

Title: Effects of natural environment on mental health: an umbrella review of systematic reviews and meta-analyses

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Abstract

Objectives: To synthesize the evidence on the effects of exposure to natural environment on mental health to inform future policymaking, practice, and research.

Methods: A systematic search of nine major databases and additional sources were conducted using relevant keywords for the natural environment and mental health till November 2019. We included systematic reviews or meta-analyses reporting any measures of associations between the natural environment and mental health. The data on study characteristics and research findings were extracted using the JBI data extraction tool and synthesized narratively.

Results: Twenty reviews were included in this umbrella review reporting both correlational and experimental studies. Among diverse population groups, the exposure to the natural environment was associated with improvements in depressive symptoms, anxiety, mood disorders, stress, cognitive and emotional functions, affect, happiness, and overall mental wellbeing.

Conclusions: The findings of this review inform beneficial mental health outcomes associated with exposure to the natural environment.

Policy implications: This umbrella review suggests collaborative policymaking, advanced research, and evidence-based practice protecting the natural environment and improving mental health across populations.

Background

Mental health is recognized as a critical component of overall human health and wellbeing.¹ In recent years, several concerns regarding mental health at the population level have emerged across scientific and professional communities. First, mental disorders contribute to a major proportion of the global burden of diseases. Nearly 32% of total years lived with disability (LYD), and 13% of disability-adjusted life-years around the world can be attributable to mental illness.² Second, the availability and accessibility of mental health services remain poor even in developed countries, which leave many individuals untreated who require professional care.³ Third, the number of trained psychiatrists, psychologists, and other mental health professionals is critically low across global nations.³ This paucity of human resources affects the overall mental healthcare delivery. Fourth, the affordability of mental healthcare services is a major barrier to avail mental health services in many countries.^{3,4} Fifth, a wide range of sociocultural problems, including social stigma and lack of awareness, affect the reporting, diagnosis, and treatment of mental illness at the individual and community level.^{3,5} Therefore, the true burden of mental illness remains underestimated and poorly addressed in most part of the world.³⁻⁵ These challenges demonstrate how the demand for mental health services continues to outpace the supply of treatment facilities. In addition to strengthening mental health services globally, it is essential to examine how mental disorders can be prevented and how positive mental health can be promoted to alleviate mental health disparities.⁶⁻⁸

Mental health is deeply impacted by interactions between physiological, psychological, behavioral, socioeconomic, environmental, genetic, and epigenetic conditions.⁹ In many instances, the contextual factors may outweigh the influence of intrapersonal attributes to determine mental health status among the individuals.^{4,9} Several studies suggest that the lived experience in a given environment influences how individuals perceive and respond to the psychological stressors, which involve complex psychopathological processes leading to mental health outcomes.¹⁰ In this discourse, a growing body of research highlights that the natural environment can positively influence mental health outcomes among individuals and populations.^{10,11} Such interactions and associated mental health outcomes are often moderated by the type of natural environment, time spent on such places, and forms of sensory inputs, including olfactory, auditory, tactile, and visual senses received from the environment.¹⁰ Several

correlational and experimental studies have shown that human psychological processes and mental health outcomes are associated with the exposure to green space like garden, park, forest, and trees near the streets.^{10–12}

Considering the high burden of mental illness and an urgent need for sustainable strategies to promote mental health, it is essential to synthesize the evidence on the impacts of the natural environment on mental health. Systematic reviews and meta-analyses conducted with optimal methodological rigor can offer high-quality evidence informing further research and development of effective policies and practices.¹³ Given that more than 11 systematic reviews and meta-analyses are published in a day, it is essential to synthesize the findings of multiple reviews to consolidate the findings in a systematic umbrella review to better inform science and practice.¹⁴ This umbrella review aims to evaluate and appraise the current evidence on the effects of the natural environment exposure on mental health and wellbeing, which may facilitate future mental health practice, research, and policy development.

Methods

Operationalizing the review: guidelines, frameworks, and definitions

In this umbrella review, we followed two guidelines to ensure the methodological rigor of the literature review process. First, we used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines,¹⁵ which is widely used for standardizing the reporting of systematic and meta-analytic reviews. Second, we adopted the Joanna Briggs Institute (JBI) methodology for umbrella reviews,¹⁴ which provide further guidelines specific for synthesizing the findings from multiple reviews. Further, we adopted a Population, Exposure, Comparator, and Outcomes (PECOS) framework to examine the constructs of the review. In this framework, we included any population as the study participants who were exposed to any form of the natural environment for any duration. Further, we did not restrict any specific comparator, which allowed to include any comparator participants as well as studies evaluating the effects of the natural environment on the same individuals. The outcomes of interest are any variable that is related to mental health and wellbeing among the study participants. To operationalize this framework, we specified definitions of the core concepts of this review.

Nature encompasses elements and phenomena of earth's structures and living creatures across spatial scales, including soil, trees, public parks, forests, urban creek, wilderness, green space, and stable or dynamic processes within those places.¹⁶ Experiencing nature includes the interactions of the individuals, deliberate or unintentional, with stimuli from the natural environment through sensory organs, which can be perceived within the intrapersonal perceptions and sociocultural contexts.^{10,17}

Further, we adopted the definition of World Health Organization which stated mental health as, "a state of wellbeing in which an 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."¹ This broader definition includes not only mental disorders, but also psychological processes and conditions like affect, emotion, and cognition within the scope of mental health studies. Moreover, mental health and wellbeing also involves happiness, resilience, and abilities to have healthy relationships, which enable individuals to lead meaningful lives and engage in their social spaces.

Searching the literature

We searched MEDLINE, PubMed, PsycINFO, Academic Search Ultimate, CINAHL, Health Source Nursing/Academic Edition, Health Policy Reference Center, Cochrane Library, and Environment Complete databases using a set of search query including keywords and Boolean operators to retrieve the relevant literature as per the objective of this review. The search strategy consisted of keywords related to the natural environment, mental health, and systematic review or meta-analysis. The detailed search strategy is available in Table 1. All the databases were searched since the inception of respective databases till November 21, 2019, without any language restriction. Moreover, we used the "cited by" function in Google Scholar to evaluate the articles citing primarily recruited studies. Furthermore, we communicated with scholars working in the fields of environmental and mental health sciences to learn about potential articles fitting the objective of this review. All the citations were uploaded to RefWorks¹⁸ and Rayyan¹⁹ software for citation management and systematic evaluation processes, respectively.

Table 1: Search strategy and keywords for this umbrella review

Search query	Keywords (searched within titles, abstracts, subject headings like MeSH, and general keywords)
1	“green space” OR “greenspace” OR “greenness” OR “greenery” OR “wilderness” OR “wild land” OR “natural land” OR “natural environment” OR “municipal land” OR “community land” OR “public land” OR “wild space” OR “municipal space” OR “natural space” OR “open space” OR “municipal park” OR “botanic park” OR “park access” OR “urban park” OR “city park” OR “park availability” OR “public garden” OR “natural neighbourhood” OR “natural facilities” OR “vegetation natural” OR “belt green” OR “wild area” OR “trail green” OR “natural area” OR “green area” OR “woodland” OR “forest” OR “shinrin-yoku” OR “forest bathing” OR “NDVI” OR “normalized difference vegetation”
2	“mental” or “psychological” or “psychiatric” OR “mental health” OR “mental health services” OR “mental disorders” OR “mental illness” OR “common mental disorders” OR “psychosocial” OR “psychosomatic” OR “emotional” OR “psychiatric disorders” OR “psychiatric illness” OR “behavio*” OR “obsessive compulsive” OR “dementia” OR “depress*” OR “suicide*” OR “schizophrenia” OR “bipolar disorder” OR “mood disorder” OR “alcohol” OR “anxiety” OR “substance abuse” OR “substance use” OR “panic” OR “addiction” OR “posttraumatic” OR “Alzheimer’s” OR “post-traumatic” OR “PTSD” OR “dissociative” OR “personality disorder”
3	Systematic review OR Meta-analysis
4	1 AND 2 AND 3

Selection of studies

After removing the duplicates, two authors independently evaluated the titles/abstracts of the citations as per the recruitment criteria. Articles were included if they were: a) systematically conducted qualitative research synthesis using qualitative (meta-synthesis or narrative synthesis) or quantitative (meta-analysis) approaches, b) reported relationships, effects, or impacts of exposure to natural environments on mental health of any population, c) published as peer-reviewed journal articles, d) found full text in English.

We excluded articles if they: a) were not systematically conducted reviews or meta-analyses (for example, primary or secondary data analyses, letters, opinions, unstructured reviews etc. were excluded), b) did not report any measures of relationships, effects, or impacts of exposure to natural environments on mental health, c) were not peer-reviewed journal articles (for example,

dissertations, reports, policy briefs, book chapters were excluded), d) did not have full text in English.

After the blinded initial screening, conflicts on the eligibility of articles were resolved at the presence of a third author based on consensus.

Evaluation of the methodological quality of the included studies

Critical appraisal of the recruited studies is an essential process of conducting an umbrella review. To ensure methodological appropriateness, we used the JBI critical appraisal checklist for systematic reviews and research synthesis checklist to assess the methodological quality of the included studies.¹⁴ Two authors independently evaluated each of the recruited studies, which was finalized by discussing it with a third author. The checklist consists of ten items; each item can receive one point, and the overall quality score of a study can range from zero to ten. In this review, studies receiving zero to four, five to seven, and eight to ten were categorized as low, medium, and high-quality studies, respectively.

Data extraction and synthesis

A codebook was prepared using the JBI data extraction tool for systematic reviews and research synthesis.²⁰ Two authors independently extracted data on following domains: the authors, title and objective of the studies, year of publication, names of databases, timeframe of conducting a literature search, origin, and type of the primary studies in respective reviews, sample characteristics, and key findings on mental health implications of exposure to natural environment. Considering heterogeneity in the methods and outcomes of the recruited reviews, a narrative synthesis of the extracted data was conducted and presented in this umbrella review. Qualitative or narrative findings were synthesized from multiple reviews, whereas quantitative data were presented with the range of rates within a 95% confidence interval (CI), wherever reported.

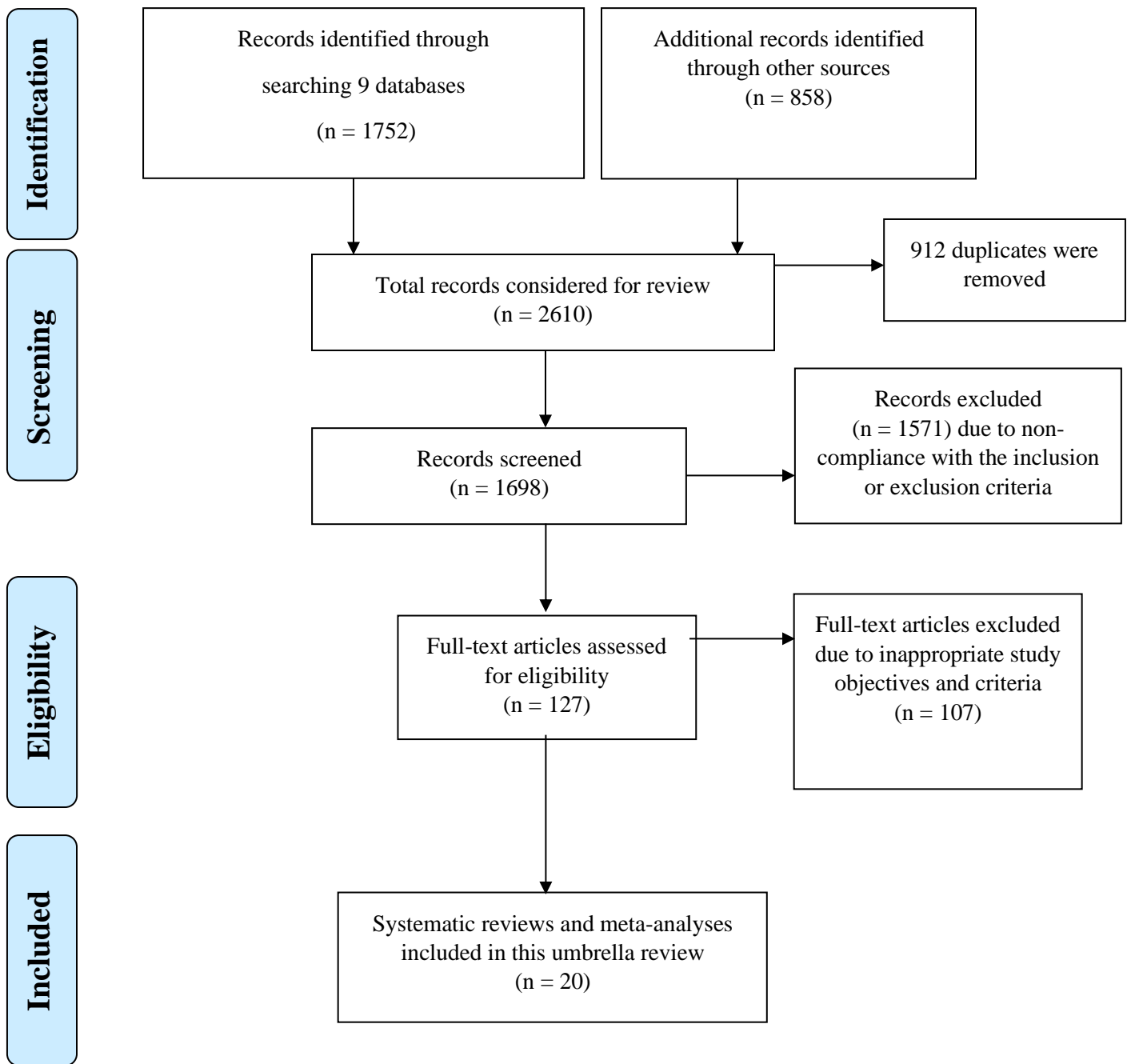


Figure 1: Flow diagram of the umbrella review

Results

We found 1752 citations through searching nine databases and 858 citations from additional sources, totaling 2610 citations. After removing 910 duplicate citations, we evaluated the titles and abstracts of 1698 citations according to our recruitment criteria. At the end of the evaluation, we excluded 1571 citations that did not meet our criteria. Further, we evaluated the full-text articles of the remaining 127 citations. Lastly, we excluded 107 articles which did not meet at least one of our criteria and included 20 articles in this umbrella review (see Figure 1).^{21–40}

Characteristics of the recruited studies

A majority of the recruited articles (n = 13) were systematic narrative reviews,^{22–24,26–28,31,34,36–39} and remaining articles were meta-analytic reviews (see Table 2).^{21,25,29,30,32,33,35,40} Moreover, only five studies were published until 2016,^{21,22,33–35} whereas most (n = 13) studies were published since 2017. The number of databases searched in the respective reviews ranged from 2 to 10, with a median of 5 databases. The mean number of primary studies included in each review was 25.4, with a range of 5 to 52 studies. The quality evaluation of the reviews found no study with low quality, six studies with medium quality,^{24,27–29,38,40} and remaining 14 studies with high methodological quality (see Supplemental File 1).^{21–23,25,26,30–33,35–37,39}

Global distribution of primary studies recruited in the review studies

All the included systematic reviews and meta-analyses represent primary studies that were conducted mainly in North America, Europe, and Oceania. Nine reviews had at least one study from Asia,^{21,25,26,28–30,35,36,40} whereas only two reviews had at least one study from Central or Latin America^{22,29}, and only one study included a primary study from South Africa.²³ Seven reviews included no primary study from Central or Latin America, Africa, or Asia.^{24,27,31,32,34,38,39}

Characteristics of the samples and study populations

The sample sizes varied across primary studies in respective reviews. The minimum sample size in all reported primary studies as three and the maximum sample was reported as 345,143.^{22,26} The recruitment strategy in the primary studies varied across contexts, which included community settings, educational institutions, hospitals, geriatric care center, and multiple recruitment sites. Moreover, most of the reviews (n = 6) evaluated primary studies that recruited

Table 2: Characteristics and the key findings of the included systematic reviews and meta-analyses

Author and year of publication	Name and timeframe of searching Databases	Number and type of primary studies; meta-analysis or systematic review	Origin of included studies	Sample size and characteristics of the study population (if reported)	Key findings on relationships between the natural environment and mental health and wellbeing
Capaldi et al. (2014) ²¹	PsycINFO and Dissertation and Theses Full Text; 2013-14	21 (with 30 non-overlapping samples); meta-analysis	Canada (46.7%), The United States (20%), Europe (10%), Asia (3.3%), and multiple locations (10%)	Sample size was 8523 (ranging from 22 to 2224); mean age of the participants was 31.91 years (SD = 11.37), 38.62% to 86.10% sample were female, (M = 65.33, SD = 11.84); University or college students were 33.3% of the participants, whereas 40% were community members	The relationship between nature connectedness and happiness had a small but significant effect size ($r=.19$ and $r=.18$ in fixed and random effects models, respectively). Vitality had the strongest relationship with nature connectedness ($r=.24$), followed by positive affect ($r=.22$) and life satisfaction ($r=.17$). The strongest association was between happiness and inclusion of nature in self ($r=.27$), compared to nature relatedness ($r=.18$) and connectedness to nature ($r=.18$).
Gascon et al. (2015) ²²	MEDLINE and Scopus; 2014	28 (23 cross-sectional, 4 longitudinal, and 1 ecological studies); systematic review	Most studies were conducted in Europe, including 8 in the UK and 5 in the Netherlands. Four studies each were conducted in the US and Oceania, one in Latin America, and	Sample size ranged from 100 to 345,143; four studies included children aged 3 to 10 years	Limited evidence on the mental health benefits of the green and blue environment were found. Studies reported decreased depression, stress, behavioral problems, and treatment for mental disorders among people living closer to the natural environment. However, the findings were inconsistent, and fewer studies reported evidence on the younger population.

			none in Asia or Africa		
McMahan and Estes (2016) ³³	PsycINFO, Google Scholar, PsycARTICLES, and SpringerLINK; 2013	32 (with 31 effect sizes); meta-analysis	The United States (53.6%), Japan (14.3%), Canada (14.3%), Sweden (10.7%), Netherlands (3.6%), UK (3.6%)	The sample size was 2356 (sample ranged from 12 to 206); women consisted of more than half of the study participants in most studies, mean age ranged from 20 to 28.5 years	Exposure to natural environments was associated with a moderate increase ($r = .31$) in positive affect and a smaller decrease ($r = -.12$) in negative affect. The effects had heterogeneity with moderators, including the type of emotion assessment and exposure to nature, location of study, and mean age of the study participants.
Keijzer et al. (2016) ³⁴	MEDLINE and Scopus; 2016	13 (8 cross-sectional, three longitudinal, and two ecological studies); systematic review	Most studies were from the US ($n=9$) and one study each from Australia, Sweden, Spain, and the UK	Sample size ranged from 17 to 2623; 3, 4, and 6 studies included adults, older adults, and children as study participants	Limited evidence suggested improved school performance, cognitive development, attention capacity, and protective functions against attention deficit disorders among children; reduced odds of concentration problems and improved attention capacity among adults; and improved cognitive functions and lower risk of dementia among the older adults.
Ohly et al. (2016) ³⁵	PsycINFO, MEDLINE, EMBASE, AMED, SPORT Discus, Environment Complete, and Web of Knowledge; 1989-2013	24 (31 quantitative studies including 16 RCTs); meta-analysis	Most studies were conducted in the US ($n=17$), followed by Sweden ($n=5$), Italy ($n=3$), Netherlands ($n=2$) Norway ($n=1$), and Asian countries ($n=3$)	Sample size ranged from 12 to 185; most ($n=19$) studies recruited students, followed by children, adults, and elderly participants	Limited positive effects of exposure to natural environments were found for three measures of attention restoration: Digit Span Forward, Digit Span Backward, and Trail Making Test B. The findings were limited by small numbers of studies and samples, heterogeneity in quality indicators, and outcomes.

Lee et al. (2017) ³⁶	PubMed, EMBASE, Cumulative Index to Nursing and Allied Health, PsycARTICLES, Korean Studies Information Service System, Research Information Sharing Service, and DBpia; 2016	28 (6 RCTs, 11 non-equivalent controlled studies, 11 crossover trial studies); systematic review	Republic of Korea (60.7%), Japan (25%), China (10.7%), the UK (3.6%)	Sample size ranged from 11 to 92; 57.1% participants were healthy adults, 42.9% were adults with health problems	A total of 21 studies showed significant improvement in depression following forest therapy, whereas seven studies reported no significant changes in depression in comparison to the control group participants. Moreover, 8 out of 11 crossover trials and 8 out of 11 non-equivalent control group studies reported significant improvements in terms of depression scores. Furthermore, 5 out of 6 RCTs reported significant improvements in depressive symptoms.
McCormick (2017) ³⁷	PubMed, Ovid, Scopus; 2012-17	12 (1 qualitative, 11 quantitative); systematic review	Not specified	Children and adolescents aged 5 to 20 years	Access to green space was associated with improved mental health and well-being, cognitive development of children, attention restoration, memory, competence, social support, stress, supportive social groups, behaviors, and symptoms of ADHD, and higher standardized test scores.
Carver et al. (2018) ³⁸	Academic Search Complete, Art & Architecture Source, CINAHL Complete, Environment Complete, MEDLINE	9 (quantitative); systematic review	Three studies each from Australia, Europe, and the US	Sample size ranged from 15 to 211; sample comprised residents, caregivers, and staffs of aged care facilities	Most studies (n=7) reported positive associations between greenery among residents of aged care facilities and some aspects of residents' mental well-being. One study reported a reduction in depression following garden use, while another study reported physiological indicators of stress (blood pressure, heart rate) and found no association with garden use.

	Complete, PsycINFO; 2017				
Houlden et al. (2018) ³⁹	Applied Social Sciences Index and Abstracts (ASSIA), PsycInfo, PubMed, Scopus, and Web of Science; 2016-18	52 (4 controlled case studies, six longitudinal cohort studies, one ecological analysis, four uncontrolled case studies, and 37 cross-sectional Surveys; systematic review	Five from the USA, six from Canada, ten from Australia, 15 studies from the UK, and the remaining 16 studies from other European countries.	Sample size ranged from 25 to 30,900; Studies recruited young adults; 3 studies included university students whereas two studies had older adults as study participants	Limited evidence was found on mental health outcomes, including mental wellbeing and life satisfaction were associated with the types, visits, and access to green space.
Stevenson et al. (2018) ⁴¹	PsycINFO, SPORTDiscus, MEDLINE, Embase, Scopus, and Web of Science; 2013-17	42 (46 quantitative studies including 38 studies); meta-analysis	20 studies were conducted in Europe, 15 in North America (32.6%), 9 in Asia, one in Australia, one in New Zealand, and one in multiple countries	Sample size ranged from 12 to 104; diverse groups of participants were recruited across studies including children and adolescents	Low to moderate effect sizes were found for working memory (Hedges $g=0.162$), cognitive flexibility ($g=-0.317$), and attentional control ($g=-0.156$) are improved after exposure to natural environments. Moderator analyses found these effects can be enhanced in real natural exposure relative to virtual exposures.
Tillmann et al. (2018) ²³	PubMed, Scopus, PsycINFO, Geobase, ProQuest, SPORTDiscus, Sociological Abstracts, Leisure and Tourism	35 (all quantitative studies, 15 cross-sectional and 11 intervention studies); systematic review	11 studies were conducted in the USA, 8 in the UK, two from New Zealand, 2 in Canada, one in South Africa, and the remaining 11 in different European countries	Sample size ranged from 12 to 17249; children and adolescents aged 0.75 to 18 years old were recruited in those studies	About half of the studies reported a significant positive association between nature and mental health outcomes, including emotional well-being and attention deficit or hyperactivity disorder, overall mental health, self-esteem, stress, resilience, depression, and health-related quality

	Database, Physical Education Index and EMBASE; 1990-2017				of life. The remaining half of the studies did not report any significant relationships.
Vanaken and Danckaerts (2018) ²⁴	PubMed and Scopus; 2018	21 (12 cross-sectional, 7 longitudinal, 2 ecological studies); systematic review	11 studies were from Europe, six from North America, and four from Oceania; no studies were found from Asia, Africa, or South Africa	Sample size ranged from 72 to nearly 3 million; children and adolescents were focus population among the included studies	Studies reported beneficial associations between green space exposure and children's emotional and behavioral difficulties, hyperactivity, and inattention problems. Also, limited evidence supported a beneficial association with mental well-being among children and depressive symptoms in adolescents and young adults. The findings were consistent even after adjusting for demographic and socioeconomic confounders.
Antonelli et al. (2019) ²⁵	PubMed, Embase, Scopus, Web of Science, Cochrane Library, and Google Scholar; 2019	22 (8 included in quantitative synthesis); meta-analysis	12 studies were conducted in Japan, followed by 4 in South Korea, two from China, and remaining four from European countries	Sample size ranged from 9 to 348; most studies (n=20) had healthy adult participants	In most studies (n=20), cortisol levels were significantly lower after intervention among forest groups compared with comparison groups or baseline, highlighting improvements in stress. The meta-analysis showed that salivary cortisol levels were significantly lower in the forest groups compared with the urban groups both before (MD = - 0.08 µg/dl, 95% CI - 0.11 to - 0.05 µg/dl, p < 0.01, I ² = 46%) and after intervention (MD = - 0.05 µg/dl, 95% CI - 0.06 to - 0.04 µg/dl, p < 0.01, I ² = 88%).

Lackey et al. (2019) ²⁶	Scopus, Proquest Dissertations and Theses Global, and PsycInfo; 2018	51 sources (40 articles, ten dissertations/thesis, one book chapter); systematic review	23 studies were conducted in the US, and the remaining 27 studies were from Europe and Japan	Sample size ranged from 3 to 3060; most studies (n=43) included adult participants	Most (90%) studies reported at least one positive association between nature-based recreation and mental health outcomes, including improvements in affect, restoration, cognition, mental health resilience and wellbeing, and decreases in anxiety and depressive symptoms.
Norwood et al. (2019) ²⁷	MEDLINE, CINAHL, Embase, PsycInfo, and Scopus; 2018	6 (including four controlled studies); systematic review	Three studies were from the UK, two from the US, and one from Spain	Sample size varied across studies; all studies had young participants aged below 18 years	Exposure to nature appeared to have a positive impact on young people, which include positive changes in attention, memory, and mood.
Lakhani et al. (2019) ²⁸	MEDLINE, Web of Science, and CINAHL; 2017	18 (both qualitative and quantitative studies); systematic review	Six studies were from the US, three from the Netherlands, two each from Australia and the Republic of Korea, and one study each from the UK, Japan, Norway, Taiwan, Finland	Sample size not specified; adult participants with known medical conditions including dementia (n=14), stroke (n=2), and brain injury (n=2) were recruited in the primary studies	Most studies reported beneficial effects of natural exposure like green space or garden on psychological, emotional, and psychosocial health outcomes. A majority of studies were focused on dementia; limited evidence was found for mental health outcomes among people with other neurological disabilities.
Pritchard et al. (2019) ²⁹	PsycINFO, MEDLINE, PsychArticles, Science Direct, CINAHL Plus, PubMed, EBSCO e-journals and	25 articles (with 34 samples, 18 journal articles, five theses, and two others); meta-analysis	Unique study samples were from Canada (38%), Europe (26%), the US (24%), and one sample each from Colombia, Hong	Sample size ranged from 39 to 2203; the age of the participants ranged from 11 to 63.42 years, most of them were adults (44%) followed by	Nature connectedness was found to be associated with eudaimonic and hedonic wellbeing. The findings suggest a small mean effect size ($r = .24$, 95% CI 0.20, 0.27) with significant variability ($Q = 41.55$, $p < 0.01$) and moderate heterogeneity ($I^2 = 54.28\%$) for eudaimonic wellbeing. Also, a small

	Biomedcentral; 1999-2016		Kong, Australia, and India	college or university students (34%)	mean effect size ($r = 0.20$, 95% CI 0.17, 0.23) with high variability ($Q = 124.37$, $p < 0.001$) and high heterogeneity ($I^2 = 76.68\%$) was observed for hedonic wellbeing.
Roberts et al. (2019) ³⁰	MEDLINE, PsycINFO, Embase, Scopus, and Web of Science; 2018	33 (16 randomized crossover studies, 5 non-randomized crossover studies, seven studies used parallel groups, 3 had a factorial design, 2 were single-group crossover studies)	Most studies ($n=13$) were from Japan, followed by US ($N=5$), China ($n=4$), Sweden ($n=3$), UK ($n=2$), Korea ($n=2$), and one study each from Denmark, Spain, Poland, and Finland	Sample size ranged from 8 to 280; most participants were young, more than half of the studies recruited college or university students, several studies included people with depressive symptoms, poor mental health, and other chronic diseases	A small yet significant reduction in depressive mood following short-term exposure to the natural environment was observed. The effect sizes ranged from -2.3 to 0.84. Random-effects model reported overall effect size -0.3 (95% CI -0.5, -0.1, $z = 0.31$, $SE = 0.09$, $Q = 277.97$, $p < 0.01$.)
Trøstrup et al. (2019) ³¹	PubMed, Cinahl, PsycINFO, and Cochrane Library; timeframe not specified	5 (2 RCT studies, two quasi-experimental studies, and one evaluation study); systematic review	Two studies were from the US, and one study each from Canada, Norway, and Switzerland	Sample size ranged from 21 to 278 across studies; participants had known clinical conditions including cancer, cardiorespiratory problems, and spinal cord injury	Most studies (4 out of 5) reported positive impacts following nature-based interventions including a reduction in symptom distress and improvement in cognitive functions ($p < 0.04$), self-efficacy and positive affect ($p < 0.03$), overall mental health ($p < 0.01$), lower depression, better psychosocial functions, and improved self-compassion. Patients with psychosomatic symptoms did not have significant changes following the intervention.

Weeland et al. (2019) ³²	PsycINFO, ERIC, Web of Science, MEDLINE, and Google scholar; 2019	31 (15 correlational and 16 quasi-experimental studies); meta-analysis	Most studies (n=17) were from the US followed by the UK (n=10), and remaining studies from other European countries and Oceania	Sample size from all the studies was 21,443; children and/or parents were included where the mean age of the participating children as 7.84 (SD=2.46) years	3-level meta-analyses found small but statistically significant positive overall associations of nature with self-regulation among children in both correlational (15 studies, $r = .10$; $p < .001$) and (quasi-) experimental (16 studies, $d=.15$; $p < .01$) studies. In the correlational studies, the type of instrument measuring exposure to nature significantly moderated the strength of association. Stronger associations were found in assessments based on parent-reports than compared to an index.
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children and adolescent participants.^{22–24,27,32,37} Four reviews reported primary studies that included students as study participants.^{21,29,30,39} One review reported primary studies focusing on elderly participants.³⁸ Three reviews included primary studies where the participating individuals had previously diagnoses acute and chronic health conditions.^{28,31,36} Remaining studies (n = 6) had participants from multiple age groups and diverse demographic characteristics.^{25,26,33–35,40}

Effects of the natural environment on mental health and wellbeing

The primary studies in most of the reviews (n = 15) reported correlational measures of association between the natural environment and mental health; however, five reviews evaluated the impacts of nature-based interventions.^{25,26,28,31,36} Overall, the reviews reported multiple mental health conditions associated with exposure to the natural environment.

Most of the reviews (n = 10) reported varying levels of improvement in depressive symptoms, anxiety, and mood disorders.^{22,23,25,27,30,31,36,37} For example, Roberts and colleagues found significant reduction (effect size -0.3, 95% CI [-0.5, -0.1], $p < 0.01$) in depression after short exposure to natural environment.³⁰ Another review reported a significant reduction in depressive illness among participants who received forest therapy.³⁶ Moreover, eight reviews found improvement in attention processes and reduction in attention-related disorders.^{23,24,26,27,34,35,37,40} For example, Ohly and colleagues conducted a meta-analysis of 24 quantitative studies including 16 randomized trials, which found exposure to natural environment was associated with three measures of attention restoration including Digit Span Forward, Digit Span Backward, and Trail Making Test B.³⁵ Furthermore, six reviews found exposure to natural environment was negatively associated with stress among the study participants.^{22,23,25,26,37,38} For example, a meta-analysis by Antonelli and colleagues assessed the salivary cortisol level as a measure of stress among the participants.²⁵ This study found a significant reduction in salivary cortisol level (mean difference -0.05 µg/dl, 95% CI [-0.06, -0.04], $p < 0.01$) after forest bath intervention. In addition, five reviews reported improved cognitive functions were associated with exposure to the natural environment.^{26,31,34,37,40} For example, McCormick and colleagues found 12 studies that reported improved cognitive development among children who had access to green space.³⁷ Also, the natural environment was associated with positive affect and reduced negative affect among participants in 4 reviews.^{21,26,31,33} For instance, a meta-analysis by McMahan and colleagues

found a significant moderate increase in positive affect ($r = .31$) and a small decrease in negative affect ($r = -.12$) among participants who had exposure to the natural environment.³³

The effects of the natural environment were also assessed for emotional functions. Three reviews reported improved behavioral and emotional conditions among individuals who had better access to green space, among which Vanaken and Danckaerts reported beneficial impacts of green space among children with behavioral and emotional difficulties.^{23,24,28} Moreover, exposure to the natural environment reduced the risks of dementia among older adults.^{28,34} Two reviews reported the association between happiness and exposure to nature.^{21,29} For example, Capaldi and colleagues conducted a meta-analysis of 21 studies and found small but significant effect size ($r = .19$ and $r = .18$ in the fixed and random-effects model, respectively) highlighting the beneficial relationship between nature connectedness and happiness.²¹ Furthermore, access to the natural environment was found to be associated with improved academic performance among children.^{34,37} Also, exposure to the natural environment had beneficial effects in terms of reduced symptom distress among chronic disease patients,³¹ reduced need for psychiatric care,²² better self-regulation,³² psychological resilience,^{23,26} and improved overall mental health and wellbeing.^{23,26,28,31,37–39}

In addition, many reviews appraised the findings reporting a low number of studies and small to medium effect sizes. Also, many reviews reported the effects of the moderator variables on the relationship between the natural environment and mental health.^{32,33,40} For example, Weeland and colleagues found the type of instrument used across studies had a moderating effect on the measures of the relationship between nature and mental health outcomes.³² Another study by McMahan and colleagues reported several moderators, including the type of outcome, exposure to nature, location of the study, and mean age of the participants, which had moderated the association between exposure to nature and affect-related outcomes among the participants.³³ None of the studies reported any adverse mental health outcomes associated with exposure to the natural environment.

Discussion

Overview of synthesized findings

To our knowledge, this is the first umbrella review that synthesized mental health impacts of natural environmental exposure from 20 systematic reviews and meta-analyses, highlighting the beneficial effects as well as limitations of the existing literature. Most of the primary studies within those reviews were conducted in developed countries comprising of diverse population groups, including children, adolescents, young adults, elderly adults, and people living with known clinical conditions. Most reviews had high methodological quality and reported mental health impacts associated with the natural environment both from correlational and interventional studies. Exposure to the natural environment like urban green space or forest areas had various impacts on the mental health of the study participants. Studies found varying levels and measures of associations between the natural environment and mental health outcomes, which included improvements in overall mental health and wellbeing, depressive symptoms, anxiety, other mood disorders, stress, cognitive abilities, behavioral and emotional functions, and risks of dementia. In addition, exposure to the natural environment was associated with reduced psychiatric comorbidities among patients living with different diseases and decreased need for mental health care. However, the findings were limited by small sample sizes and insignificant associations reported in few studies.

Implications for future research

The findings of this review offer several critical insights for conducting future research. First, there is a marked research gap in the developing nations, which should be addressed through research collaborations among national, multilateral, and global institutions. Such research may inform how the natural environment is associated with mental health at the local and global levels. Second, the effects of exposure to nature may exert varying impacts on diverse population groups like racial and ethnic minorities, socioeconomically marginalized individuals, and other vulnerable populations,⁴² which are not studies in the existing literature. Future primary studies should evaluate such relationships between environment and mental health in the context of individual and interpersonal characteristics. Third, sociodemographic issues like housing, migration, and occupational attributes determining the quality and quantity of nature exposure may have moderator effects on mental health outcomes,⁴³ which should be evaluated in future

studies. Fourth, most primary studies emphasized on specific age groups, which may not provide how nature impacts mental health across the lifespan. Therefore, more population-based longitudinal studies may inform how changes in the natural environment can impact the mental health and wellbeing in a given population. Fifth, long term changes in the natural environment at a larger geographic area may have associations with climate change, which may affect the mental health at the population level.⁴⁴ The existing studies provide little insight into this domain, which should be evaluated in future research. Sixth, the lack of standardized instruments measuring nature exposure and mental health may have impacted the current findings, which necessitates further discourses on how researchers may develop and use more standardized measures in the future. Last but not least, fewer intervention studies compared to a greater number of correlational studies highlight the gap between knowledge creation and translation. Future implementation research should address this gap and leverage the mental health benefits of exposure to the natural environment.

Implications for policy and practice

The current evidence on the effects of the natural environment on mental health offers several implications for clinical practice and policymaking. A deeper understanding of the role of the natural environment on the mental health status can enable the practitioners to better evaluate the history and context of individual patients. The added insights from previous exposure to the natural environment can inform the diagnosis, treatment, and prognosis of mental illness of the affected individuals in a holistic manner.⁴⁵ Also, several reviews reported nature-based interventions,^{25,26,28,31,36} which inform potential avenues to adopt evidence-based approaches to increase exposure to nature at clinical and community-based mental health services. Therefore, the existing clinical guidelines and therapeutic protocols should be revisited considering the correlational and experimental findings, which may inform better mental health assessment and management. Moreover, people living with known clinical conditions may benefit from exposure to the natural environment. Therefore, incorporating nature-based care may complement regular therapies and address psychiatric comorbidities among those individuals. Furthermore, improving the natural environment and mental health may require collaborative efforts of the mental healthcare providers, public health professionals, urban planners, environmental researchers and practitioners, social stakeholders, and policymakers.⁴⁶ The growing burden of

mental illness, disparities in mental healthcare, and the rapid pace of environmental changes necessitate how effective collaboration can be developed to conduct multi-sectoral research and improve policies and practices. It is essential to integrate scientific evidence in urban and environmental policymaking and planning to improve the environmental determinants of mental health, which may further address mental health problems at the population level.

Limitations of this umbrella review

This review has several limitations, which should be acknowledged. First, our review might have excluded articles that did not have keywords that we used or those articles indexed in databases that we did not search. Second, we excluded dissertations or reports, which could have provided references meeting our criteria. Third, we could not evaluate the unpublished studies with insignificant findings, which remains as another limitation of our review. Those studies could have provided more insights into this umbrella review. However, we conducted this review adopting robust methodological approaches involving more than two reviewers to minimize potential biases. Future research synthesis should address the limitations of this review and advance evidence-based mental health in this domain.

Conclusion

This umbrella review synthesized up-to-date evidence on the effects of the natural environment on mental health. The existing evidence informs several beneficial roles of the natural environment on improving mental health among diverse populations. However, limited evidence from studies with small samples or insignificant effect sizes necessitate future research on how the natural environment can influence mental health and wellbeing. The findings of this review suggest adequate exposure to the natural environment, or the use of nature-based interventions can improve mental health among individuals and communities. Lastly, evidence-based practice and policymaking are essential for the preservation and enhancement of the natural environment to address mental illness and promote mental health across populations.

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Supplemental file 1: Critical appraisal of the systematic reviews and meta-analyses

Author and year of publication	Is the review question clearly and explicitly stated?	Were the inclusion criteria appropriate for the review question?	Was the search strategy appropriate?	Were the sources and resources used to search for studies adequate?	Were the criteria for appraising studies appropriate?	Was critical appraisal conducted by two or more reviewers independently?	Were the methods used to combine studies appropriate?	Was the likelihood of publication bias assessed?	Were recommendations for policy and/or practice supported by the reported data?	Were the specific directives for new research appropriate?	Overall score and quality rating
Capaldi et al. (2014) ²¹	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	9 (High)
Gascon et al. (2015) ²²	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	9 (High)
McMahan and Estes (2016) ³³	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	9 (High)
Keijzer et al. (2016) ³⁴	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	9 (High)
Ohly et al. (2016) ³⁵	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	8 (High)
Lee et al. (2017) ³⁶	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	9 (High)
McCormick (2017) ³⁷	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	8 (High)
Carver et al. (2018) ³⁸	Yes	Yes	Yes	Yes	No	Yes	Not sure	No	Yes	Yes	7 (Medium)
Houlden et al. (2018) ³⁹	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	9 (High)

Stevenson et al. (2018) ⁴¹	Yes	Yes	Yes	Yes	Yes	Not sure	Yes	No	No	Yes	7 (Medium)
Tillmann et al. (2018) ²³	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	9 (High)
Vanaken and Danckaerts (2018) ²⁴	Yes	Yes	Yes	Yes	No	Not sure	Yes	No	Yes	Yes	7 (High)
Antonelli et al. (2019) ²⁵	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	10 (High)
Lackey et al. (2019) ²⁶	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	8 (High)
Norwood et al. (2019) ²⁷	Yes	Yes	Yes	Yes	Yes	Not sure	Not sure	No	Yes	Yes	7 (Medium)
Lakhani et al. (2019) ²⁸	Yes	Yes	Yes	Yes	Yes	Yes	Not sure	No	No	Yes	7 (Medium)
Pritchard et al. (2019) ²⁹	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	7 (Medium)
Roberts et al. (2019) ³⁰	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	10 (High)
Trøstrup et al. (2019) ³¹	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	9 (High)
Weeland et al. (2019) ³²	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	8 (High)