize. Better restorative outcomes were reported for protected compared to non-protected areas [163], greater stress reduction may have occurred for contemplative than for non-contemplative green areas [159], while areas high in prospect and low in refuge scored better on

affect and produced better physiological outcomes than areas low in prospect and high in refuge [160].

No firm conclusions can be made on the basis of single studies, even if they can be considered informative, pointing at potentially relevant venues for future research.

4.6 Green space users and activities

In the sections above, outcomes were mostly discussed in terms of natural features and exposure, but less in terms of experience. Users' characteristics can greatly influence whether and how he or she benefits in terms of mental health from the different green spaces and related characteristics, and also which dose of the green space or green space characteristic is necessary to reach a certain effect. Relevant characteristics identified in previous research and corroborated in the present review include for instance life stage, mental health status, and socio-economic status.

Children interact differently with nature than adults, and the elderly may also have different needs and preferences than younger individuals. In the present review, these differences sometimes appeared so pronounced that even opposite outcomes were reported for children and the elderly. For instance, more residential park availability was related with a better quality of life for children, but showed a negative relation with quality of life for the elderly [75, 174], and more parks and tree canopy coverage were generally positively related with mental health outcomes for the general population, but not for children with autism [200]. These outcomes may be highly unique for the setting of those studies, but research has also pointed at differential effects based on life stage, with for instance more emphasis on being active and socializing for the youth than for the elderly [234].

Some studies pointed at more pronounced effects for people with mental health problems [102], which is in line with earlier findings [54-56]. People with worse mental health sometimes also used the green space differently, for instance by staying longer [101]. In addition, people with mental health problems may actively seek out certain environments, which was the case in a rehabilitation garden where people actively sought different types of green environments when experiencing different moods and at different stages of their rehabilitation process [214]. This might, for instance, have also been the case in a study where a significant relation was reported between more time spent in the forest (often a more secluded environment) and lower self-image, as compared to the park or a private garden [33]. The present review also points at differential beneficial outcomes of green space qualities for people with good versus poor mental health, such as the presence of flowering plants [152, 214].

Certain outcomes were only found for specific sub-groups. For instance, effects were found for females but not for men [129, 151, 208, 209, 211], or only for respondents with lower socio-economic status (e.g., [173]). The importance of socio-economic status as a potential mediating factor for health-effects of green space has already been established in previous research (e.g., [58]), but has also been challenged by outcomes included in the present review [178]. This latter study [178] suggested to look at interactions between socio-economic status and qualities of the park, such as safety perception. Other relevant characteristics that may matter but could not be differentiated on in the present review are for instance lifestyle factors, connectedness to nature, occupation, or family composition (e.g., having young versus older versus no children, marital status).

Another important finding of the present review is that mental health outcomes of green spaces may depend on what people are doing in the green space. A distinction was sometimes made between

participants engaging in active versus passive activities. For instance, in urban green space, more pronounced benefits were found for those contemplating the setting or walking than for those reading and socializing [99]. On the other hand, better results were reported for active park lingerers than for walkers for the elderly visiting the park and no difference with passive scanners [103]. Six studies in this review explicitly focused on people exercising in natural environments [43, 111, 149, 154, 155, 168] and found superior effects on mental health for those engaging in physical exercise in either the park, the forest, or a sports pitch than in the garden or at the beach [236], no difference between running in grassland, a heritage park, along the beach, or alongside a river [237], and better outcomes when walking in green corridors, or farmland compared to walking in urban green space [168].

4.7 Putting the green space in context

Not only can differences be expected between different types of green space visitors (or viewers), but the physical context in which the study is conducted also matters a great deal, not only in terms of exposure but also for the experience the green space visitors will have. This relates to (geographical) location, with differences in population density, climate, and culture. Some studies, for instance, only found positive effects of green space for people living in high-density areas [188], or only for urban and peri-urban areas [75]. The population density of the location in which the study is conducted is often not reported, and therefore sometimes also made it difficult in the present systematic review to distinguish between highly urban, less urban and rural settings in the outcomes.

Locations can also differ greatly in climate. For one study, the authors attributed finding only non-significant effects of the park on several mental health outcomes to the fact that they performed their research in a tropical region and claimed benefits of the park may not hold here [171]. In hot climates, the presence of shady areas under trees may be of greater importance than in more temperate climates. Indeed, one of the qualitative studies indicated that shady park areas were often used [216] and the potential of green spaces to cool down the city have been reported as an additional benefit [27, 98, 238].

The season in which the study was conducted was not always reported and one study indicated that trees and bushes undergoing different seasonal changes may also affect people differently [152]. Mental health outcomes of green space thus also depend on the season and weather type under which exposure took place, but these contextual factors are often overlooked [239]. An additional example can be found in the trees and other plants category. Whereas the majority of studies found at least one positive relation between tree canopy and mental health outcomes, a study from Bulgaria did not report any significant results for tree canopy [223]. This study, however, was conducted among students between October and November and thus during autumn. Potentially, a lack of effects could be due to the fact that mental health effects of tree canopy were measured while the trees were in autumn colours or even without leaves already. Season, climate, and weather are thus important factors to take into account when designing a study, or at least when reporting the study, but also when reviewing study results or when designing urban green space.

Shade from the sun is one way in which light interacts with effects of green spaces, light pollution from the city is another example [113]. Some studies considered the light conditions in parks and an important element for park visits [182] or as a quantifier of the quality of the park [178]. Besides light, other sensory modalities may be of importance such as smell or sound, but these contextual

factors have not received much attention, although one study did outline sensory aspects of woodland that study participants enjoyed [206].

4.8 Limitations

The first two limitations relate to decisions made when defining the set-up of this systematic review. First, during the literature search, the term nature and natural had to be deleted as they rendered too many irrelevant records, since many people use these terms in a symbolic fashion rather than referring to natural environments. Therefore, studies that did not use terms specific for green space types or characteristics in their title or abstract may not have been retrieved by the search, nor were those that used nature rather than green space. Second, the search was narrowed down to direct effects on mental health and did not include outcomes that were not directly measuring mental health but that were indirectly related to it, such as physical activity or the cognitive aspect of attention restoration. A publication bias may exist in peer-reviewed publications (see, e.g., [240]), therefore there may be an overrepresentation of positive effects of green spaces.

Not all studies reported important characteristics of their study, including the population density or the season in which the study was conducted. For the present review, it may be especially problematic that it is not always clear whether a study as performed in a dense urban environment or a quieter peri-urban or rural area, as these differences may affect the outcomes.

4.9 Quality of the included studies

Some limitations of the included studies limited the conclusions that could be drawn. First, not all studies directly compared different green space types or characteristics. Therefore, many comparisons between different green space types had to be made indirectly, for instance by comparing which green space types generated significant and positive effects on mental health compared to those that generated no effects or even negative effects. Therefore, a study in which two green space types both showed significant positive outcomes compared to e.g. a built-up environment were rated as having a similar effect in the indirect comparison. However, there may still exist differences between these green space types in effect size. It would be desirable that in future research, or even when using existing datasets, more direct comparisons are made.

Second, benefits of a certain green space type or characteristic may depend greatly on the amount of exposure (e.g., [8, 59]), especially when looking at long-term mental health outcomes that may develop over time. When effects develop over time, results from momentary measurements of a one-time exposure (as often is the case for experimental studies), or studies focusing only on availability as a proxy for actual exposure may not provide a complete overview of the effects of green space on mental health. These studies comprised a large proportion of the present review, though. Thus, smaller – or less pronounced – effects on long-term mental health in the present review may not necessarily (only) reflect differential effects of green space qualities, but rather differences in accumulated exposure. This limits the ability to draw firm conclusions based on the review.

Third, a number of studies were included that looked only at proximity or availability of only one type of green space (e.g. urban parks). These studies may have ignored other types of green space that might fulfil similar functions (and could act as a substitute for the green space type under study). Depending on the local context, the presence of these ‘substitute’ green space types may be

negatively related to that of the type under investigation, and could also be a source of heterogeneity in outcomes.

Fourth, even though a relatively high number of studies were included, they were not always of good quality. Especially in the experimental study category, overall scores for the critical appraisal were not high. None of the studies, in addition, could be considered a Randomized Controlled Trial and it was especially the blinding of participants and outcomes that proved problematic. Blinding of participants to the manipulation is a known challenge when testing effects of environmental interventions, but blinding of outcome assessment and a more stringent design in terms of randomization and generalisation to the population under study are important avenues for improvement of the experimental studies. In addition, many studies in this category used students as a convenience sample, which limited the generalisability of the results to the entire population. In terms of green space manipulations, the studies often provided a good overview of the visit duration and frequency, but not always of the familiarity of the environment to the participants, nor did it provide information about the person-environment fit in almost all studies, i.e., did a person visit this location more often, or did they prefer other green space types. One study did investigate preferences for natural space types, comparing the forest to the sea, and found differential effects for people with different preferences [233].

In the cross-sectional and longitudinal category, the quality was generally better but still an improvement can be accomplished by including more longitudinal study designs, by a better alignment of study sample with the population, and by more detailed knowledge of the actual exposure in terms of duration and frequency of the individual visits (as many studies only look at proximity or availability of green space types or elements on mental health outcomes). In line, contrasting different green space types seems necessary to rule out substitute effects of the different green space types.

For the qualitative studies, stakeholder involvement scored low for all studies, which could be considered an important avenue for improvement. In addition, even though the studies used specific green space types the analysis and results did not differentiate between these different green areas, which made the results difficult to interpret in terms of differential effects of the individual green space types.

Fifth, the studies focused mainly on urban green space, the park, the forest, and the category trees and other plants. Less attention was given to other green space types, and even less attention was given to green space characteristics. Little research, for instance, focused on mountains or compared different types tree species in the forest. In addition, more recent developments such as vertical greening in urban environments have received little attention thus far. There are many different green space types and characteristics and therefore it may not be so surprising that not all of these natural features have received enough attention yet, but there certainly is potential for future research to further expand the knowledge base for the beneficial effects of specific green space types and characteristics. Advancing our knowledge on natural features would, however, greatly benefit from a more detailed description of green space types and characteristics included in the studies. Even though parks and forests as overarching categories can be distinguished in the present review, the subtleties between the different types of parks or forests can often not be fully distinguished based on the description provided. In addition, there are many different descriptions for the same category (i.e., parks are sometimes also included in urban green space) and different green space

types are often merged into a single category (e.g., mountain, heath, bog) which makes it difficult to draw conclusions.

4.10 Progressing urban green space salutogenic design

Despite the mentioned limitations, the outcomes of the present report provide useful insights that can inform decision makers, urban planners and landscape architects when designing urban green space. Even though most urban green space types had a positive relation with mental health, the comparisons between the different green space types produced highly heterogeneous results. The first and foremost conclusion of the report is thus that generally speaking, it is not one green space type or quality that stands out over the others in terms of the beneficial effects on mental health. Or, alternatively, there is not one specific green space type that works best for all target groups and for all geographical locations and contexts. In addition, results indicate that the same green space type may produce different mental health outcomes for different subgroups of the population and for different seasons, geographical locations, and microclimates. Therefore, it seems important to get to know the future population's needs and preferences, and adapting the green space design to that. A thorough social, ecological, and environmental analysis can assist to exploit the full potential of urban green space. A variety of green spaces rather than standard configuration of a single type of green space and / or higher concentrations of a certain green space typology or quality may be necessary to accommodate all different types of green space user profiles and their needs, especially in the highly diverse and dynamic urban and peri-urban settings and while facing the consequences of climate change. There needs to be a more thorough understanding, though, of who needs which type of green space and at what time before firm design implications can be formulated. This would benefit from a more thorough mapping of the actual exposure of individuals to the specific green space types and gaining a better understanding in the experiences people have in these green spaces.

Even though not all is known about who needs what type of green space or element and at which time, there are a number of key findings. Parks, forests, grassland, and other urban green spaces (such as green community squares, or greenways) can independently improve mental health. Distinctive effects were found between forests and parks for long-term and short-term exposure. Potentially, parks may be more beneficial for long-term mental health and forests more for short-term effects, but more research is necessary to investigate this as effects may depend on actual exposure (which in turn depends on exposure potential) and experiential characteristics of the exposure.

Not only designated urban green spaces such as urban parks or forests appeared to matter, but also street greenery, trees, and urban green space. Outcomes indicated a clear relation between more trees and better mental health [180, 181, 188, 193, 194, 196-199]. The importance of nearby nature was also reflected in the importance of private gardens [127, 184], but also greenery at work [191]. This also points at the complexity of the relation between green space exposure and mental health, as for this category of outcomes it is difficult to distinguish between, for instance, purposeful and incidental exposure.

There will never be an exact formula for the choice of, for instance, vegetation or the density of planting, as effects of single elements will always depend on the context they are placed in. However, it is important to think carefully about the choice of vegetation and the level of biodiversity, and once again also in relation to the target user group. Flowering plants can be seen as too stimulating for

some, but not for others. Seasonal changes matter in how areas are perceived, and benefits of green spaces may differ between seasons. Green areas are not only beneficial in spring and summer, but can also be beneficial in the autumn and winter. Here also lies a considerable challenge for future research, as appearance of green spaces not only differs substantially between seasons, differences in weather conditions and daylight exposure may also result in changed activity patterns and are also on their own related to mental health outcomes, such as Seasonal Affective Disorder [see, e.g., 239].

Participants seemed to prefer a certain level of human involvement in green areas. Managed meadows or grassland appear to provide better outcomes, whereas mixed results on this aspect were found for forests. Shrubland, on the other hand, especially in the presence of highly connected patches produced mainly negative associations with mental health outcomes that would be worth avoiding.

Last, a synergy in beneficial effects may occur when combining green space with blue space, such as a lake or the sound of a fountain or a brook [144, 145].

5. Concluding remarks

The Covid-19 pandemic has not only confirmed the importance of green space in the city for mental health, stress relief and reflection or for providing an opportunity to socialize with friends or to be physically active, it has also reminded us of the importance of the views from our windows as in regions with strict lock-down green space could only be viewed through the window [241-243]. The outcomes of the present report confirm the results of previous systematic reviews indicating that green space is beneficial for mental health [60-66], not only of designated green space types such as the park but also, and in general, street greenery. It is, therefore, not only important to think of more commonly defined urban green spaces, such as parks or forests, but also to value and consider the daily and often unintentional micro-restorative experiences [244] people can enjoy from trees and grass within residential, commercial, or business areas. In other words, the review indicated that all urban and peri-urban green types and characteristics matter for mental health and wellbeing.

Even though rather consistent benefits of green spaces were reported, the direct comparisons of the different green space types and characteristics rendered very mixed results. The largest group of studies focussed on either the park (and the urban green space) or the forest. Contradictory effects were found in direct comparisons between the two, with superior effects for the forest than the park on short-term mental health outcomes, as reported in most experimental studies and the exact opposite in three cross-sectional studies on long-term mental health outcomes. At least two explanations can be provided for the heterogeneity in these comparison results; i) differences in the actual exposure; ii) differences in specific characteristics between the two types of green space; and iii) differences in the diversity of user characteristics and needs as well as microclimatic circumstances and different cultural representations.

The distinction between short-term and long-term mental health benefits provided by the park and the forest once again illustrates the complexity of the pathways linking exposure to green space with mental health benefits [17, 59]. It is still uncertain whether these differences in effects were due to idiosyncratic elements in the research design (i.e., experimental studies looking at effects of a single exposure, whereas long-term benefits may depend on an accumulation of exposures) or whether these green space types really serve different purposes in terms of mental health outcomes. If long-term benefits depend on actual exposure, and more specifically, the internal absorbed dose [59], then there is a need to know more about this. Experience has especially received little attention in the existing evidence base [59]. This information cannot be retrieved from cross-sectional and longitudinal studies only looking at residential availability of green, nor from experimental studies looking at effect of a single visit. More longitudinal and in-depth (experimental) studies are consequently necessary to further explore the relation between exposure and mental health outcomes, but also to gain a better understanding of when people explicitly choose to go to an urban green space, what they are doing there, and what experiences they are having (e.g., [59]).

The systematic review did not point at one particular green space type or characteristic that is best, or a gold standard that works best for everyone, everywhere, and at every time. Instead, there was high heterogeneity in outcomes between different green space types and characteristics. Heterogeneity may be explained in terms of differences in exposure duration between different green space types and characteristics, but also in terms of differences in experiences. Not all studies in the present review distinguished between different population types, but those that did look at either a specific subsample of the population (e.g., elderly or children) or included individual-level factors such as gender or socio-economic status, often pointed at different effects for different

population segments. What adds complexity is that these variations not only occur between individuals, but also within a single person. On a bad day, a person may benefit more from a specific green space or characteristic than on a good day. In addition, factors such as geographical location, different cultural perspectives, and climatic conditions may also influence how specific green space types and characteristic influence mental health. Here also lies a potential challenge as climate change is not only affecting biodiversity in the cities, but it is also influencing the microclimate of different urban areas within a single city. This may signal a need for variety in green space types to capture all potential users, with different needs and undertaking varied activities rather than there being one particular standardized solution for each city.

The studies included in the review were highly heterogenous in terms of objectives, theoretical frameworks, covariate data, target population, and research methods. Previous systematic reviews have indicated that this diversity makes drawing solid conclusions difficult [8, 13, 17, 62-64, 66, 75-77]. This was also the case for the present review, and would – for instance – also significantly complicate performing a meta-data analysis. At the same time, the present review has indicated that when trying to identify benefits of specific green space types and specific green space characteristics on mental health, this diversity in outcomes and user characteristics may not necessarily be a weakness but, instead, a prerequisite for gaining a better understanding on how exactly different green space types and characteristics influence mental health and wellbeing as well as the differences between individuals and different contexts (e.g., geographical location, climate, season). However, there needs to be a more systematic way to study this, with more longitudinal studies. One way to go about this is to purposefully address this heterogeneity in the research methodology, for instance, by enabling a direct comparison not only between different green space types and characteristics, but also between different users (e.g., age, mental health status), different activities (e.g., active versus passive activities), or different locations (geographical locations, or in areas with different population densities), or different seasons, or including different cross-cultural perspectives. Future research could shed light on these factors important to understand the pathways from green space exposure to mental health. Especially viable in this respect are studies employing big data collection and / or ecological momentary assessment or experience sampling methodologies, as these methods enable longitudinal designs and the sampling of everyday experiences, and allow for time budgeting (extracting total time spent on e.g., a certain activity or in a specific environment based on multiple random momentary assessments) that can shed light on actual exposure and experience [245].

The present review has confirmed a general beneficial relation between green space and mental health, an association that seems to hold for most green space types. Comparisons between different green space types have nonetheless revealed heterogeneity in outcomes that points at potential underlying pathways that deserve further attention. Two main strategic fields for future research seem particularly relevant: i) a better assessment of actual exposure, and of the role of individual experiences within specific green spaces; and ii) gaining knowledge on how actual exposure to – and experience with – specific natural features can help improve and maintain mental health, thus enhancing the understanding of the relevance of the exact types, characteristics, and variety of green spaces. Such an understanding is increasingly required to tailor urban green space design not only to the specific needs and preferences of the urban and peri-urban dwellers, but also to adapt to and mitigate health risks associated with the increasing threats jointly posed by urbanisation, social injustice and climate change.

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