



EUROPE

# A scoping study on the link between exposure to or interaction with the natural environment and mental health outcomes

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Published by the RAND Corporation, Santa Monica, Calif., and Cambridge, UK

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## Acknowledgements

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We would like to thank Dr Sarah Ball, Senior Analyst at RAND Europe, and Axelle Devaux, Research Leader at RAND Europe, for their quality assurance role on this project. We would additionally like to thank RAND Knowledge Services for their assistance in running the search within PubMed for this scoping review.

# Preface

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RAND Europe has been commissioned by The VELUX Group to conduct a brief scoping study on the recent academic literature on the subject of effect of exposure to nature on mental health.

This work consists of a review of the existing literature through literature reviews conducted in the last year and Cochrane reviews from the last five years.

The report is likely to be of interest and relevance to the general public, architects and planners, policy makers, academics, and professional bodies.

During the entire research process, RAND Europe has retained full editorial control of and independence in relation to the analyses performed and presented in this report. This work informs the public good and should not be taken as a commercial endorsement.

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## Summary

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This report presents the results of a rapid scoping review that has been conducted on the following research question: ‘Is there scientific evidence of an association between exposure to, or interaction with, the natural environment and mental health outcomes?’ While the study has been carried out in a systematic and transparent way, it should be stressed that it cannot be described as a systematic literature review, which would provide a much more in-depth view of the body of literature. Due to the limited scope and rapid nature of this work, we restricted the search to articles retrieved in PubMed published in the last year (5 April 2018 to 5 April 2019) and to articles included in the Cochrane Library published in the last five years (5 April 2014 to 5 April 2019). Furthermore, we limited the search to include reviews only, in order to capture a wide breadth of data despite the small scope of this study. Hence, the present study is in a way a ‘review of reviews’. In spite of these notable limitations, the approach taken can be described as robust.

In line with the above restrictions, 10 papers have been identified and selected for inclusion into this review of reviews. Based on these, the following key statements can be made. First of all, in terms of quantity of evidence, the body of scientific literature related to the above research question is growing very rapidly. In support of the first statement, while our search string only yields fewer than 100 articles published per year up until 1990, this started to slowly pick up in the subsequent years and increase to around 300 articles published per year 2010. Since then, the number has increased very rapidly, to almost 1,700 articles published in the last year.

The second statement that can be made is that there is emerging evidence of a positive association between being in a natural environment or engaging with nature-based interventions, on the one hand, and improvement in mental health, on the other. In considering evidence in support of the second statement, we found it useful to group the papers reviewed by the demographic group which they focused on: (1) the general population; (2) those with physical or mental illnesses; and (3) children and adolescents. An additional group of papers which did not easily fit into any of the above categories was titled (4) environment, focussing on the impact that different environments have on aspects of mental health. In terms of the first group, the general population, this positive association has been found in particular in qualitative studies, and the findings are mostly based on self-reported impacts. It should also be stressed that in quantitatively oriented studies and in studies that did not rely on self-reported outcomes, the results were generally not strong enough to make conclusive statements. With regard to the second group, i.e. those with physical or mental illnesses, relevant studies did find evidence suggesting a tendency towards improved mental health and well-being for patients who were receiving a therapy that somehow related to nature, for example by participating in gardening activities. Yet again, the reviews that

were reviewed as part of this study generally qualified the evidence as not strong enough to make definite judgements. With respect to the third of the above groups, namely children and adolescents, covered by one of the 10 reviews included in our study, at least half of the papers examined by that review identified positive relationships between nature and mental health. More specifically, these concerned the following aspects of mental health: attention deficit disorder/hyperactivity disorder (ADD/ADHD), overall mental health, stress, resilience, and health-related quality of life (HRQOL). In the final group of papers, dealing with the impact of nature on mental health and well-being in different environments, one review looked in particular at papers focussing on the role of nature in urban environments. It found that about half of the papers it reviewed reported natural elements, such as vegetation, botanical gardens, flowering meadow green rooves and green spaces, as having or predicting perceived restorative value for participants. Box 1 presents the types of outcomes that the studies we reviewed focused on.

**Box 1 Type of outcome measured to assess mental health and well-being**

Mental health/state
Quality of life
Emotional well-being
Spirituality
Behaviour(al disorders)
Alertness or cognitive function
Mood
Irritability
Anxiety or depression
Happiness
Life satisfaction
Autism spectrum disorder
Dementia
Suicide
Restorative effects
Self-esteem
Stress or distress
Resilience
Exhaustive disorder
Attention deficit hyperactivity disorder (ADHD)

It is important to keep in mind a number of aspects when interpreting the results. First of all, it is essential to note the diversity among the papers reviewed in all aspects: the type of interventions described or definitions of nature used, the population assessed, the tools and methods used. Second, there is the heterogeneity in the outcomes measured, which is linked to the multi-faceted nature of mental health and mental well-being. For these reasons, it is not possible to aggregate the existing data to support any

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emerging trends. Overall, the evidence base is currently weak, which is also a finding stated frequently in the reviews that we looked at. In view of all the above, we would like to emphasise the need for caution in interpreting the results of this study.



# 1. Setting the scene

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The aim of the work presented in this report has been to identify, analyse and synthesise available scientific literature that is related to the following research question: ‘Is there an association between exposure to or interaction with the natural environment and mental health outcomes?’ For this, a rapid scoping ‘review of reviews’ has been conducted with a primary focus on European and northern European geographical contexts, but not to the exclusion of others if the topic area was deemed to be highly relevant. The search criteria and inclusion/exclusion criteria applied to this study were limited in scope due to the rapid timeline of this project; however, we maintained a systematic and rigorous approach, in line with RAND Europe’s quality standards. (Please see further details on the search strategy and inclusion/exclusion criteria in subsections 2.2 and 2.3.)

It should be noted that the literature to be analysed was limited to reviews; hence the present document constitutes a ‘review of reviews’. Furthermore, the search was limited to very recent publications (reviews published in the last 12 months and indexed in the PubMed database and reviews published in the last five years and indexed in the Cochrane library). The reasons and implications of this limitation are explained in the subsequent section on methods.



## 2. Methods

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### 2.1. Definitions

For the purposes of this scoping review, *nature* was defined as ‘the phenomena of the physical world collectively, including plants, animals, the landscape, and other features and products of the earth, as opposed to humans or human creations’ (English Oxford Dictionary 2019).

With respect to the definition of *mental health*, the World Health Organization characterises it as ‘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’ (World Health Organization 2014).

### 2.2. Search strategy

We conducted a rapid scoping review of reviews using academic literature sources. Munn et al. (2018) describe a scoping review as ‘an ideal tool to determine the scope or coverage of a body of literature on a given topic and give clear indication of the volume of literature and studies available as well as an overview (broad or detailed) of its focus’ (Munn et al. 2018). We carried out this scoping review in a systematic and transparent way; however, it is not a systematic review, which provides a much more in-depth view of the body of literature and often has less selective inclusion criteria.

We searched for literature using two databases of relevance to this topic area: PubMed and the Cochrane Library. The search terms, which were limited to title and/or abstract, are set out in Box 2.

#### Box 2 Search terms

Terms relating to nature as the exposure of interest: (nature OR natural OR outdoor OR outdoors OR daylight OR indoor OR indoors OR polluted OR polluted OR pollutes OR pollutant OR pollutants OR pollution OR active OR activity OR green space\* OR green-space\* OR microclimate\*)

#### AND

Terms relating to mental health as the outcome of interest: (“mental health” OR “mental wellbeing” OR “mental well-being” OR satisfied OR satisfy OR satisfaction OR content OR contented OR contentment OR enjoy OR enjoys OR enjoyed OR enjoyable OR enjoyment OR fulfill OR fulfilled OR fulfills OR fulfilling OR fulfillment OR stress OR anxiety OR anxious OR depressed OR depression OR depress OR depresses OR depressing OR mood OR “quality of life” OR QoL)

Due to the limited scope and rapid nature of this work, we restricted the search to articles retrieved in PubMed published in the last year (i.e. 5 April 2018 to 5 April 2019).<sup>1</sup> In addition, the search of the Cochrane Library<sup>2</sup> covered articles published in the last five years, in order to ensure that we captured the high-quality evidence sources relating specifically to the effectiveness of interventions, over a longer time period, so as to not inadvertently miss important pieces of evidence in the Cochrane Library, which has a high quality standard but does not publish as frequently.<sup>3</sup> We further limited the search to include reviews only, in order to capture a wide breadth of data despite the small scope of this study. Protocols were not eligible for inclusion and were therefore excluded. No limitations were applied for the population.

### 2.3. Study selection

Table 1 details the study inclusion and exclusion criteria, which mainly follow the population, intervention, comparison, outcomes and setting (PICOS) criteria (Methley et al. 2014).

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<sup>1</sup> We did not include grey literature sources (i.e. literature published outside of traditional academic journals).

<sup>2</sup> Cochrane Reviews are systematic reviews of primary research in human healthcare and health policy. They investigate the effects of interventions and are internationally recognised as the highest standard in evidence-based healthcare. For more information, please see: <https://www.cochranelibrary.com/>

<sup>3</sup> The PubMed database also captures Cochrane reviews; therefore any reviews published within the Cochrane Library in the past year would have also been picked up by PubMed.

**Table 1 Inclusion and exclusion criteria**

PICOS categories	Inclusion criteria	Exclusion criteria
<b>Population</b>	<b>Humans (no other limits applied)</b>	<b>Non-human subjects</b>
<b>Intervention</b>	<b>Exposure to or interaction with nature or nature-based interventions (see definition above)</b>	<b>Studies investigating impact of non-nature-based interventions only</b>
<b>Comparison</b>	<b>Studies were not included or excluded on the basis of comparison groups, as we were interested in all literature in which the intervention of interest related to the defined outcomes</b>	<b>None</b>
<b>Outcomes</b>	<b>Mood; general mental health as defined by authors; specific mental health conditions, such as depression, anxiety and attention deficit hyperactivity disorder (ADHD); cognitive function; mental well-being</b>	<b>Solely focused on physical health</b>
<b>Setting</b>	<b>Focus on European and North American countries (but not to the exclusion of others)</b>	<b>Developing countries</b>
<b>Language</b>	<b>English only</b>	<b>Non-English language</b>

## 2.4. Screening

The study team had three reviewers in total who were involved in assessing the relevance of the identified records. The first, (NE), screened the title and abstract of each paper against the study selection criteria as set out above. Full-text screening of potentially relevant articles was then carried out primarily by another reviewer (AH) with support from a second reviewer (DR).

## 2.5. Data extraction

Two reviewers (AH and DR) simultaneously carried out data extraction alongside full-text screening. They used a pre-piloted Excel template to extract data (where available) on categories such as the population of focus, geographical scale (e.g. local, national or international level and/or population size), the type of exposure to ‘nature’ or nature-based intervention being described, outcomes of interest and the impact of these outcomes. A further two reviewers (CH and PS) then worked with NE on extracting further, more detailed information about the specific outcomes and measures used.

## 2.6. Synthesis of data

An internal workshop meeting bringing together members of the research team was held to discuss the emerging findings included in the data extraction stage. This allowed the team to cluster these findings into themes, which are presented in the next chapter. A PRISMA diagram (Moher et al. 2009) is also presented in the next chapter, indicating the screening process for the scoping review.

## 2.7. Limitations

While we have taken a systematic approach to this rapid scoping review, there are a number of limitations to note.

First, the focus of this work was to look at mental health-related outcomes. This therefore meant that we did not explicitly take into account other potentially important outcomes, such as physical health or social-related outcomes. We did not exclude papers where these outcomes were mentioned in addition to mental health outcomes; however, this was not the focus of this review and has therefore not been included in the findings.

Second, due to the rapid nature of this work, it was not possible to include other academic databases or grey literature sources as part of our search strategy. As such, any potential evidence not captured as part of reviews held within PubMed or the Cochrane Library is missing, and this needs to be taken into account when interpreting these results. To account for this limitation, we limited our search strategy to reviews only, so as to capture a wider range of evidence than would have been possible had we been focusing on a number of smaller, primary studies.

Third, the time period for our search strategy is limited within PubMed to the last year and the Cochrane Library to the last five years, and we did not snowball references of included papers. However, similar to our justification around not including other academic databases or grey literature sources, we have restricted our search to reviews only, which are anticipated to cover a much longer time period than single, primary studies.

Finally, the spelling of 'fulfill', 'fulfills' and 'fulfillment' as part of our search terms was limited to the US spelling; however, given that we were not limiting our results to a UK focus, we anticipate that this did not significantly impact findings.

### 3. Results

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#### 3.1. Overview of the literature (characteristics of reviewed papers)

##### 3.1.1. Quantity of evidence

An initial scoping exercise indicated that there is a large body of literature in this area. Figure 1 presents the number of results by year in PubMed using a crude search strategy of ‘mental health AND nature.’ The steep rise of the number of papers published in the last 10 years highlights an increasing interest and trend in this area of research.

Using the search strategy described in Box 1, we searched PubMed database, which identified 914 reviews in the last year, demonstrating the popularity of this area of research. A further 775 reviews were identified from searching the Cochrane Library, bringing the total to 1,689 publications across the two platforms. On screening these articles, we settled on a subset of 18 from PubMed and three from the Cochrane Library for full-text screening. During full-text screening, a further 11 publications were excluded on the basis that they did not fulfil our selection criteria, giving a final result of 10 reviews, of which three were Cochrane reviews from the Cochrane Library, for inclusion in our study (Figure 2).

**Figure 1 Number of records identified through the initial scoping exercise by year (1950–2018)**

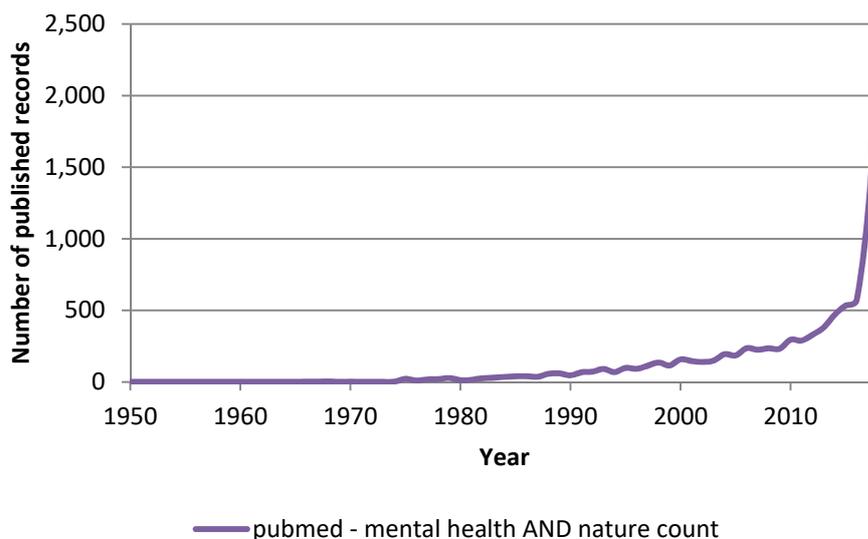
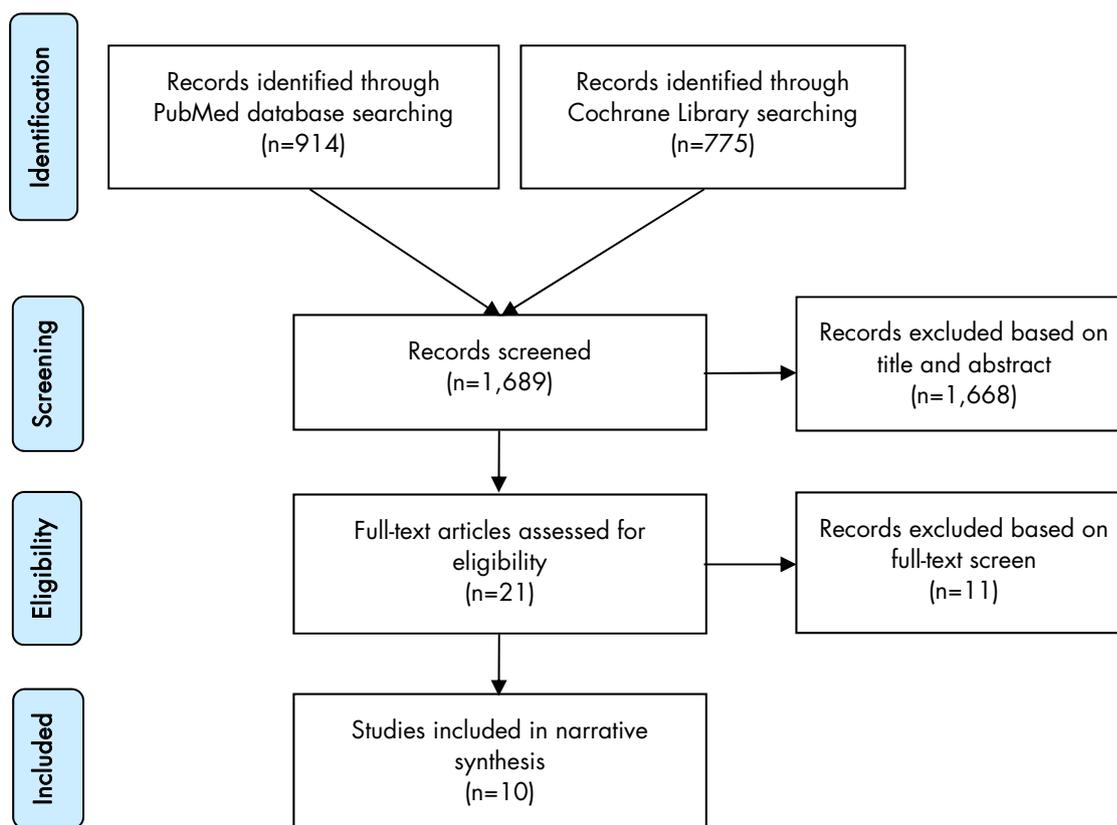


Figure 2 presents the flow of papers from screening through to extraction.

Figure 2 PRISMA flow diagram



Source: Adapted from Moher et al. (2009).

### 3.1.2. Characteristics of papers

Papers eligible for full-text screening comprised of 13 systematic reviews (including three identified from the Cochrane Library), five general literature reviews without a specific method specified, two integrative reviews and one critical review. This is illustrated in Table 2.

Table 2 Methodological characteristics of papers eligible for full-text screening (n=21)

Database	Total papers	Cochrane Systematic	Other Systematic	Literature	Integrative	Critical
PubMed	18	-	10	5	2	1
Cochrane	3	3	-	-	-	-

Table A 1 in Appendix A provides the final list of papers included for extraction and describes their corresponding focus. Of the final 10 papers that were eligible for data extraction, all but one (Liu et al. 2014), which focused on Hong Kong only, include studies from four or more countries. All three Cochrane reviews were included for extraction, in addition to seven other systematic reviews.

### 3.1.3. Quality of evidence

We limited the study criteria to reviews only to ensure that, within the small scope of this project, we could recognise the breadth of discussion, rather than focusing on primary papers, which have a narrower focus. However, all Cochrane reviews, in particular, comment on the weak quality of the evidence, such as poor-quality study designs, insufficient or incomplete data or high risk of bias due to self-reporting outcomes (Husk et al. 2016; Liu et al. 2014; Pachito et al. 2018). Additional limitations set out by the papers we extracted are set out in the within Appendix A. With this in mind, caution should be observed in interpreting the findings presented below.

## 3.2. Defining *nature* and the reported outcomes

We found a multitude of ways in which *nature* was defined and a multitude of outcomes of interest that were investigated across the papers included. Exposure to or interaction with nature was not limited to time spent in the ‘wilderness’ or the ‘outdoors’, but, rather, was conceptualised in many different ways, including interaction with gardens and spaces with vegetation, water-based nature spaces, or urban settings beautified with natural grass or flowers. Table 3 provides detail, by paper, of the types of exposure to or interaction with nature described.

The outcomes measured and reported in the papers we reviewed were also diverse. The focus of our research question on mental health and well-being meant that from the outset we were somewhat limiting the pool of outcomes with potential associations with nature. However, while we did have a primary focus on mental health, we did not discount papers simply because they additionally reported on other outcomes, such as physical health or social-related outcomes. The mental health outcomes reported ranged from very specific outcomes, such as autism and attention deficit hyperactivity disorder (ADHD), depression and anxiety, to ‘mental health’ as a broad term. We list the types of mental health or mental health-related outcomes reported in the included studies in Table 4. Some of these may overlap in categories.

Table 3 Type of exposure to or interaction with nature as reported in identified papers

Type of exposure	Husk et al. 2016	Liu et al. 2014	Pachito et al. 2018	Trostrup et al. 2019	Eigenschenk et al. 2019	Zhao et al. 2018	Weber and Trojan 2018	Tillman et al. 2018	Garcia-Llorente et al. 2018	Kondo et al. 2018
Outdoor enhancement and conservation	X									
Horticulture therapy <sup>4</sup>		X						X	X	X
Interaction with the natural setting (e.g. nature walks or outdoor sports)				X	X				X	X
Different types of light (e.g. direct vs indirect sunlight)			X							
Water-based nature ('blue' spaces)				X				X		
Exposure to outdoor ambient ozone						X				
Urban-based nature (e.g. grass patches, parks)							X			

<sup>4</sup> Defined as the therapeutic value of participating in garden activities, such as growing fruit or vegetables and/or flowers (Lui et al. 2014).

Table 4 Types of outcomes investigated in identified papers

Type of outcome	Husk et al. 2016	Liu et al. 2014	Pachito et al. 2018	Trostrup et al. 2019	Eigenschenk et al. 2019	Zhao et al. 2018	Weber and Trojan 2018	Tillman et al. 2018	Garcia-Llorente et al. 2018	Kondo et al. 2018
Mental health/state	X	X		X	X	X		X		
Quality of life	X	X			X			X		
Emotional well-being	X	X			X		X	X		
Spirituality	X									
Behaviour(al disorders)		X				X				
Alertness or cognitive function			X							X
Mood			X		X					X
Irritability			X							
Anxiety or depression					X			X	X	X
Happiness					X					
Life satisfaction					X					
Autism spectrum disorder						X				
Dementia						X				
Suicide						X				
Restorative effects							X			X
Self-esteem					X			X		
Stress or distress					X			X	X	X
Resilience					X			X		
Exhaustive disorder									X	
Attention deficit hyperactivity disorder (ADHD)								X	X	

### 3.3. Findings from the reviewed papers

There is mixed evidence in the recent literature on the role and importance of exposure to or interaction with nature in mental health and well-being. The 10 papers we reviewed focused on different populations, types of exposure, and health status. To try to tease out some of these nuances, we have divided these into the association between nature and mental health and well-being in the following populations:

- The general population
- Those with physical and/or mental illnesses
- Children and adolescents

Additionally, we have grouped a selection of the papers in terms of the impact of nature on mental health and well-being in different environments. We set these out below.

#### 3.3.1. The general population

Three papers took into account the population in general, not limited by age, gender, ethnicity, or other limitations (Eigenschenk et al. 2019; Husk et al. 2016; Kondo, Jacoby, and South 2018). Overall, most qualitative studies demonstrated an association between interaction with the natural environment and improved mental health, albeit not causally. The same was not true of quantitative studies, which tended to find no such association. We present the findings in more detail below.

Both Eigenschenk et al. (2019) and Kondo, Jacoby, and South (2018) reported some evidence in support of the overall improvement of mood and mental health and a reduction in negative states, such as stress and anxiety (Kondo, Jacoby, and South 2018; Eigenschenk et al. 2019) or depression (Eigenschenk et al. 2019) when exposed to or interacting with nature, for example by participating in an outdoor walk or in such activities as cycling, stress exercises and tree climbing. Where measured objectively, there were many studies examined by the authors that did not find statistically significant association (though this was not true for all studies) (Eigenschenk et al. 2019; Kondo, Jacoby, and South 2018).

Eigenschenk et al. (2019) conducted a literature review on the following aspects of mental health and well-being: overall well-being (quality of life, happiness and life satisfaction, mood, resilience, revitalisation, positive engagement, stress, depression, anxiety, tension, confusion, anger, rumination, loneliness, neuroticism, positive experiences) and mental health (self-esteem, self-efficacy, social effectiveness, self-confidence, self-concept), and their relationship with affective states and coping strategies, and they identified 74 studies related to this topic area (they reviewed 133 studies in total, but the remaining 59 studies focused on life-long learning and education and physical health, rather than mental health). The authors concluded that there was evidence of a reduction in stress, depression, anxiety, tension, confusion, anger, rumination, loneliness and neuroticism through participation in outdoor sports, but that the feeling of calmness and tranquillity may also be decreased following outdoor exercise. However, it is not clear whether this finding is more related to the effect of partaking in any form of exercise, regardless of location, or whether the observed effect can be attributed to the exercise taking place outdoors specifically. Eigenschenk et al. also report the positive effect of nature on the participants' perceived experiences, such as feelings of enjoyment and pleasure and connectedness to nature. As such,

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there is demonstrable but limited evidence of a positive effect of nature on the individual within the general population, but this is mostly through subjective measures. A noteworthy point made by Eigenschenk et al. is that the studies do not adequately take into account negative effects of nature, giving the example of time spent in the sun increasing Vitamin D production but also increasing the risk of sun damage to the skin (Eigenschenk et al. 2019).

Husk et al. (2016) reviewed both quantitative and qualitative papers (n=19) as part of a Cochrane review 'to assess the health and well-being impacts on adults following participation in environmental enhancement and conservation activities' and found conflicting evidence. Evidence came from the United States, Canada and Australia. The qualitative studies they reviewed (n=8) found that participants experienced an improvement in mental health and mental health-related outcomes which individuals had self-reported. However, the quantitative pool of resources they reviewed (n=7) gave a different picture. These studies could not detect an impact of exposure to nature on mental health and well-being. They did find some evidence of positive effect on quality of life, levels of physical activity and self-reported health, although the authors were not able to determine causation. The authors also found that some studies reported an increase in mental fatigue and feelings of anxiety when subjects were exposed to nature by participating in outdoor environment enhancement and conservation activities. With respect to these quantitative studies, Husk et al. also report that they were unable to identify any studies involving randomisation, although two of the studies did adopt a controlled design. Three further studies used a mixed-methods approach, but Husk et al. do not report on these studies as a distinct subgroup. The authors concluded that the studies they reviewed were of poor quality, both in design and in reporting, and they had a high-risk of bias, and that as a result, the authors were unable to conduct a meta-analysis or any subgroup analyses.

### 3.3.2. Those with physical or mental illnesses

Four additional review papers focused on populations with physical or mental illnesses (Garcia-Llorente, Rubio-Olivar, and Gutierrez-Briceno 2018; Liu et al. 2014; Trostrup et al. 2019; Zhao et al. 2018).

Trostrup et al. (2019) reviewed five studies looking at nature-based interventions in somatic and psychosomatic patients<sup>5</sup> and their impact on self-reported mental health outcomes. These interventions varied from six-day outdoor intervention programmes through to subjects having a view of natural settings from individuals' bedrooms. They report a statistically significant difference for the four studies encompassing the somatic patients but did not find any significant differences in the paper focusing on those with psychosomatic disorders. However, due to the small number of articles considered, as well as variable outcomes explored in the review, the authors conclude that the study cannot demonstrate strong evidence of an association between nature-based interventions and mental well-being.

A Cochrane review conducted by Liu et al. (2014) identified one study relating to the impact of horticultural therapy on patients with schizophrenia. The study was carried out on a farm in Hong Kong with 24 patients with schizophrenia or schizophrenic-like disorders. The authors describe horticultural

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<sup>5</sup> *Somatic patients* refers to those with one or more health conditions affecting the body alone. *Psychosomatic patients* refers to those with one or more health conditions affecting both the mind and the body.

therapy as the ‘therapeutic value of participating in garden activities such as growing fruit or vegetables and/or flowers’ (Liu et al. 2014). Lui et al. conclude a slight tendency towards improved well-being, quality of life, mental state and behaviour for those receiving the therapy in comparison with the control group (it is not clear whether these patients were all taking conventional medications for schizophrenia or not), but acknowledge that this is based on a small study of low quality, as it was single-blinded and inadequately randomised; therefore no definitive judgement can be made on the evidence surrounding the impact of nature on mental health and well-being in this population.

A review by Zhao et al. (2018) examined the effect of ozone exposure on populations exhibiting a range of mental health issues, including autism, suicide, and sexual dysfunction, and on those without a pre-existing condition. The review provided no conclusive evidence supporting the association between ambient ozone exposure and mental health outcomes, due to disagreement between the papers included, heterogeneity in study design and quality, low quality of relevant studies, and the insufficient number of studies covered per mental health outcome. The authors conclude that although data from animal studies links ozone exposure to adverse mental health outcomes, further high-quality epidemiological human studies are needed.

Finally, Garcia-Llorente, Rubio-Oliver, and Gutierrez-Briceno (2018) reviewed 98 studies pertaining to a number of different populations at risk of social exclusion, including those with poor psychological and/or mental health and those with learning and/or physical disabilities. For example, in one study, individuals suffering from depression or stress were reported to need less medical help when treated with therapeutic gardening in comparison with standard conventional therapy. However, the evidence was less certain in a study evaluating whether nature-based therapies in forests could be used to rehabilitate patients suffering from exhaustion disorder. The study remained inconclusive on the lasting impact of engaging in forest-based activities, with the authors suggesting that the effects of this therapy may be temporary. Since Garcia-Llorente, Rubio-Oliver, and Gutierrez-Briceno (2018) aimed principally to evaluate the literature on ‘green care’ as an emerging scientific discipline rather than the green care interventions themselves, we cannot apply their analysis too directly to our conclusions.

### 3.3.3. Children and adolescents

Tillmann et al. (2018) focused on children and adolescents more specifically, only evaluating studies on those aged 0 to 18. The majority of studies cited in the 35 papers they reviewed reported a positive relationship between nature and mental health when considering such outcomes as attention deficit disorder/hyperactivity disorder (ADD/ADHD), overall mental health, stress, resilience and health-related quality of life (HRQOL). Not all of these outcomes were statistically significant in their associations. The remaining papers did not find any significant associations between nature and mental health, thereby rendering the evidence base for these studies inclusive. Nevertheless, the authors of this study conclude that although the findings vary based on mental health outcome as well as the type of nature interaction, nature is positively associated with the mental health of children and teenagers, such as decreased ADD/ADHD symptoms and reduced stress levels. For more information, please see Appendix A.

### 3.3.4. The environment

Finally, the two remaining papers focused on the impact of nature on mental health and well-being in different environments (Pachito et al. 2018; Weber and Trojan 2018).

Pachito et al. (2018) reviewed evidence (which they acknowledge is of low quality) pertaining to the alertness and mood of daytime office workers. Only one of the studies they reviewed focused on the impact of varying proportions of direct vs. indirect sunlight on these two outcomes. No association was seen between this exposure and mood on the basis of this study. Nevertheless, the authors of this paper rated the study as poor quality, as it was unclear how randomisation allocation was concealed; therefore, more evidence may be needed before a conclusive statement can be made as to the impact of direct sunlight. The other four studies reviewed as part of this paper focused more on the association between cool white light and blue-enriched light and improved alertness over standard illumination in offices. There was some association between cool white light and improvement in alertness, but this was not true for mood. However, blue-enriched light did appear to improve both alertness and mood.

Weber and Trojan (2018) reviewed a different setting, focusing on the role of nature in urban environments. Of the 39 studies identified, 18 reported natural elements such as vegetation, botanical gardens, flowering meadow green roofs and green spaces, as having or predicting perceived restorative value for participants. Joye and van den Berg define restoration as ‘the experience of a psychological and/or physiological recovery process that is triggered by particular environments and environmental configurations’ (Joye and van den Berg 2013), which we are using as a proxy for well-being. The strength of evidence emerging from these 39 studies ranged from inconclusive through to positive associations between nature in urban environments and perceived restorative effects. However, a formal quality assessment was not undertaken, and the authors report that the paucity of statistical analyses limited the degree to which causal relationships could be established.



## 4. Discussion and conclusions

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It is important to keep in mind a number of aspects when interpreting the results. First of all, it is essential to note the diversity among the papers reviewed in all aspects: the type of interventions described or definitions of *nature*, the population assessed, the tools and methods used. Second, there is the heterogeneity in the outcomes measured, which is linked to the multi-faceted nature of mental health and mental well-being. For these reasons, it is not possible to aggregate the existing data to provide a weight of evidence behind any emerging trends. Overall, the evidence base is therefore currently to be seen as weak, which is also a finding stated very frequently in the reviews that we looked at. In view of all the above, we would like to emphasise the need for caution in interpreting the results of this study.

Based on the 10 papers that have been identified and seen as relevant for this ‘review of reviews’, the following conclusions can be drawn. First of all, in terms of quantity of evidence, the body of scientific literature related to the above research question is growing very rapidly. While our search string only yields fewer than 100 articles published per year up until 1990, this started to slowly pick up in the subsequent years and increased to around 300 articles published per year 2010. Since then, the number has increased very rapidly, to almost 1,700 articles published in the last year. These numbers also make clear that the subject is still in its infancy.

The second statement that can be made is that there is emerging evidence of the positive association between being in a natural environment or engaging with nature-based interventions, on the one hand, and improvement in mental health, on the other. In terms of the first group of reviews that our study has analysed, relating to the general population, this positive association has been found in particular in qualitative studies, and the findings are mostly based on self-reported impacts. It should also be stressed that in quantitatively oriented studies and in studies that did not rely on self-reported outcomes, the results were generally not strong enough to make conclusive statements. Among the second group of reviews we identified, focussing on people with physical or mental illnesses, relevant studies did find evidence suggesting a slight favouring of improved mental health and well-being for patients who were receiving a therapy that somehow related to nature, for example by participating in gardening activities. Yet again, the reviews that were reviewed as part of this study generally qualified the evidence as not strong enough to make definite judgements. With respect to the third group, namely children and adolescents, covered by 1 of the 10 reviews included in our study, at least half of the papers examined by that review identified positive relationships between nature and mental health. More specifically, these concerned the following aspects of mental health: ADD/ADHD, overall mental health, stress, resilience, and health-related quality of life (HRQOL). In the final group of papers, dealing with the impact of

nature on mental health and well-being in different environments, one review looked in particular at papers focussing on the role of nature in urban environments. It found that about half of the papers it reviewed reported natural elements such as vegetation, botanical gardens, flowering meadow green roofs and green spaces as having or predicting perceived restorative value for participants.

This initial and rapid scoping work highlights the need for further, robust studies to determine the strength of the relationship between nature and mental health, identifying and understanding the factors which influence this relationship, and also, as (Eigenschenk et al. 2019) highlight, to understand the negative impact of increased exposure to nature or natural settings.

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## Appendix A. Detailed table of included studies

Table A 1 Information on the 10 papers data were extracted from

Reference	Source	Type of review	Populations	Measures reported	Countries	Sample and analysis
Husk et al. 2016	Cochrane	Cochrane	Adults (aged $\geq 18$ years)	Measures of emotional and mental well-being: WEMWBS <sup>6</sup> , Depression, emotional state Scale (ESS), Rosenberg self-esteem scale, Profile of Mood states (POMS), Community Cohesion Scale, researcher-devised study-specific measures of self-reported health, problems sleeping and feeling anxious. Quality of life measures: SF36, SF12, researcher-devised study-specific measures of various self-report perceptions on health and well-being related to QOL.	UK, United States, Canada, Australia	Data precluded meta-analysis or subgroup analysis and therefore no statistics reported.  3648 participants across 19 studies. (3277 in quantitative studies and 371 in the eight qualitative studies that stated participant numbers). One qualitative study did not report participant numbers.  Authors conclude: <ul style="list-style-type: none"> <li>Minimal quantitative evidence of any association (positive or negative) between nature and health.</li> <li>High level of qualitative evidence demonstrating</li> </ul>

<sup>6</sup> Warwick-Edinburgh Mental Wellbeing Scale (<http://www.healthscotland.com/documents/1467.aspx>).

						perceived positive effects.
Liu et al. 2014	Cochrane	Cochrane	Schizophrenic patients	<b>Well-being and quality of life:</b> Personal Wellbeing Index (PWI-C) Scale: 0 to 77 (low score = poor) Mental state and behaviour: DASS21 Scale (0 to 84, high = poor)	Hong Kong	1 RCT study (22 participants)  Control: 1.5 Intervention (Horticultural therapy intervention): 0.9 lower (range 10.5 lower to 8.55 higher) Control: -0.5 Intervention (Horticultural therapy intervention): 23.7 lower (range 35.37 to 12.03 lower)  Authors conclude: <ul style="list-style-type: none"><li>Not enough evidence to draw sufficient conclusions about the effectiveness of horticultural therapy in patients with schizophrenia or suspected schizophrenia.</li></ul>
Pachito et al. 2018	Cochrane	Cochrane	Daytime workers in offices	<b>Mood (positive):</b> Positive and Negative Affect Schedule (PANAS) (10 (worst) to 50 (best)) <b>Mood (negative):</b> PANAS (10 (best) to 50 (worst))	Northern hemisphere countries 'between latitudes 47° 60' and 59° 91''	5 studies (3 RCTs; 2 CBA <sup>7</sup> s) (282 participants) Mood: 94 participants (effective sample size 34)  <b>Mood Positive:</b> Control: Mean 25.9 CCTL Mean Difference: 2.08 higher (0.1 lower to 4.26 higher)  <b>Mood negative:</b> Control: Mean 13.7 CCTL Mean Difference: 0.45 lower

<sup>7</sup> CBA: Controlled before–after study

						<p>(1.84 lower to 0.94 higher)</p> <p>Authors conclude:</p> <ul style="list-style-type: none"> <li>• The evidence is of very low quality for all outcomes considered.</li> <li>• Controlled studies (n=2) and one RCT may indicate that individually applied blue-enriched light and individually administered bright light in the afternoon is as effective as morning exposure for improving mood.</li> <li>• Very low-quality studies and weak evidence from controlled studies (n=2) indicate that high CCT light and varying proportions of direct and indirect light do not affect mood of daytime workers in the workplace.</li> <li>• One very low-quality study showed that exposure to morning and afternoon bright light are equally effective for the improvement of alertness and mood in subsyndromal seasonal affective disorder.</li> </ul>
Eigenschenk et al. 2019	PubMed	Systematic	No restrictions on age (included children, adolescents/teenagers, adults, and elderly)	<b>Mental health and well-being:</b> overall well-being (quality of life, happiness and life satisfaction, mood, resilience, revitalisation, positive engagement, stress, depression, anxiety, tension, confusion, anger, rumination, loneliness, neuroticism, positive experiences) and mental health (self-	United States, Canada, New Zealand, Australia, UK, Ireland, other European countries	<p>Mental Health and Well-being n = 74 studies. Education and LifeLong Learning n=57 studies. Narrative synthesis only.</p> <p>Authors conclude:</p> <ul style="list-style-type: none"> <li>• Stress, depression, anxiety,</li> </ul>

				<p>esteem, self-efficacy, social effectiveness, self-confidence, self-concept), relationship with affective states and coping strategies.</p> <p><b>Education and life-long learning:</b> intrapersonal development (physical, mental, cognitive, emotional, social, behavioural, spiritual aspects of self, personal skills, motor skills, emotional intelligence, personal responsibility, mindfulness, enhance spiritual and aesthetic awareness), educational motivation and achievements (educational performance and motivation, sense of purpose for learning, engagement, academic learning, efficacy, achievement), and cognitive aspects (attention, memory span, brain structure, function, connectivity, intellectual flexibility, problem-solving skills), interpersonal development (communication skills, cooperation, social interaction, relationships, responsibility, empathy, engagement, social trust, overall group cohesion).</p>		<p>tension, confusion, anger, rumination, loneliness, and neuroticism could be reduced by participation in outdoor sports.</p> <ul style="list-style-type: none"> <li>• Participants report many positive experiences: pleasure and enjoyment, meditation, independence, basic psychological needs of autonomy, competence and relatedness, experiences of flow, comfort and intense emotions, enhanced feeling of body, discovering the pleasure of achievement, vital strength, higher will to live in drug addicts, an intense nature experience.</li> <li>• Negative effect: feelings of calmness and tranquillity may be decreased following outdoor exercise.</li> </ul>
Garcia-Llorente et al. 2018	PubMed	Systematic	Individuals at risk of social exclusion (refugees and displaced persons, long-term unemployed persons, offenders, people suffering from addictions, people suffering for physical disabilities or illness, older population, people with learning disabilities, children and young people at risk of exclusion, people suffering from mental health illness, people suffering from psychological health illness)	Most common methods to evaluate green care interventions were interviews (43%) and surveys (41%). Interviews involved semi-structured guides and open-ended questions to explore users' experiences with green care practices. Other studies used quantitative data from surveys using experimental or quasi-experimental designs at clinical assessments. Some scales mentioned for these survey studies are: perceived stress scale,	European countries: The Netherlands, UK, Norway, Sweden, Italy, Denmark, Spain, Germany, Switzerland, Belgium, Finland, France	98 studies total. Study aimed to evaluate the literature on green care as a scientific discipline (terms associated with green care, specific approaches used by countries, aims of studies) rather than the green care interventions themselves. Study referred to two green care interventions in some detail.

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				West Haven-Yale multidimensional pain inventory or the hospital anxiety and depression scale. Other methodologies used are: participant observations (8%), official statistics (7%), focal groups (7%), participatory methods (2%) and recordings (2%).		
Kondo et al. 2018	PubMed	Systematic	Adults (including students) with mean age of each study ranging from 20 to 85	<p>Methods included: anthropometric measurements of the cardiovascular system and self-report. Only a few studies used blood, actigraph and EEG as modalities of stress outcome measurement (these studies had small sample sizes and generated mixed results from which no generalisations can be made).</p> <p><i>7 general categories of stress outcome measurements:</i> anthropometric measurements of the cardiovascular system, saliva, blood, urine, actigraph, electroencephalography (EEG), self-report.</p> <p><i>Self-report scales</i> <b>Anxiety:</b> Hospital anxiety depression scale (HAD), Spielberger State-Trait Anxiety Inventory (STAI) <b>Attention:</b> Focus of Attention Scale (TFOAS), Necker Cube Pattern Control task (NCPCT) <b>Cognitive function:</b> Backward Digit Span (BDS) <b>Mood:</b> Inventory of Personal Reactions (ZIPERS) Overall Happiness Scale, Philadelphia Geriatric Center Positive</p>	Japan, UK, South Korea, Finland, The Netherlands, Norway, Lithuania, United States, Sweden	<p>43 studies total. 23 studies conducted in Japan, rest conducted in Europe and United States.</p> <p>All studies had an experimental research design and about half (24) included a randomised study design component.</p> <p>Sample sizes for more than half of the studies were small (&lt;20).</p> <p>Authors conclude: Primary indicators of stress (heart rate, blood pressure and self-report) provide 'most convincing evidence' of a positive impact of exposure to nature on health and stress.</p>

				<p>and Negative Affect Rating Scale, Physical Activity Affective Scale (PAAS), Positive Affect Scale (PAS) and Negative Affect Scale (NAS), Positive and Negative Affect Scale (PANAS), Profile of Mood States, Semantic Differential (SD), Spielberger State-Trait Anxiety Inventory (STAI), Stress-Refresh feeling test, Unnamed questionnaire, University of Wales Institute of Science and Technology (UWIST) Mood Adjective Checklist (MACL)</p> <p><b>Perceived stress:</b> Unnamed questionnaire, University of Wales Institute of Science and Technology (UWIST) Mood Adjective Checklist (MACL), Visual Analog Scale (VAS)</p> <p><b>Restoration:</b> Perceived Restorativeness Scale (PRS), Restoration Outcome Scale</p> <p>Sleep: St Mary's Hospital Sleep Questionnaire (SMHSQ)</p>		
Tillman et al. 2018	PubMed	Systematic	Children and teenagers (aged 0–18 years)	<p><b>Emotional well-being:</b> Author Generated Survey: Parent Report, Bar-On Emotional Quotient Inventory: Child Report, Cantril Ladder: Child Report, Kid-KINDL Questionnaire: Child Report, Life as a Whole Scale: Child Report, Hubeners Life Satisfaction Scale: Child Report, Strength and Difficulties Questionnaires: Parent Report, Ten Domain Index of Well-being: Child Report, The Basler Well-being Questionnaire: Child Report, UWIST Mood Adjective Checklist: Child Report, Youth Self-report: Child Report,</p>	United States, UK, Canada, Spain, Lithuania, The Netherlands, Austria, Germany, Israel, South Africa, New Zealand, Australia, Sweden	<p>35 studies total.</p> <p>Categorises papers into three groups based on type of nature interaction: accessibility, exposure, engagement. Only quantitative papers included to better ensure comparability. Majority of studies had small sample sizes and were from developed regions.</p> <p>A meta-analysis was not possible due to the heterogeneity of the methods and principal summary measures reported in the papers.</p>

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			<p>Zuckerman's Inventory of Personal Reactions: Child Report.</p> <p><b>ADD/ADHD:</b> Author Generated Survey: Parent Report, Diagnostic and Statistical Manual of Mental Disorders 4th Edition: Teacher Report, Digit Span Backwards: Child Report, Necker Cube Pattern Control Task: Child Report, Opposite Worlds Test: Child Report, Strength and Difficulties Questionnaires: Parent Report</p> <p><b>Mental Health:</b> General Well-being: Child Report, Author Generated Survey: Parent Report, Mindful Attention and Awareness Scale: Child Report, World Health Organization Well-Being Index: Child Report, Life Attitudes Schedule Short Form: Child Report, Millon Adolescent Clinical Inventory: Child Report, Mental Component Score from the SF-12v2: Child Report, Strength and Difficulties Questionnaires: Parent Report</p> <p><b>Self-esteem:</b> Author Generated Survey: Child Report, Coopersmith Self-Esteem Inventory: Child Report, Kid-KINDL Questionnaire: Child Report, Rosenberg Self Esteem Scale: Child Report, Self-Esteem Questionnaire Piers and Harris: Child report, The Behaviour Assessment System for Children: Child Report</p> <p><b>Stress:</b> Bar-On Emotional Quotient Inventory: Child Report, Lewis Stressful Life Events Scale: Child Report, Perceived Stress Questionnaire: Child</p>	<p><b>Emotional well-being</b> (15 papers): removed two papers due to low quality→10 out of 23 findings identifying a significant positive relationship between nature and emotional well-being.</p> <p><b>Attention deficit disorder/hyperactivity disorder (ADD/ADHD)</b> (10 papers): after removing poor quality studies→7/13 findings identified a statistically significant positive relationship.</p> <p><b>Overall mental health</b> (9 papers): after removing poor quality studies→8/12 findings identified a significant positive relationship.</p> <p><b>Self-esteem</b> (9 papers): no studies were poor quality→10/13 findings showed non-significant relationship.</p> <p><b>Stress</b> (4 papers): after removing poor quality studies→4/5 findings identified a significant positive relationship.</p> <p><b>Depression</b> (3 papers): no studies were poor quality→4/6 findings showing no significant relationship with nature.</p> <p><b>Resilience</b> (3 papers): no studies were poor quality→3/5 findings showed significant positive associations between resilience and nature.</p>
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				<p>Report, Perceived Stress Scale: Child Report</p> <p><b>Depression:</b> Beck Depression Inventory-II: Child Report, Reynolds Depression Scale-Short Form: Child Report, The Centre for Epidemiologic Studies-Depression Scale: Child Report</p> <p><b>Resilience:</b> 14-item Resilience Scale (RS-14): Child Report, Resiliency Scale for Children and Adolescents: Child Report, The Resilience Questionnaire: Child Report</p> <p><b>Health related Quality of life (HRQOL):</b> Kid-KINDL Questionnaire: Child Report, Pediatric Quality of Life Inventory 4.0 Generic Core Scale: Child Report &amp; Parent Proxy</p>		<p><b>Health-related quality of life (HRQOL)</b> (2 papers): no studies were poor quality→4/5 findings showed a significant positive association with nature.</p> <p>Authors conclude:</p> <ul style="list-style-type: none"> <li>Findings vary based on mental health outcome and type of nature interaction, but indication of a beneficial impact on children’s and teenagers’ mental health.</li> </ul>
Trostrup et al. 2019	PubMed	Systematic	Adult patients diagnosed with a physical disease, participating in nature-based interventions	<p>Self-reported mental well-being.</p> <p><i>Cimprich and Ronis:</i>            Constructs: Symptom distress, Attentional fatigue and ‘Cognitive Capacity to Direct attention’ (CDA), i.e., ability to focus and concentrate            Instruments: Symptom Distress Scale (SDS); Digit span forward (DSF) and backward (DSB) Trail making; A and B (TMA and TMB); Necker cube pattern control (NCPC); ‘Total Attention Score’ (TAS): compound score of DSF/DSB, TMA/ TMB, NCPC</p> <p><i>Hiltzig et al.:</i>            Constructs: Self-esteem, positive/negative affect, self-efficacy, and</p>	United States, Canada, Norway, Switzerland	<p>5 studies considered in total. Narrative synthesis only. No meta-analysis conducted due to heterogeneity of studies, and no additional analyses were conducted.</p> <p><i>Cimprich and Ronis:</i> Intervention group scored significantly better on symptom distress and cognitive measures, except for Necker Cube Pattern Control, where there was non-significant improvement.</p> <p><i>Hiltzig et al.:</i> Significant increase in self-efficacy and positive affect. Differences in negative affect and self-esteem were non-significant.</p>

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			<p>personal goal attainment Instruments: Rosenberg Self-Esteem Scale (RSE) Positive Affect and Negative Affect Schedule (PANAS) Moorong Self-Efficacy Scale (MSES) SCRIP Cottage Program evaluation Questionnaire</p> <p><i>Raanaas et al.:</i> Constructs: Self-perceived physical and mental health, subjective well-being Instruments: The 12-item Short form Health Survey (SF-12) Circumplex model: AUP (activated-unpleasant affects) UAP (unactivated-pleasant affects) Satisfaction and time spent in room</p> <p><i>Rosenberg et al.:</i> Constructs: Body image, self-compassion and psychosocial function (self-esteem, depression, alienation) and quality of life Instruments: Body Image Scale (BIS) Self-Compassion Scale Short Form Psychological Screening Inventory-2 (PSI-2)</p> <p><i>Watzek et al.:</i> Constructs: Pain self-efficacy, Chronic pain management, Capability for daily activities, Attitudes towards Therapeutic Nordic Walking Instruments: Pain Self-Efficacy Questionnaire (PSEQ) The Freiburg Questionnaire—Stages of Chronic Pain Management (FQ-STAPM), ratings by both therapist and patient Spinal Function Sort (SFS)—physical capabilities Questionnaire about</p>	<p><i>Raanaas et al.:</i> Significant increase in self-reported mental health, especially in men and pulmonary patients. No significant differences in subjective well-being.</p> <p><i>Rosenberg et al.:</i> Significant improvement in body image, self-compassion, depression. Significant improvement in self-esteem, alienation, fatigue, and concentration. Effects were moderated by patients experiencing quality of life impacted by cancer treatment (greater effect if impacted). Differences in alienation, aggression, or isolation were non-significant. No significant differences between P1 (first program) and P2 (second program).</p> <p><i>Watzek et al.:</i> No significant differences in any outcomes.</p>
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				Therapeutic Nordic Walking		
Weber and Trojan 2018 <sup>8</sup>	PubMed	Systematic	No restrictions – all ages	<p><i>Bagot et al.</i> (Vegetation and restoration in urban settings): Correlational PRCS-C.</p> <p><i>Carrus et al.</i> (Restoration in botanical gardens): Field experiment PRS, Italian version.</p> <p><i>Carrus et al.</i> (Restoration in urban green spaces): Field experiment PRS, Italian version.</p> <p><i>Fornara and Troffa</i> (Restoration potential of different urban environments): Correlational PRS, Italian version.</p> <p><i>Grahn and Stigsdotter</i> (Restorative aspects of nature): Correlational self-estimates of health/unspecified.</p> <p><i>Hernández and Hidalgo</i> (Vegetation and restoration in urban settings): Correlational PRS, Spanish version.</p> <p><i>Hipp et al.</i> (Vegetation and restoration in urban settings): Field experiment, PRS.</p> <p><i>Jiang et al.</i> (Effect of tree cover density on stress recovery): Experiment, Cortisol and skin conductance levels.</p>	Australia, United States, Mexico, Italy, Spain, Sweden, Scotland, Iceland, Norway, The Netherlands, Finland, China	<p>39 studies considered in total</p> <p><i>Bagot et al.</i> (Vegetation and restoration in urban settings): Vegetation predicts perceived restoration likelihood of a playground.</p> <p><i>Carrus et al.</i> (Restoration in botanical gardens): Perceived restoration in botanical gardens was high.</p> <p><i>Carrus et al.</i> (Restoration in urban green spaces): Biodiversity has a stronger link to perceived restoration in urban compared to peri-urban environments.</p> <p><i>Fornara and Troffa</i> (Restoration potential of different urban environments): Historical environments have the same restorative potential as urban parks.</p> <p><i>Grahn and Stigsdotter</i> (Restorative aspects of nature): Refuge, diversity in species, nature, and absence of social stimuli could increase restoration likelihood of urban environments.</p> <p><i>Hernández and Hidalgo</i> (Vegetation</p>

<sup>8</sup> **PRS**: Perceived Restorativeness Scale; **PRCS-C**: Perceived Restorative Components Scale for children; **EPREE**: Spanish acronym for Scale of Restorative Potential of School Spaces (unpublished, validated by Mejia Castillo et al.); **ROS**: Restoration Outcome Scale.

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				<p><i>Jiang et al.</i> (Effect of tree cover density on stress recovery): Experiment, VAS.</p> <p><i>Kuo</i> (Green areas in poverty stricken neighborhoods): Field experiment, Digit Span Backwards test.</p> <p><i>Kuo and Sullivan</i> (Green areas in poverty stricken neighborhoods): Field experiment, Digit Span Backwards test.</p> <p><i>Lee et al.</i> (Vegetation and restoration in urban settings): Experiment, PRS.</p> <p><i>Lindal and Hartig</i> (Restoration likelihood of residential areas): Experiment, some items of the PRS.</p> <p><i>Mejía-Castillo et al.</i> (Restoration likelihood in schools): Correlational, EPREE.</p> <p><i>Nordh</i> (Methods to measure restoration): Correlational, Study 1: PRS; Study 2: One question assessing restoration; Study 3: One question assessing restoration.</p> <p><i>Nordh et al.</i> (Restoration likelihood in urban spaces): Correlational, one question assessing restoration/unspecified.</p> <p><i>Nordh et al.</i> (Restoration in parks): Correlational, PRS.</p>	<p>and restoration in urban settings): Natural elements in urban environments have a restorative value.</p> <p><i>Hipp et al.</i> (Vegetation and restoration in urban settings): Vegetation on campus increases restorative value.</p> <p><i>Jiang et al.</i> (Effect of tree cover density on stress recovery): Tree cover density increased stress recovery for male participants in a U-shaped curve, but not for female participants.</p> <p><i>Jiang et al.</i> (Effect of tree cover density on stress recovery): The association between tree cover density and stress recovery is linear.</p> <p><i>Kuo</i> (Green areas in poverty stricken neighbourhoods): Residents of buildings with nearby green areas showed less mental fatigue compared with residents of buildings with no nearby green areas.</p> <p><i>Kuo and Sullivan</i> (Green areas in poverty stricken neighbourhoods): Residents of buildings with nearby green areas showed less mental fatigue and aggression compared with residents of buildings with no nearby green areas.</p> <p><i>Lee et al.</i> (Vegetation and restoration</p>
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			<p>urban settings): Field experiment, PRS, ROS.</p> <p><i>Wang et al.</i> (Vegetation and restoration in urban settings): Experiment, PRS.</p>	<p><i>Packer and Bond</i> (Restorative values of different urban environments): Visitors to an art gallery find it restoring. However, the national parks and beaches received highest restoration rating from the overall sample.</p> <p><i>San Juan et al.</i> (Restorative potential of urban squares): The urban square higher in vegetation was perceived as more restorative, but the urban square lower in vegetation decreased stress further than the other square.</p> <p><i>Scopelliti et al.</i> (Biodiversity, affective and social components): High levels of biodiversity correlate with restoration potential of a place. Affective components mediated this relationship.</p> <p><i>Scopelliti and Giuliani</i> (Restoration likelihood in natural vs urban environments): Urban and natural environments are equally restorative.</p> <p><i>Staats et al.</i> (Restoration in different urban environments): Attentional fatigue moderates preference for a more restorative environment, here an urban park.</p> <p><i>Tabrizian et al.</i> (Green space enclosure and restorativeness): Enclosure positively affects perceived</p>
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						<p>restorativeness of an urban plaza.</p> <p><i>Tenngart Ivarsson and Hagerhall</i> (Restorativeness of gardens, usefulness of PRS): Scenes can include elements that differ in perceived restorativeness. The PRS is a useful tool for measuring perceived restorativeness.</p> <p><i>Tyrväinen et al.</i> (Restoration in different urban settings): Perceived restorativeness was rated highest for the woodland, but physiological measures of stress relief showed no difference between the settings.</p> <p><i>Wang et al.</i> (Vegetation and restoration in urban settings): Parks are restorative, which is supported by psychophysiological measures.</p>
Zhao et al. 2018	PubMed	Systematic	Populations exhibiting a range of mental health issues, including autism, suicide, and sexual dysfunction, and those without a pre-existing condition	<p><b>Autism spectrum disorder (ASD) or Autism:</b> 1) not specified; 2) not specified; 3) not specified; 4) not specified; 5) not specified; 6) not specified; 7) Mullen Scales of Early Learning (MSEL), Vineland Adaptive Behavior Scales (VABS), Autism Diagnostic Observation Schedule (ADOS)</p> <p><b>Impairment of cognitive functions:</b> 1) Simple reaction time test (SRTT), symbol–digit substitution test (SDST), serial–digital learning test (SDLT); 2) cognitive tests (executive function, verbal learning, logical memory, visual processing, visual episodic memory, semantic memory)</p>	Taiwan, South Korea, Korea, China, United States, Canada, Mexico, Spain, Germany, Belgium, Sweden	<p><b>The timing of the ozone exposure relative to measurement of mental health outcomes differs among the papers reviewed.</b></p> <p><b>Autism spectrum disorder (ASD) or Autism:</b> Association between ozone exposure and ASD or autism is unclear due to disagreement among papers covered. Number of papers examined: 7</p> <p><b>Impairment of cognitive functions and dementia:</b> Association between ozone exposure and dementia is unclear due to heterogeneity in study design and quality.</p>

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			<p><b>Dementia:</b> 1) NNA/Cr, Cho/Cr and ml/Cr ratios [N-acetylaspartate (NAA), choline, creatine (Cr) and myoinositol (ml)]; 2) not specified; 3) number of dementia-related emergencies; 4) not specified; 5) number of cases of dementia</p> <p><b>Depression disorder:</b> 1) number of emergency department visits for depression, 2) Korean version of the Geriatric Depression Scale–Short Form; 3) number of emergency department visits for depression; 4) first report of physician diagnosis or use of antidepressant medication; 5) number of emergency department visits for depression; 6) 20-item Revised Centre for Epidemiological Studies Depression Scale (CESD-R)</p> <p><b>Suicide:</b> 1) number of suicides and suicide attempts leading to police procedures; 2) number of suicides; 3) variation of weekly suicide rate from Korea National Statistical Office; 4) number of suicides from 5–85 years old; 5) number of emergency department visits from suicide attempt/ideation in hospital</p> <p><b>Disorders of sex preference:</b> 1) number of sex crimes reported by police department</p> <p><b>Mental disorders (hospital admissions):</b> 1) number of cases of daily hospital admissions for mental disorder (manic episode, depressive disorder and others)</p> <p><b>Neurobehavioral disorder:</b> 1) 6 and 18-month Bayley Scales of Infant</p>	<p>Number of papers examined: 7</p> <p><b>Depression disorder:</b> Association between ozone exposure and depression is unclear due to heterogeneity in study design and quality. Number of papers examined: 6</p> <p><b>Suicide:</b> Association between ozone exposure and suicide is unclear due to the low quality of relevant studies. Number of papers examined: 5</p> <p><b>Disorders of sex preference:</b> No final conclusion can be drawn due to insufficient number of studies covered. Number of papers examined: 1</p> <p><b>Mental disorders (hospital admissions):</b> No final conclusion can be drawn due to insufficient number of studies covered. Number of papers examined: 1</p> <p><b>Neurobehavioral disorder:</b> No final conclusion can be drawn due to insufficient number of studies covered. Number of papers examined: 1</p> <p><b>Panic attacks:</b> No final conclusion can be drawn due to insufficient number of studies covered. Number of papers examined: 1</p> <p><b>Psychiatric emergency:</b> No final</p>
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				<p>Development</p> <p><b>Panic attacks:</b> 1) number of emergency department visits for panic attacks</p> <p><b>Psychiatric emergency:</b> 1) number of psychiatric emergency visits</p> <p><b>Sexual dysfunction:</b> 1) erectile dysfunction status through self-reported questionnaire</p>		<p>conclusion can be drawn due to insufficient number of studies covered. Number of papers examined: 1</p> <p><b>Sexual dysfunction:</b> No final conclusion can be drawn due to insufficient number of studies covered. Number of papers examined: 1.</p> <p>Authors did not make any further overarching conclusions.</p>
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