



# Green Space and Mental Health: Pathways, Impacts, and Gaps

Emily Rugel<sup>1</sup>

## Summary

- Overall, exposure to green space (natural areas such as parks, forests, or community gardens) tends to have beneficial effects on stress and mood in the general population.
- Among healthy individuals, the effects of green space consistently relate to underlying components of mental well-being – such as stress, anxiety, and mood.
- For individuals with chronic illness and mental illnesses – including anxiety disorder, depression, and ADHD – access to green space can be an effective component of therapeutic interventions.
- Despite cumulative evidence linking green space to mental health, the weight of the evidence is relatively weak, relying principally on small convenience samples and cross-sectional study designs or short-term follow-up.
- Future research efforts should apply more robust measures of green space to identify factors that are associated with longer-term benefits to mental health, particularly for those specific subpopulations that stand to benefit the most, including individuals with low socioeconomic status and those with pre-existing mental health disorders.



## Introduction

Around the globe, mental health disorders are a significant and growing cause of ill health and early death, with the burden of such diseases increasing by more than a third between 1990 and 2010.<sup>1</sup> Almost a third of all Canadians have experienced a mental illness at some point during their lifetimes.<sup>2</sup> A Statistics Canada survey reported the most commonly reported illnesses to be mood disorders, including major depression and bipolar disorder (5.4%), followed by substance use disorders (at 4.4%), and generalized anxiety disorders (2.6%).<sup>3</sup> These disorders often result in significant detrimental effects on an individual's physical, emotional, and social well-being, making them the leading cause of years lived with disability worldwide.<sup>1</sup>

The chronic nature of many mental illnesses,<sup>4</sup> and their impact on an individual's ability to seek and maintain full employment,<sup>5</sup> also increases the economic burden they pose, estimated to be as high as \$52 billion in 2006 in Canada alone.<sup>5,6</sup> The roots of mental illness (and well-being) are multifactorial, including biological, socioeconomic, and environmental factors.<sup>4</sup> A comprehensive approach, as proclaimed by the Mental Health Commission of Canada,<sup>6</sup> includes an evaluation of the impact of environmental features on the development, progression, and

<sup>1</sup> University of British Columbia Bridge Program

treatment of mental health conditions. In this regard, a large body of evidence has been developed on the impact of various features of the natural and built environment on mental health, particularly in the urban context. One feature that bridges both of these domains is “green space”: natural areas such as parks, forests, and community gardens that often stand in stark contrast to the vast expanses of concrete, brick, and glass that comprise most modern cities’ surroundings. Many municipalities in Canada<sup>7</sup> and abroad<sup>8</sup> have committed to providing accessible, high-quality green space to residents, but these plans are often not guided by the potential public health benefits.<sup>9</sup> Assessing scientific evidence regarding the relationship between green space and mental health is essential to inform the development of healthy, sustainable communities.

## Objectives

The primary objectives of this review are to:

- Describe the principal pathways linking green space to mental health, and evidence supporting these suggested mechanisms and;
- Assess the peer-reviewed epidemiological literature regarding the impact of green space on the mental health of healthy individuals and on those diagnosed with mental health disorders.

## Methodology

Publications in peer-reviewed journals were accessed to identify qualitative and quantitative epidemiological studies that examined the impact of exposure to green space on mental health. Search terms and keywords were selected to allow for the identification of studies examining a variety of green space forms and a range of outcomes, varying from underlying psychological processes to specific disorders. No limits were applied with respect to the date of publication, but due to the increasing interest in this topic, the majority of summarized articles were published over the past decade. After applying inclusion and exclusion criteria, 32 articles were selected for full-text

review. An additional 13 studies were found through forward citation tracking and hand searching, and are referred to in the discussion. Appendix A provides more detail on the search strategy, including selected databases, key concepts, and inclusion and exclusion criteria.

## Definition of Key Terms

One issue that complicates any systematic inquiry into this topic is the diversity of approaches to defining and describing “green space.” The summarized studies used a variety of terms, often without specifying exactly what is meant, and there was no overarching organization or standard that can be employed as a reference. The terms “nature,”<sup>10-18</sup> “naturalness,”<sup>19,20</sup> or “natural space”<sup>21,22</sup> have been employed by some researchers when including both blue space (referring to water) and green space, or to highlight the fact that not all vegetation is green, depending on the season and location.<sup>19</sup> Areas that are restricted in some way, such as private gardens, may be distinguished from those that are accessible to all, such as “public open space”<sup>23</sup> or “public natural space.”<sup>24</sup> Some studies focus narrowly on a specific form of green space, such as a playground,<sup>21</sup> garden or arboretum,<sup>15,25-30</sup> forest,<sup>10,13,14,31-39</sup> park,<sup>22</sup> or “streetscape greenery,” trees and other plantings along streets.<sup>40</sup>

Because this review sought to capture the full range of research in this area, the broadest possible definition of green space was employed: any form of nature featuring vegetation, including virtual exposures such as viewing a photograph of a forest. The measures used to gauge exposure were similarly broad, including both subjective and objective assessments, and those based on known exposure (as in a laboratory setting or a guided walk in the woods) and presumed exposure (such as park proximity).

## Results and Discussion

A total of three systematic reviews or meta-analyses, 19 experimental, one longitudinal, 17

cross-sectional, two mixed-methods, and four qualitative reports were evaluated. Three interdependent pathways linking exposure to green space and mental health were described in these studies: 1) psychophysiological benefits, including reductions in stress and improvements in directed attention and mood; 2) augmented mental health benefits of physical activity; and 3) facilitated social contact, with concomitant improvements in levels of social support and social capital.

## Psychophysiological responses

A substantial amount of research has focused on the underlying psychophysiological responses to green space, both in controlled laboratory settings and outdoors. This line of inquiry is grounded in two distinct, though complementary, theories: Ulrich's stress reduction theory,<sup>41</sup> or SRT, and attention restoration theory (ART), first described by Rachel and Stephen Kaplan.<sup>42</sup> In SRT, exposure to nature induces a relaxed psychological state marked by lower levels of stress (50). ART, on the other hand, proposes that natural environments contain elements that help individuals recover from the mental fatigue required to voluntarily direct attention to multiple tasks within their day-to-day lives.<sup>15</sup> Both chronic stress<sup>43</sup> and stressful life events<sup>44,45</sup> are known risk factors for anxiety and depression. Difficulties with attention are central to a number of mental health disorders, including schizophrenia<sup>46</sup> and attention deficit hyperactivity disorder (ADHD).<sup>47</sup>

Overall, these studies indicate that exposure to green space improves individuals' moods<sup>14,15,18,29-31,33-35,39,48-51</sup> For instance, a study among healthy university students that compared the effects of an hour-long walk in an urban setting to one in an arboretum found improvements, on average, in both mood and directed attention after participants walked in the more natural setting.<sup>15</sup> This finding was replicated in a study that used a similar within-subjects design but focused on adults with major depressive disorder, with the nature walk improving both positive mood and directed attention in general.<sup>14</sup> These studies highlight the complementary nature of SRT and ART as

theoretical frameworks, explaining the affective impacts and attentional effects, respectively.

The impact of green space on levels of the stress hormone cortisol is mostly beneficial, with one study showing no effect,<sup>10</sup> but others showing significant decreases in comparison to less natural settings<sup>32,34,38,39,52</sup> or with increased exposure to green space,<sup>52</sup> and another showing reductions in cortisol, but only at certain times of day.<sup>33</sup> Some of these differences may have arisen due to inappropriate accounting for diurnal patterns of cortisol expression (or cortisol slope).<sup>38</sup> A study in Scotland collected multiple cortisol samples over the course of a day and determined that people residing in neighbourhoods with parks, forests, and other natural environments not only reported less stress, but also had healthier cortisol slope profiles.<sup>52</sup>

A number of studies evaluated general mental health, anxiety, and depression in a healthy population. A nationally representative longitudinal survey of households in the United Kingdom indicated that greater amounts of both publically accessible green space and private gardens in individuals' neighbourhoods reduced mental distress and increased life satisfaction.<sup>49</sup> A nationwide study in Scotland found that individuals who reported the greatest lack of environmental goods (including parks and playgrounds) in their neighbourhoods were almost twice as likely to report anxiety and depression as residents not so deprived.<sup>21</sup> Further highlighting the importance of perceptions of green space access, residents of Adelaide, Australia, who rated their neighbourhoods as highly green – based on park and path access, streetscape greenery, and other pleasant natural features – had almost twice the odds of being in better overall mental health.<sup>53</sup> Not all of the results are in agreement, however: a large study from the Netherlands that utilized nationwide data drawn from general medical practitioners reported that associations between mental health benefits such as lower rates of anxiety and depression and the presence of larger green spaces (including forests and conservation areas) were relatively weak.<sup>54</sup>

Such studies also point to the importance of considering quality of green space along with quantity. Residents of neighbourhoods in Perth, Australia, that contained medium- or high-quality public open space – as defined by participants' appraisals of features such as attractiveness, comfort, and safety – had twice the odds of low psychological distress as residents of neighbourhoods with low-quality space (OR = 2.26, 95%CI = 1.36, 3.76).<sup>23</sup> In a study conducted in four large Dutch cities, increases in quantity and quality of green space were linked to better mental health status, but the strongest relationship was found for high-quality streetscape greenery.<sup>40</sup>

The mix of findings in this pathway may also reflect variations between population subgroups. For example, among studies looking at directed attention and concentration, positive effects of access to green space were demonstrated among low-income children<sup>20</sup> and children with ADHD<sup>22,55</sup> but not among pregnant women.<sup>17</sup>

## Augmenting mental health benefits of physical activity

Natural spaces may have a role in promoting physical activity or reducing levels of overweight and obesity. Green space has been shown to encourage individuals to engage in physical activity,<sup>56</sup> particularly walking<sup>57</sup> in natural settings, and is hypothesized to enhance mental health benefits in comparison to exercise indoors or in urban settings. The evidence for an increase in physical activity rates is somewhat inconsistent, however. A study of 4,950 middle-aged adults in the United Kingdom found no association between access to or quality of green space and recreational physical activity (such as bicycling, swimming, and tennis),<sup>58</sup> and a systematic review reported that only 40% of included studies found a positive association between green space and physical activity rates.<sup>56</sup>

In addition to the type of exercise under study, the form and quality of green space is a consideration, with specific features such as trails and wooded areas seen as particularly conducive to physical activity in the general population. One of the most

common forms of exposure to green space was in the form of a short walk in a natural setting. A systematic review of studies employing a mix of designs reported positive effects on mood for brief, one-time walks held outdoors (or in virtual natural environments) in comparison to those indoors.<sup>51</sup> A stronger association was found with exercise in green space,<sup>11</sup> or for greener settings when all of the environments were relatively natural.<sup>19</sup> A meta-analysis that combined data from ten studies undertaken across the United Kingdom with a total of 1,252 participants found improved self-esteem and mood across a range of green environments (including forests, urban parks, and wilderness areas).<sup>12</sup>

## Facilitated social contact

Green space may provide a unique setting for individuals to come together and socialize, strengthening existing networks that individuals rely on for social support<sup>59,60</sup> and promoting engagement in socially oriented activities that can increase social capital within communities.<sup>61</sup> Both social support and social capital have been found to mitigate stress by providing a sense of security, enhancing self-confidence, reducing the feeling of being alone, and buffering the impacts of stressful situations on an individual.<sup>62</sup> As with physical activity, specific aspects of natural settings may be particularly important, with more structured green space such as parks and community gardens providing a unique niche for social contact.<sup>60</sup> This pathway was described by six studies,<sup>13,16,29,53,60,61</sup> especially in terms of the benefits for individuals with disorders such as anxiety or schizophrenia that may impede their interactions with others<sup>13,61</sup>

As an essential element of “Nature Therapy,” green space was posited as a unique means of connecting individuals both to the “wider-universal matrix” and to their peers, particularly among individuals with mental health disorders that left them isolated.<sup>13</sup> Residents of the United Kingdom who felt socially excluded due to issues such as unemployment or economic deprivation reported that a months-long course of environmental volunteering, which generally involved hands-on activities such as habitat maintenance and trail-



building, increased their sense of connection to their communities as well as improving their interpersonal social skills.<sup>16</sup> However, no comparison was made to a program of volunteering indoors or in less natural environments. Elderly individuals in Finland, many of whom had mobility issues that limited their interactions, most often cited “seeing others” as their primary motivation for garden visits that featured trees, walking paths, and a pond.<sup>29</sup>

The results of studies that examined broad populations were less consistent. A cross-sectional study of more than 2,000 adults in Adelaide, Australia, found that those who described their neighbourhoods as containing a greater number of natural elements such as parks and streetscape greenery reported higher levels of social coherence and social interaction.<sup>53</sup> However, residents of two separate Washington, D.C., suburbs had ranked natural features as being below items such as the size of housing lots and street network design as built design features relating to their sense of community.<sup>61</sup> Furthermore, higher overall neighbourhood greenness was linked to lower levels of social support in Chicago; however, larger total park acreage correlated with higher levels of social support.<sup>60</sup>

## Green space as a tailored treatment for mental health disorders or other illnesses

Overall, green space shows potential as a setting for therapy,<sup>13,31,32</sup> or as a targeted treatment in itself.<sup>11,14,28,38,55</sup> As with studies that focused on generally healthy individuals, the most commonly reported benefits among non-institutionalized individuals with mental health disorders were improvements in attention,<sup>14,22,55</sup> mood,<sup>11,14,25,50</sup> and depression symptoms.<sup>28,32,37</sup> In a few instances, the effects were substantially stronger than those seen among individuals without mental illness.<sup>14,26,50</sup> In some cases, the benefits were dramatic: among children with ADHD, a single, 20-minute walk in a park resulted in improvements in attention roughly equal to the peak effects of the most common pharmaceutical treatment for the condition;

however, the study was not designed to assess whether these effects persisted.<sup>22</sup> A four-week course of cognitive-behavioural therapy for individuals with major depressive disorder (as a complement to ongoing pharmaceutical treatment) showed that treatment in a forest setting was more effective at reducing symptoms and inducing remission than the same treatment provided in a hospital setting.<sup>32</sup> Among individuals who participated in forest treatment, 60% experienced remission from depression, compared to only 21% in the hospital therapy arm and 5% in the outpatient control group.<sup>32</sup> Similarly, a nine-day therapy program for alcoholics with depression conducted in a forest led to a remission of depression symptoms.<sup>37</sup> On the other hand, in a study that evaluated garden visits among older adults residing in a nursing home, depressed individuals experienced fewer positive effects on recovery, concentration, and pain from their visits, although this may have been due in part to greater difficulties accessing the garden site.<sup>29</sup> Using qualitative analyses, adults with exhaustion disorder described improvements in sleep, mood, and social interactions after spending time in a garden at a rehabilitation center<sup>25</sup> and older adults with depression valued the feeling of peace and serenity that a guided walk through a Japanese garden offered them.<sup>27</sup>

Use of green space in health-care settings may have psychological benefits for both patients and staff, acting as a “curative balm”<sup>27</sup> and providing “a good setting to get away from hospital stress, to feel more peaceful.”<sup>30</sup> Therapy in a forest setting to breast and lung cancer patients encouraged improvements in emotional and mental health.<sup>31</sup> Similarly, forest therapy for elderly individuals with mild hypertension increased mental quality of life.<sup>38</sup> However, the studies in this area suffer from a number of methodological issues, as illustrated in a recent Cochrane systematic review, in which there were no studies that met their stringent inclusion criteria for determining the relationship between green space and health outcomes among hospital patients.<sup>63</sup>

## Strengths and Limitations of Evidence Base

Approximately one-quarter (11 of 45) of the studies summarized in this evidence review were described as randomized controlled trials or as experiments with an exposure and control arm,<sup>10,11,15,17,18,27,32,34,35,37,38</sup> which is a substantial percentage in the environmental health field. However, none of these articles reported on the randomization procedure sufficiently to judge its robustness.

Sample sizes for the cross-sectional studies were generally small (ranging from 20 to 96), although a single trial included 498 adults.<sup>36</sup> In addition, the study population was often homogenous, exemplified by studies solely of university students<sup>15,18,34</sup> or men,<sup>10,34</sup> which limits the generalizability of findings. The reliance on convenience samples within the cross-sectional studies is another source of potential bias, and was reported in eight studies.<sup>19,25,26,29,30,48,52,55</sup> Overall, comparison between the studies was hampered by the different mental health outcomes assessed, which ranged from ratings of well-being and symptoms to disorders and also physiological measures.

Studies that included a range of participants revealed differences with respect to age, gender, and socioeconomic status. For instance, a meta-analysis examining exercise in natural settings found the largest effects on mood among men and the middle-aged.<sup>12</sup> With respect to SES, greater improvements in mental health were reported for individuals on lower levels of the socioeconomic ladder, whether defined by income or education<sup>64,65</sup> or by employment status.<sup>16,52</sup> Other potential confounders that were not accounted for in the reviewed studies include noise,<sup>66</sup> air pollution,<sup>67</sup> and crowding.<sup>68</sup>

Given that socioeconomically deprived communities may have less and lower-quality green space as observed in multiple locations around the globe,<sup>69-71</sup> and that individuals living in poverty or with low levels of education may be particularly vulnerable to mental health disorders,<sup>4</sup>

the potential for unmeasured confounding in the large number of studies that did not include SES in their models is particularly concerning. This is especially true in cross-sectional studies, although a number included at least one measure of SES,<sup>48</sup> or integrated a robust assessment of SES that combined multiple indicators such as household education and income level.<sup>23,24,26,40,49,52-54,64,65,72,73</sup>

Another important methodological issue is the reliance on brief exposure times, ranging from a 15-minute viewing session in a lab<sup>10</sup> to an hour-long walk in a park.<sup>11,14,15,31</sup> Two studies assessed participants at multiple time points over a longer period of time,<sup>20,49</sup> but one did so by way of a regression approach that estimated the impact of changes in green space access, rather than assessing changes in exposure directly,<sup>49</sup> and the other involved only 17 participants.<sup>20</sup> The dearth of studies focusing on long-term effects is of concern since a dose-response relationship would provide further evidence of the impact of green space on mental health. Larger effects over longer (though still short) timeframes have been observed.<sup>12</sup>

There is a great deal of variation in the type of exposure studied, ranging from satellite-based measures of overall green space<sup>49,54,60,64</sup> to individual botanic gardens and arboretums<sup>14,25-28,30</sup> or even virtual forests.<sup>10,18</sup> This heterogeneity makes it difficult to summarize the body of evidence and challenging to compare studies with conflicting results. It also makes the findings less translatable into specific urban policy and design strategies, while indicating that the results are not due simply to the definition of exposure.

Consistency in many of the study findings – particularly the association between green space and mood improvements<sup>14,15,18,29-31,33-35,39,48-51</sup> and regarding green space as a treatment or treatment setting for individuals with mental health disorders<sup>11,13,14,28,31,32,38,55</sup> – is the major strength of the evidence base. A large number of the cross-sectional studies also relied on randomly chosen or representative samples,<sup>21,23,24,40,51,54,60,64,65,72,73</sup> increasing their internal validity, and many had a broad geographic scope, making them more applicable to diverse communities.

## Research Gaps

An obvious gap in the knowledge base is the paucity of longitudinal designs of individuals or groups studied over time, allowing for observations of changes in green space access that occur as cities develop, expand, and gentrify and of any associated changes in mental health outcomes. Investigations that examine the impact of municipal efforts to increase green space or distribute it in a more equitable fashion should be encouraged. Another important design feature is to control for confounding, particularly due to differential socioeconomic conditions. In order to inform planning and policy, future research efforts also need to examine factors that may promote or impede access to, and use of, green space for particular demographic groups, including those with low socioeconomic status and pre-existing mental health disorders. This is particularly important in light of the fact that the studies described here suggest differential impacts of green space according to demographic characteristics or health status. Finally, paying greater attention to the precise definition of green space exposure is essential to advancing the state of the literature and critical to guiding the development of new policies and projects.

## Conclusions

Overall, the results of this evidence review indicate that exposure to green space has clear benefits for fundamental components of mental health, including overall mood and feelings of stress and anxiety. Green space also has potential as a complement to other forms of treatment (such as cognitive behavioural therapy) for individuals with mental health conditions, particularly those with mood and anxiety disorders. However, the weight of the evidence is relatively weak due to a number of common methodological flaws in this area of inquiry, including a reliance on small, convenience samples; a failure to properly account for confounding, particularly by socioeconomic status; and a lack of longitudinal studies. Future research efforts should use clear, specific measures of

green space to identify the characteristics and frequency of access to green space that are associated with longer-term benefits to mental health, and, in this way, support planners and policymakers in the design of healthier communities.

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Table 1. Summary of Study Setting, Methods, and Results (in reverse chronological order)

Authors, Date	Study Location	Study Sample	Study Design & Pathway	Primary Exposure or Intervention	Main Findings
Annerstedt et al. (2013) <sup>10</sup>	Sweden	30 healthy adult men	Experimental, nonrandomized controlled trial (P)	Virtual environments representing a forest and associated sounds (such as birdsongs and running water) and a soundless forest.	Natural sounds may be an important component of green space as a means of promoting stress recovery.
White et al. (2013) <sup>49</sup>	United Kingdom	12,818 adults for mental distress; 10,168 adults for life satisfaction	Longitudinal, representative sample (P)	Percentage of local green space was based on the UK's Generalised Land Use Database, and included both general green space and gardens, with blue space entered in models as a separate factor.	Employing a fixed-effects model to estimate the impact of changes in green space levels, a residential area comprising 81% green space was associated with reductions in mental distress and increased life satisfaction.
Huynh et al. (2013) <sup>24</sup>	Canada	17,249 youth (primarily aged 11-16)	Cross-sectional, random sample (P)	"Public natural space" measured in three ways: 1) total natural space; 2) green space (such as parks, wooded areas, and botanical gardens); and 3) blue space (including oceans, lakes, rivers, and streams).	No association reported between natural space and positive emotional well-being, although weakly protective effects were seen for blue space alone in small cities.
Nakau et al. (2013) <sup>31</sup>	Osaka, Japan	22 adults with breast and lung cancer	Experimental, nonrandomized, controlled trial (P)	Forest therapy consisting of a 40-minute walk among Japan World Exposition Commemorative Park's forests, streams, and gardens.	In comparison to gardening, yoga, and supportive group therapy, forest therapy was linked to greater improvements in mental and emotional health.
Adevi & Martensson (2013) <sup>25</sup>	Sweden	5 adults with exhaustion disorders	Qualitative (P)	Time spent in a rehabilitation garden containing growing beds, groves, and meadows.	Participants described improvements in mood and sleep after time spent in the garden.
Berman et al. (2012) <sup>14</sup>	Ann Arbor, United States	20 adults with major depressive disorder	Experimental, randomized trial; within-subjects design (P)	An hour-long walk in an arboretum filled with a variety of trees and plants and secluded from traffic and crowds.	The arboretum walk improved working memory and positive affect more than one in an urban setting.

(P) = psychophysiological; (E) = exercise (physical activity); (S) = social contact



Authors, Date	Study Location	Study Sample	Study Design & Pathway	Primary Exposure or Intervention	Main Findings
Mao et al. (2012) <sup>34</sup>	Hangzhou, China	20 healthy male university students	Experimental, “randomized”, controlled trial (P)	Two hour-and-a-half walks conducted over the course of a day in a broadleaf evergreen forest or in an urban environment.	Participants assigned to the forest walks experienced improved mood and reduced levels of stress and inflammatory biomarkers in comparison to the urban walkers.
van Dillen et al. (2012) <sup>40</sup>	The Netherlands	1,553 adult residents of large cities	Cross-sectional, random sample within selected neighbourhoods (P)	Green space forms included both large parcels (such as forests and recreation areas) and smaller, integrated parcels in the form of streetscape greenery; quality was based on a custom appraisal tool.	Improved mental health was associated with both more and higher-quality green space, with the strongest relationship found for streetscape greenery.
Francis et al. (2012) <sup>23</sup>	Perth, Australia	911 individuals	Cross-sectional, random sample (P)	Quantity and size of neighbourhood “public open space,” based on publically available data, and quality, assessed via participants’ self-reports of characteristics such as attractiveness, variety of supported activities, and safety.	Individuals living in areas with higher-quality green space had twice the odds of low psychological distress as those from areas with low-quality green space; no association was found with quantity of green space.
Berger & Tiry (2012) <sup>13</sup>	Tel Aviv, Israel	Not detailed	Qualitative (S)	Half-day therapy sessions conducted in a forest and at the seashore.	Nature Therapy activities fostered engagement among group members.
Ward Thompson et al. (2012) <sup>52</sup>	Dundee, Scotland	25 “deprived” adults (all of lower SES; 72% unemployed)	Cross-sectional (P)	Neighbourhood green space was based on nearby woodlands, scrub, parks, and other natural areas.	Percentage of neighbourhood green space and self-reported stress were inversely related, even in models adjusted for SES and demographics.

(P) = psychophysiological; (E) = exercise (physical activity); (S) = social contact

Authors, Date	Study Location	Study Sample	Study Design & Pathway	Primary Exposure or Intervention	Main Findings
Barton et al. (2012) <sup>11</sup>	United Kingdom	53 adults with mental health issues	Experimental, nonrandomized, controlled trial (E)	A six-week course of green exercise, comprising weekly 45-minute walks in public green spaces (such as parks and reserves).	Green exercise improved self-esteem and mood, but greater improvements in mood were found with social activities.
Drahota et al. (2012) <sup>63</sup>	Multiple locations	102 studies	Systematic review (N/A)	No studies examining green space exposures met inclusion criteria.	No studies examining green space exposures were summarized.
Shin et al. (2012) <sup>37</sup>	Chungbuk, South Korea	92 chronic adult alcoholics	Experimental, "randomized", controlled trial (P)	The forest therapy program consisted of psychological exercises, meditation, and counseling conducted in a Recreational Forest, primarily composed of oak and pine trees.	On average, individuals achieved remission of depression symptoms after nine days in a forest therapy program, while controls did not. Individuals who were more depressed experienced the greatest improvements.
Sung et al. (2012) <sup>38</sup>	Seoul, South Korea	56 older adults with mild hypertension	Experimental, nonrandomized, controlled trial (P)	The forest therapy program included both educational sessions and guided activities in two "recreation forests", consisting of mixed pine and broadleaf trees and featuring walking paths.	Forest therapy participants experienced significantly greater reductions in stress levels than controls, as well as larger improvements in self-reported mental health.
Fanet al. (2011) <sup>60</sup>	Chicago, United States	1,699 adults	Cross-sectional, random sample (S)	Neighbourhood-level green space, measured in three ways: 1) overall greenness (based on satellite measures); 2) size of park acreage; and 3) distance from a participant's to the nearest park.	Highlighted importance of different forms of green space, with parks found to reduce stress by increasing social support, while overall greenness was found to lower both social support and stress, negating any benefits.
Martens et al. (2011) <sup>35</sup>	Zürich, Switzerland	96 adults	Experimental, "randomized", controlled trial (P, E)	A short (30- to 40-minute) walk in either a tended forest (marked by a low amount of dead and brush wood) or a wild forest, which was less maintained.	The walk in the tended forest increased positive mood and sense of calmness to a greater degree than the walk held in the wild forest.

(P) = psychophysiological; (E) = exercise (physical activity); (S) = social contact

Authors, Date	Study Location	Study Sample	Study Design & Pathway	Primary Exposure or Intervention	Main Findings
O'Brien et al. (2011) <sup>16</sup>	London and other cities, United Kingdom	2 studies: 1) 88 marginalized adults, 2) unemployed adults	Cross-sectional; qualitative analysis reported (S)	1) Semiweekly environmental volunteering (such as habitat maintenance); 2) Monthly environmental volunteering at natural urban and rural sites.	Across both studies, individuals reported improvements to their mental health and social skills, as well as a sense of satisfaction from contributing to their communities.
Thompson Coon et al. (2011) <sup>51</sup>	Multiple locations	11 studies (with individual sample sizes ranging from 8 to 269; 6 solely university students)	Systematic review of 5 randomized, 5 nonrandomized comparative trials, 1 survey, and 6 within-subjects studies (P, E)	All included studies directly compared a single session of outdoors activity to the same activity conducted indoors, although virtual reality studies using projected images of the outdoors were also assessed as interventions.	Six studies demonstrated a positive effect of walking outdoors on mood, including improvements in feelings of self-esteem, energy, and vitality and reductions in feelings of depression, tension, frustration, or concern.
Lee et al. (2011) <sup>33</sup>	Hokkaido, Japan	12 male adults	Experimental, randomized trial; within-subjects design (P)	A 15-minute viewing session conducted in either a broadleaf deciduous forest or an urban setting.	Forest views were found to improve participants' mood and decrease stress levels, but had no impact on blood pressure.
Roe & Aspinall (2011) <sup>50</sup>	Scotland	2 studies: 1) 123 adults with good and poor mental health; 2) 24 adults with good and poor mental health	1) Experimental nonrandomized trial; 2) Experimental nonrandomized trial; within-subjects design (P)	1) One-hour guided, group walk in woods and open countryside; 2) One-hour guided, group walk in either a rural park or an urban town center.	Across both studies, the rural walk improved mood and mindset, with greater benefits for those in poor mental health; in addition, the urban walk promoted restoration solely for those in poor mental health.
Valtchanov et al. (2010) <sup>18</sup>	Not specified	22 university students	Experimental, "randomized", controlled trial (P)	Participants viewed either control images of abstract paintings or images of natural settings (including shrubs, flowers, and trees), with the latter also accompanied by forest-related scents.	Natural views significantly improved participants' moods, with no changes seen among participants who viewed the images of abstract paintings.

(P) = psychophysiological; (E) = exercise (physical activity); (S) = social contact

Authors, Date	Study Location	Study Sample	Study Design & Pathway	Primary Exposure or Intervention	Main Findings
McCaffrey et al. (2010) <sup>28</sup>	Delray Beach, United States	40 older adults with depression	Experimental trial; mixed-methods (P)	A two-hour reflective walk and journaling exercise conducted in the Morikami Museum and Japanese Garden, which features 20 acres of gardens, an extensive bonsai collection, koi ponds, and waterfalls.	Reflective walks resulted in fewer symptoms of depression, with individuals reporting feelings of escape from daily pressures and an appreciation of nature's beauty.
Barton & Pretty (2010) <sup>12</sup>	United Kingdom	10 studies; 1,252 adults	Meta-analysis (E)	Green exercise conducted in a range of natural environments and at a variety of intensities.	Improvements in self-esteem and mood were found across studies, with larger changes in self-esteem among individuals with mental illness.
Mackay & Neill (2010) <sup>19</sup>	Canberra, Australia	101 adults	Cross-sectional, convenience sample (E)	A range of exercise types (including bicycling, cross-country and trail running, boxing, and walking) conducted in environments marked by a high proportion of natural elements.	Individuals exercising in natural environments experienced greater reductions in anxiety than those exercising in less natural environments.
Parra et al. (2010) <sup>73</sup>	Bogotá, Colombia	1,966 older adults	Cross-sectional (S)	Within a study of numerous subjective and objective environmental attributes, green space measures included safety of parks and recreational areas and public park density.	Perceptions of safety in local parks were positively associated with improvements in self-reported mental health quality of life.
van den Berg et al. (2010) <sup>54</sup>	The Netherlands	4,529 adults	Cross-sectional, "representative" sample (P)	Green space around an individual participant's residence included agricultural lands, urban green space, forests, and conservation areas, but did not include streetscape greenery, or gardens or trees directly surrounding a residence.	Individuals with the most green space within 3 kilometers were less affected by stressful life events and reported better mental health, but no association was found with green space within 1 kilometer. In addition, these effects were less pronounced than those found for physical and overall health.

(P) = psychophysiological; (E) = exercise (physical activity); (S) = social contact



Authors, Date	Study Location	Study Sample	Study Design & Pathway	Primary Exposure or Intervention	Main Findings
Barton et al. (2009) <sup>48</sup>	England	132 park visitors	Mixed-methods, between-subjects (P)	A visit to one of four National Trust sites – including a coastal lowland heath, river valley, woodland, and fen – averaging two hours in duration.	Small increases in self-esteem and larger increases in mood were self-reported by those surveyed after a visit in comparison to those surveyed entering the park.
Kim et al. (2009) <sup>32</sup>	Seoul, South Korea	63 adults with major depressive disorder	Experimental, nonrandomized, controlled trial (P)	Weekly three-hour cognitive-behavioural therapy sessions conducted over the course of a month at the Hong-Reung Arboretum, an experimental forest featuring a variety of trees, shrubs, herb gardens, and alpine plants.	The course of therapy conducted in the forest setting resulted in higher remission rates and improved treatment response in comparison to therapy offered in hospitals or outpatient. However, no differences were seen in depressive symptoms.
Maas et al. (2009) <sup>65</sup>	The Netherlands	345,143 children and adults	Ecological (P)	Large neighbourhood green space (excluding streetscape greenery, backyard gardens, etc.).	The presence of large areas of green space within 1 kilometer of the home was linked to a lower prevalence of anxiety disorders and depression, with a stronger relationship found among children and individuals of lower SES.
Ellaway et al. (2009) <sup>21</sup>	Scotland	1,637 adults	Cross-sectional, random sample (P)	Street-level incivilities, such as litter and sewage smells, and the absence of environmental goods (such as parks and playgrounds).	Perceived absence of environmental goods (including green space, among others) was associated with 2.5 times odds of reporting anxiety and 1.94 odds of reporting sadness/depression.

(P) = psychophysiological; (E) = exercise (physical activity); (S) = social contact

Authors, Date	Study Location	Study Sample	Study Design & Pathway	Primary Exposure or Intervention	Main Findings
Faber Taylor & Kuo (2009) <sup>22</sup>	Not specified	17 children aged 7-12 with ADHD	Single-blind experimental trial; within-subjects design (P)	A 20-minute guided walk conducted in an urban park, a downtown setting, or a residential area.	The park walk was found to offset concentration deficits normally experienced by individuals with ADHD over the short term, an improvement roughly equal to the peak effects of the most common ADHD prescription medications.
Berman et al. (2008) <sup>15</sup>	Ann Arbor, United States	2 experiments: 50 university students in all	Experimental trials: 1) Randomized controlled trial; 2) Within-subjects design (P)	1) An hour-long walk in the Ann Arbor Arboretum; 2) Viewing pictures of nature in a laboratory setting.	1) Participants walking in nature experienced improvements in directed attention and mood, while those walking in urban settings did not. 2) Viewing images of nature improved directed and executive attention.
Sugiyama et al. (2008) <sup>53</sup>	Adelaide, Australia	2,194 adults	Cross-sectional (P, S)	Green space was based on self-reported access to parks, nature reserves, and cycling or walking paths, as well as the presence of greenery, tree cover, and "pleasant natural features".	Residents of the greenest neighbourhoods had almost twice the odds of reporting better mental health, a relationship that persisted in adjusted models.
Nielsen & Hansen (2007) <sup>72</sup>	Denmark	1,200 adults	Cross-sectional, random sample (P)	Green areas included small and large urban parks, urban squares featuring greenery, lakes and oceans, green sports facilities, and both private and public gardens.	Distance from the home to green areas was more closely associated with low levels of stress than actual use, although frequent users of green space were less likely to rate themselves as highly stressed.
McCaffrey (2007) <sup>27</sup>	Delray Beach, United States	60 older adults with mild and moderate depression	Experimental, "randomized", controlled trial; only qualitative findings reported (P)	Group walks through the Morikami Museum and Japanese Garden, which features 20 acres of gardens, an extensive bonsai collection, koi ponds, and waterfalls.	Individuals walking in the garden reported feelings of peace, serenity, and reflection.

(P) = psychophysiological; (E) = exercise (physical activity); (S) = social contact

Authors, Date	Study Location	Study Sample	Study Design & Pathway	Primary Exposure or Intervention	Main Findings
Tsunetsugu et al. (2007) <sup>39</sup>	Oguni, Japan	12 male university students	Experimental, randomized trial; counterbalanced, within-subjects design (P)	Comparison and control groups consisted of a 15-minute walk and 15-minute viewing session held in either a deciduous broadleaf forest or a city.	Stress levels were lower following the 15-minute walk in the forest than in the urban setting; the forest walk also produced feelings of comfort, calm, and refreshment.
Morita et al. (2007) <sup>36</sup>	Chiba, Japan	498 healthy adults	Experimental, randomized trial; within-subjects design (P)	A two-hour walk through the Tokyo University Forest (referred to as “forest bathing” in this context) compared to a similar urban walk.	The short walk in the forest reduced depression and anxiety, and improved mood, with greater benefits seen among stressed individuals.
Rappe & Kivela (2005) <sup>29</sup>	Helsinki, Finland	30 older adults	Cross-sectional, convenience sample (P, S)	Exposure included both visits to and views of a garden featuring trees, a pond, and walking paths located in a nursing home and service center for the elderly.	Garden visits improved mood, recovery, sleep, and concentration. Depressed individuals experienced fewer benefits with respect to recovery and concentration than the non-depressed.
Kuo & Taylor (2004) <sup>55</sup>	United States	452 parents of children with AD/HD	Cross-sectional, convenience sample (P)	Green outdoor settings were defined as any “mostly natural area”, and included parks, farms, and private backyards.	Natural outdoor activities reduced symptoms of attention-deficit hyperactivity disorder (ADHD) significantly more than activities in less natural or indoor settings.
de Vries et al. (2003) <sup>64</sup>	The Netherlands	10,197 children and adults	Cross-sectional, random sample (P)	Neighbourhood-level green space and blue space, including private home gardens.	Natural space offset the increased risk of mental illness among individuals residing in urban areas; significant effects were seen only among low-SES individuals.

(P) = psychophysiological; (E) = exercise (physical activity); (S) = social contact

Authors, Date	Study Location	Study Sample	Study Design & Pathway	Primary Exposure or Intervention	Main Findings
Stark (2003) <sup>17</sup>	Not specified	54 women in third trimester of pregnancy	Experimental, "randomized", controlled trial (P)	Participants in the intervention arm were instructed to spend 120 minutes per week in restorative activities involving "nature", both outdoors (such as listening to birds or building a snowman) and indoors (such as caring for plants).	Women participating in restorative activities involving nature made fewer errors on one test of attention, but no differences were seen in mood or directed attention between the groups.
Kohleppel et al. (2002) <sup>26</sup>	Florida, United States	312 adults	Cross-sectional, convenience sample (P)	A visit to one of three separate botanic gardens; no details were provided on the average length of visits or specific garden features.	Visiting a botanic garden was identified as an important stress-reduction strategy, with additional benefits experienced by depressed individuals.
Wells (2000) <sup>20</sup>	Not specified	17 children from low-income households	Longitudinal, within-subjects design (P)	Residential "naturalness" scores were based on views and components of front and back yards.	Moving to homes with more natural surroundings significantly improved children's attentional capacity.
Whitehouse et al. (2000) <sup>30</sup>	San Diego, United States	83 healthy adults; 6 healthy children, 16 children with various illnesses	Qualitative (P)	The study appraised a formal healing garden located in a children's hospital, which featured public art in the form of sculptures and mosaics, as well as natural plants, flowers, and greenery.	Ninety percent of adults reported improved moods following a visit to a garden located at a children's hospital; preferences and usage of the garden differed between healthy and ill children.

(P) = psychophysiological; (E) = exercise (physical activity); (S) = social contact



# Appendix A: Literature Search Strategy

## A.1 Selected Databases

- **CINAHL** (accessed via EBSCO), **Embase** (accessed via OvidSP), **MEDLINE** (accessed via OvidSP), **Psycinfo** (accessed via EBSCO), and the **Science Citation Index and Social Science Citation Index** (accessed via Web of Knowledge)

## A.2 Search Concepts and Keywords

Two principal domains were identified for use in the databases described above: green space and mental health. To capture the first domain, keywords included: *greenery, greenness, green space, natural space, natural view, open space, park, playground, garden, trees, and forest*. In order to locate studies related to mental health, terms included: *mental health, mental well-being, mental illness, mental disorder, psychological, psychosocial, depression, anxiety, stress, bipolar, schizophrenia, personality disorder, and obsessive-compulsive disorder*.

Boolean logic was integrated to combine the two constructs and to avoid the inclusion of irrelevant results (e.g., “trees.mp. NOT decision tree.mp.”). Where possible, controlled vocabularies (such as the Medical Subject Headings created for use in MEDLINE) were employed along with keywords. In addition, wildcards were integrated to help account for variability in spellings (such as “green space” versus “greenspace”). In addition, a set of evidence-based search filters developed by the Scottish Intercollegiate Guidelines Network (SIGN) were incorporated into the searches conducted within MEDLINE and Embase in order to improve the specificity of the search. All searches were conducted in December of 2013 and January of 2014, with no restriction on the original publication date of studies.

## A.3 Inclusion and Exclusion Criteria

Articles published in non-English languages were included as part of the abstract-review process, but were not incorporated into the final analysis due to a lack of resources available for translation. In terms of study design, individual and cluster randomized controlled trials, cohort studies, case-control studies, and observational designs were all eligible for inclusion. Studies examining virtual exposure to green space in a laboratory setting were also included. Commentaries, editorials, and studies reported solely as abstracts (such as conference proceedings) were excluded. In addition, after reviewing abstracts, a decision was made to exclude studies on the mental health outcomes of gardening, because this was thought to merit an independent review.

## A.4 Literature Organization and Storage

Bibliographic details and links to electronic versions of all 176 articles selected for full-text review were maintained in a RefWorks online citation management database.

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200 – 601 West Broadway  
Vancouver, BC V5Z 4C2

Tel.: 604-829-2551  
[contact@ncceh.ca](mailto:contact@ncceh.ca)



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