Beyond "bluespace" and "greenspace": A narrative review of possible health benefits from exposure to other natural landscapes

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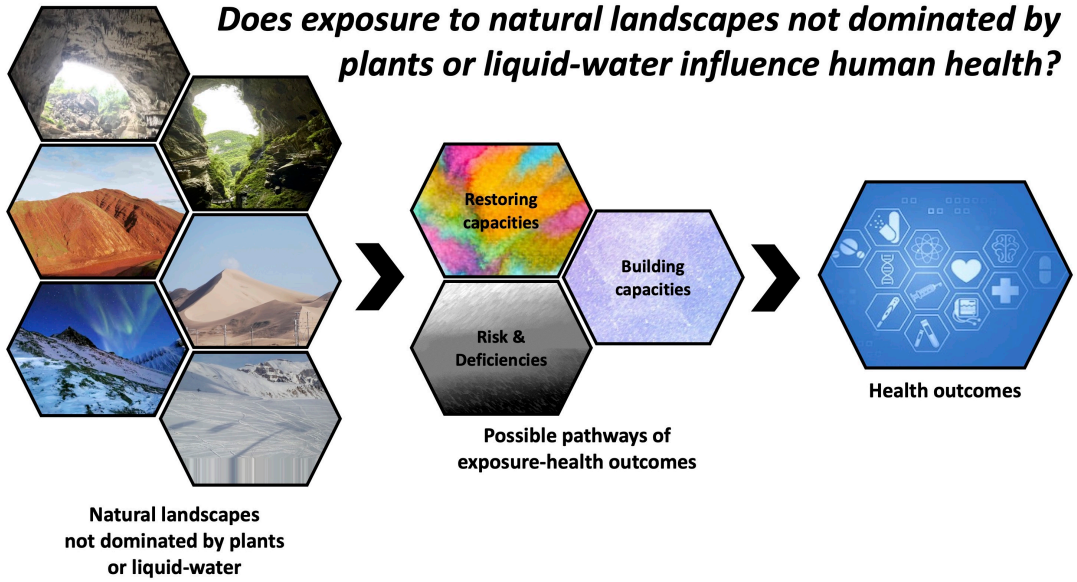
Graphical Abstract



Abstract

Numerous studies have highlighted the physical and mental health benefits of contact with nature, typically in landscapes characterized by plants (i.e., “greenspace”) and water (i.e., “bluespace”). However, natural landscapes are not always green or blue, and the effects of other landscapes are worth attention. This narrative review attempts to overcome this limitation in past research by pursuing the following objectives: (1) categorizing these natural landscapes, (2) summarizing the literature on health benefits of exposure to landscapes beyond "greenspace" and "bluespace," and (3) presenting the potential mechanisms underlying any health benefits derived from exposure to these other landscapes.

We propose that natural landscapes are composed of at least one of three components: (1) plants (e.g., trees, flowering plants, grasses, sedges mosses, ferns, and algae), (2) water (e.g., rivers, canals, lakes, oceans), and/or (3) rocks and minerals, including soil. Landscapes not dominated by plants or liquid-state water include those with abundant solid-state water (e.g., polar spaces) and rocks or minerals (e.g., deserts, caves). Possible health benefits of solid-state water or rock/mineral dominated landscapes include both shorter-term (i.e., viewing images) and longer-term (i.e., living in these landscapes) exposure durations. Reported benefits span improved emotional and mental states and medical treatment resources for respiratory conditions and allergies.

Restorative and instorative mechanisms underlying health benefits consist of commonly discussed theories in the "greenspace" and "bluespace" literature as well as less discussed pathways in that literature. Benefits of shorter-term exposure may be explained by attention restoration theory and stress reduction theory. Benefits of longer-term exposure may result from the cumulative effects of shorter-term exposures as well as psychological benefits explained by post-traumatic growth theory, supportive environment theory, and place attachment. Additional mechanisms may include distinct types of physical activity and immune system benefits, among others.

This is the first review to draw attention to the potential salutogenic value of natural landscapes beyond "greenspace" and "bluespace." It is also among the first to highlight the limitations and confusion that result from classifying natural landscapes using colors. Since the extant literature on natural landscapes - beyond those with abundant plants or liquid-state water - is limited in regard to quantity and quality, additional research is needed to understand their restorative potential and therapeutic possibilities.

Keywords: nature therapy; tourism; nature; well-being; brown space; white space

1. Introduction

The health benefits of contact with nature contact are widely recognized across human cultures. For example, 天人合一 (the harmony between humanity and nature) is a core idea in Chinese culture (Lai et al., 2022). Shinrin-yoku, or forest bathing, is an increasingly popular form of nature therapy used to promote physiological and psychological health in many parts of the world (Hansen et al., 2017). American poet Ralph Waldo Emerson also described "the lover of nature is he whose inward and outward senses are still truly adjusted to each other; who has retained the spirit of infancy even into the era of manhood" (Emerson, 1903), inspiring a fascination with nature-based health promotion in Western countries (Larson & Hipp, 2022). Modern empirical research supports a strong link between nature and human health but also highlights potentially variable effects across diverse types of natural landscapes via different mechanisms (Hartig et al., 2014).

The health-promoting potential of nature exposure is often assumed to be driven by our genes (Kaplan & Kaplan, 1989; Kellert & Wilson, 1993; Ulrich, 1983). Most of human evolutionary history has occurred in natural surroundings (Joye & van den Berg, 2011; Moura et al., 2017). Not until recent centuries following the industrial revolution have humans in many areas lived outside of and apart from nature-rich environments (Turner et al., 2004; Vlahov & Galea, 2002). Therefore, evolutionary-driven connections with natural landscapes and resulting health impacts are likely to remain viable today (Laland & Brown, 2006; Robinson & Breed, 2020).

Plants and liquid water are common components in natural landscapes. Water is a fundamental part of life, and plants provide ecosystem services, including the production of organic matter for food and oxygen for breathing (Carpenter et al., 2009). Aside from the essential function of supplying basic resources for survival (Reid et al., 2005), much scientific literature has been published on the health benefits of natural settings rich in these ecosystem services (Bratman et al., 2019; Zhang et al., 2020). Such studies often use colors to code landscapes with these components (Twohig-Bennet & Jones, 2018; White et al., 2020). In particular, "greenspace" refers to landscapes rich with plants (e.g., trees, flowering plants, grasses, sedges mosses, ferns, and algae), and "bluespace" refers to landscapes with open water (e.g., canals, rivers, lakes, oceans). However, these dichotomous characterizations omit key elements of nature.

Emerging concepts such as "white space" (e.g., snow-covered landscapes; Brooke & Williams, 2021; Finlay, 2018; Korpela et al., 2014; Olwig, 2005; Yli-Panula et al., 2022), “brown space” (e.g., deserts; Nazif-Munoz et al., 2020; Olvera-Alvarez et al., 2021; Yin et al., 2022), and "red nature" (e.g., volcanos; Kotera et al., 2021) bring more types of landscapes into scholarly discourse. Human perceptions of landscapes are undoubtedly shaped by sight and visual attributes, such as color, that contribute to experiences related to places (Bell, 2012; Lengen, 2015). Nevertheless, there are limitations to the use of color-coding to describe natural landscapes. For instance, other sensory perceptions such as sound may have a strong influence of the health benefits associated with nature (Buxton et al., 2021). Additionally, color may not accurately describe landscapes that are alien to most people. For example, general readers may not associate “red nature” with volcanoes without extra description (Kotera et al., 2021). To add more complexity, even plants and water change color with time and place (Zhou et al., 2022).

Some studies reveal the psychological benefits of landscapes that have few plants or minimal liquid water, such as deserts (Yin et al., 2022). Scholarly examination of the shorter-term psychological and physiological responses to these landscapes, and the health outcomes associated with longer-term exposure of living in these settings, may challenge the consensus that people prefer natural resource-rich environments (i.e., those with abundant plants and/or liquid water). These clues underscore the importance of expanding the definition of nature beyond "greenspace" and "bluespace" and exploring the potential mechanisms driving health benefits associated with exposure to less-normed natural landscapes.

The first objective of this narrative review is to develop a framework that categorizes the broad array of natural landscapes. The second objective is to review the available literature on the possible health benefits of exposure to natural landscapes that are not dominated by plants or liquid water. The third and final objective is to identify possible mechanisms that might explain how shorter-term and longer-term exposure to these landscapes may promote human health and well-being.

2. Methods

Given the novelty of the topic matter and the anticipated diversity of relevant papers, we employed a narrative approach to identify and summarize the literature. Narrative reviews are qualitative research syntheses that describe the results of other studies without a dominant focus on the statistical significance of the findings (Baumeister & Leary, 1997; Siddaway et al., 2019).

We first identified natural landscapes that were not dominated by plants or liquid water but were discussed as restorative landscapes. We studied the keywords in the nature archetypes identified by Scandinavian researchers Ottosson and Grahn (2021) and the nature interactions identified by North American researchers Kahn et al. (2012). Additionally, we referenced the findings of a scoping review on therapeutic landscapes (Taheri et al., 2021) and a book on the health benefits of exposure to eight types of natural landscapes (Loewe, 2022).

Keyword searches were then conducted in three databases: Scopus, Pubmed, and Web of Science. The keywords included "brown space*", "brownspace*", "desert*", "arid", "mountain*", "ridge*", "bedrock", "boulder*", "big rock*", "rock formation*", "rock outcrop*", "gray space*," grayspace", "white space*", "whitespace*", "snow-cover*", "artic", "Antarctic", "red space*", and "redspace*". We screened titles and abstracts for empirical, peer-reviewed articles published in English that included some form of exposure and psychological responses, physiological responses, or health outcomes (i.e., incidence/prevalence of disease, illness, or mortality). Additional articles were retrieved by screening the author's personal libraries and using ancestry-search methods (i.e., forward and backward searches) (Nørgaard et al., 2022).

All studies of natural landscapes aside from those dominated by plants or liquid water were considered. Specific components of nature (e.g., animals, aromatic essential oils) were excluded since our focus was on entire landscapes that existed in the physical world or could be presented in simulations (i.e., pictures, movies, or virtual reality). We excluded spaces usually unavailable for the public, such as outer space and deep underwater landscapes. All

authors discussed the classification and inclusion of potential non-green and non-blue natural landscapes. Disagreements were resolved by consensus.

Since the impacts of exposure could be regulated by the duration of exposure (Shanahan et al., 2016), we followed the approach of previous studies by collecting information from the included papers about any reported health benefits and presenting mechanisms by shorter-term vs. longer-term exposures. Shorter-term exposure referred to a singular experience that lasted from a few minutes to a few hours, such as was common in laboratory research (Mason et al., 2022; Roberts et al., 2019). Longer-term exposure referred to more than a few hours to days or years of contact, which usually resulted from living in a landscape (Gascon et al., 2015).

3. Results and discussion

3.1. Types of natural landscapes and health benefits

We observed that most natural landscapes consist of one to three components: water, plants, and/or rocks and minerals (Figure 1). Water covers over 70% of the earth's surface, and plants occupy over 30% of the land (Congalton, 2021). Plants are largely limited to regions with favorable climatic conditions, water, or sunlight; otherwise, water, rock or minerals are dominant. Geologic processes including physical and chemical weathering causes rocks or minerals to appear as bedrock, outcroppings, formations, debris, sand, lava fields, or soil. Water can exist in three states: liquid, solid, and gas. Liquid water only exists in a limited temperature range, such that polar regions and landscapes at higher latitudes during winter can be covered with solid-state water (i.e., ice and snow). In these cases, landscapes are dominated not by a single component but by multiple components (i.e., snow-covered boreal forests). Due to the complexity of these layered landscapes and the scarcity of available studies, we focused our review on landscapes dominated by a single component and psychological or physiological responses resulting from their exposure.

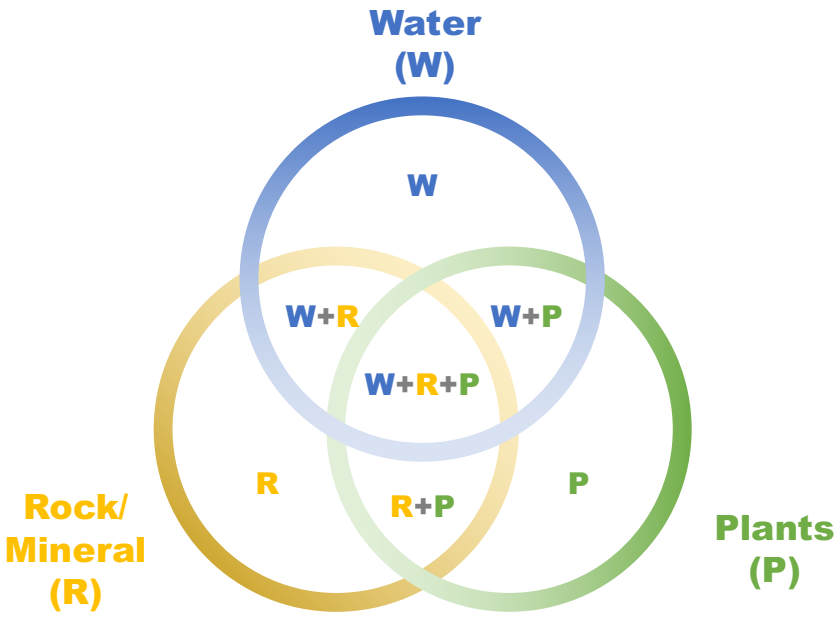


Figure 1. Most natural landscapes are composed of water in its liquid or solid state, plants, rocks/minerals, or a combination of the three.

3.1.1. Landscapes dominated by water in a solid state

Water-dominated landscapes usually refer to freshwater or marine landscapes, such as oceans, lakes, canals, or rivers (White et al., 2010). However, marine, freshwater, and even terrestrial areas can be covered with ice or snow, representing landscapes visually different from those shaped by liquid water (Figure 2). For example, ice and snow are the main components to which people entering the Arctic or Antarctic are exposed. Likewise, snow and ice may dominate other landscapes in winter, particularly in high altitude or latitude areas (e.g., frozen alpine lakes, snowy mountains, tundra, alpine meadows, and cold deserts) (Figure 2). These landscapes could be considered something other than "bluespace" given their colorful shades of white and gray. Only a few clues have indicated the health benefits of exposure to these landscapes.

Figure 2. Examples of landscapes dominated by water in its liquid-state (1-3) and solid-state (3-9)

We found little evidence to support the beneficial effects of shorter-term exposure to landscapes dominated by solid water. However, ice and snow are regarded as a major resource for the future of tourism (Wang & Zhou, 2019). The beauty and fascination of frozen landscapes are well documented (Brooke & Williams, 2021; Duffy, 2013; Lengen, 2015), including in polar landscapes (Shah, 2015; Summerson & Lieser, 2018), which may explain why many tourists visit polar spaces for sightseeing (Bauer, 2013). Thus, although not studied, the aesthetic values of polar spaces may be associated with some emotional benefits.

In addition to polar spaces, alpine landscapes in the European Alps, Pyrenees, Himalayans, Andes, and Rocky Mountains are often covered with ice or snow and have motivated glacier tourism (Wang & Zhou, 2019). We found little empirical evidence of their health benefits, however. Some scholars have suggested that glacier tourism and outdoor recreation activities promotes fitness and postulated on emotional or social benefits resulting from hiking, climbing, mountaineering, and skiing (Burtscher et al., 2019; Finkenzeller et al., 2011; Müller et al., 2011).

Clues to the health benefits of longer exposures to landscapes dominated by solid water can be obtained from studies of expeditions and deployments. Zimmer et al. (2013) conducted a systematic review of Antarctic psychological research between 2000 and 2010. The review concluded that improved emotion, mood, and a decline in factors contributing to psychological functioning disturbances were possible benefits of Antarctic experiences. Later studies underlined personal growth as a positive outcome resulting from living in polar spaces. A study on Antarctic deployment found "personal strength" was the highest perceived category of personal growth (Blight & Norris, 2018). Similar findings were obtained in the Arctic. Kjærgaard et al. (2017) studied six two-man Danish military teams deployed in the Arctic and found increased personal strength after their time there. Another study compared 384 navy soldiers assigned to Antarctica with 2396 counterparts assigned elsewhere and found Antarctic soldiers showed gains in health and wellbeing over the winter season (Palinkas, 1991).

3.1.2. Landscapes dominated by rocks and minerals

Rock and mineral-dominated landscapes are usually present in areas not covered by plants and water. According to ecosystem classifications (Keith et al., 2020), these landscapes mainly include deserts (terrestrial) and caves (subterranean) (Figure 3). Further, deserts can include cold and dry-heat deserts. The former is usually present in high altitude or latitude areas that are dominated by ice/snow in the winter and rocks/minerals in the summer. The latter is the one better known by most populations and present in tropical and temperate areas. Based on our review of the extant literature, only the dry-heat deserts have been studied for their potential health benefits. Generally, these rock and mineral-dominated landscapes can include sediment (i.e., soil, sand, gravel), rock faces (i.e., slabs, cliffs, boulders), loose rocks (i.e., talus, scree, glacial moraine), and unique erosional forms (i.e., towers, domes, spires, blocks, rills, grikes, clints, and hoodoos) (Migoń et al., 2017).

Figure 3. Examples of landscapes dominated by rocks and/or minerals

3.1.2.1. Deserts

Deserts may appear to hold little value, given their lack of plants or water and life in general. However, deserts are prominent types of natural environments on Earth and are home to more than 20% of the global human population (Tchakerian & Pease, 2015). Due to global climatic changes and resulting desertification, desert exposure is projected to increase in the

coming decades (Huang et al., 2015). Meanwhile, deserts are valuable tourism resources (Michopoulou et al., 2021). Therefore, some scholars advocate that the health benefits of deserts, particularly as it relates to shorter-term exposures, deserve more attention (Yin et al., 2022).

Some simulation studies of deserts have observed positive outcomes resulting from exposure. Middle Eastern college students exposed to a 1-min coastal desert video (an environment familiar to this population) showed better performance on a subsequent memory task than students showed videos of a temperate forest (a less familiar environment) (Pilotti et al., 2019). Nursing students from El Paso, TX, who viewed a 10-min 360-degree video of a desert in virtual reality (VR) showed similar levels of stress recovery to those students who viewed a 360-degree video of a public park with trees and grass (Yin et al., 2022). U.S. adults also reported that exposure to a desert image was less depleting and stressful than exposure to a built-up urban center (Shalev, 2016). One study consisted of a field-based exposure. In a desert-based walking program in Israel, themes of physical and mental well-being (i.e., relaxation, peacefulness) were expressed across a diverse range of participants, including those who previously disliked deserts (Teff-Seker & Orenstein, 2019).

We found one experimental study of longer-term exposure to deserts. Participants' brain activity during a 4-day trip to Utah found reduced posterior alpha power, suggesting an attentional restoration effect (Hopman et al., 2020). More clues were found for residential scenarios. A study in Kenya revealed that the desert landscape supported physical and mental well-being by offering freedom of movement and a sense of peace (Dan et al., 2021). Similar findings were observed along the Israeli-Jordanian border (a desert area), where desert landscapes were described as contributing to stress relief and affinity to nature among local residents (Sagie et al., 2013). Spatial epidemiology studies have found mixed evidence for the health benefits of living in desert areas. For instance, associations of residential non-built up impervious areas (i.e., bedrock and sand) around El Paso, TX, nursing students' homes with depression and diabetes incidence were mixed (Nazif-Munoz et al., 2020; Olvera-Alvarez et al., 2021).

Some medical therapies have originated in desert landscapes. Uyghur sand therapy uses sand heated by the sun to cure chronic osteoarthritis (Wang et al., 2018). Such therapy usually requires repeated treatments, so it can be considered a longer-term exposure. One study observed that participants felt the healing benefits of the haptic sensations of burning, heat, and swelling while touching the hot sand (Wang et al., 2018). Another study documented 13,115 cases of sand-based therapy in deserts in Xinjiang, China. Findings suggested that sand-based therapy may help with arthritis, rheumatoid arthritis, hyperosteogeny, sciatica, and lumbar disc protrusion. Efficacy for these symptoms was reported to be as high as 90% (Niyazi-Aishan, 2002). Controlled animal trials revealed that Uyghur sand therapy might alleviate cartilage inflammation and enhance bone strength (Hu et al., 2015; Kahal et al., 2009), although the quality of evidence to support the effectiveness of Uyghur sand therapy on humans remains limited.

3.1.2.2. Caves

Caves are subterranean rock/mineral-dominated landscapes that lack plants due to insufficient sunlight. We observed very little discussion of them in the literature discussing

the health benefits of nature. Conversely, there was a body of literature discussing the medical applications resulting from repeated exposures to caves.

We found no evidence to suggest benefits of shorter-term exposure to caves. However, like deserts, caves can have some aesthetic qualities. It has been reported that caves with such features as stalagmites and stalactites attract more than 500,000 visitors every year (Baker & Genty, 1998). They may therefore promote some positive emotional responses from visitation.

Cave climates may bring a series of respiratory health benefits, which have been called "speleotherapy" or "halotherapy" (Rashleigh et al., 2014). Since such therapy has been developed for curing chronic respiratory issues and usually requires repeated and extended exposures, it is considered a longer-term exposure (Beamon et al., 2001). Numerous studies have underlined the potential of such therapies in treating allergic rhinitis, asthma, and chronic obstructive pulmonary diseases (Beamon et al., 2001; Eslaminejad et al., 2017; Freidl et al., 2020). Also, owing to the cave climates, mitigation of skin allergies is believed to be another benefit of cave therapy (Lăzărescu et al., 2014).

There are also clues that longer-term exposure to caves may benefit mental and physical health. For example, a 19-day intervention revealed that speleotherapy might be conducive to reducing anxiety and increasing walking ability (Kendrová et al., 2016). Another 12-week study reported that speleotherapy helped athletes enhance their athletic performance, such as increasing boxers' punch speed, jump, reaction, VO_2max (how efficiently someone uses oxygen during exercise), and balance (Söyler et al., 2021). Salt therapy, an extension of speleotherapy in caves dominated by salt crystals, has been claimed to provide relaxation, a calm mind and emotions, and feelings of revitalization and refreshment (Shah, 2019).

3.2. Mechanisms driving health benefits

The normative perspective of evolutionary psychology suggests people tend to prefer landscapes that are abundant in elements humans have utilized for survival, such as water for drinking or plants for food/shelter. The existence of health benefits provided by natural landscapes not rich in life-supporting resource may therefore appear to be counter-intuitive. Nevertheless, some of these theories may extend to natural landscapes not dominated by plants or liquid-state water, while other theories and pathways may be more unique to the natural landscapes discussed in this review. According to a widely referenced theoretical framework, three dimensions link nature exposure to human health: reducing harm, restoring capacity (i.e., restorative effects), and building capacity (i.e., instorative effects) (Markevych et al., 2017). Harm reduction refers to the functions of some natural landscapes (e.g., tree-rich areas) in mitigating noise, heat, air pollution, and other stressors (Wolf et al., 2020). Restoring capacity refers to recovery from negative states, impacts, or deficient conditions, such as attentional fatigue or stress. In contrast, building capacity refers to natural landscapes' ability to promote health through behavior and psychological states absent of a deficient condition. Examples of natural landscapes' building capacities include promoting social cohesion and physical activity (Kondo et al., 2018).

Although the three-domain framework was developed for plant-rich landscapes ("greenspaces"), some parts (restoring and building capacities) can be adapted to classify the potential mechanisms for natural landscapes not dominated by plants or liquid-water. We

found no evidence for the "reducing harm" dimension within these landscapes but retained this dimension in our framework to recognize it may emerge in future research. To highlight the potential risks posed by these landscapes, we followed Marselle et al. (2021) and added risks (i.e., dangers) and deficiencies (i.e., situations or populations where health benefits are not observed) to illustrate possible adverse effects of exposure (Figure 4).

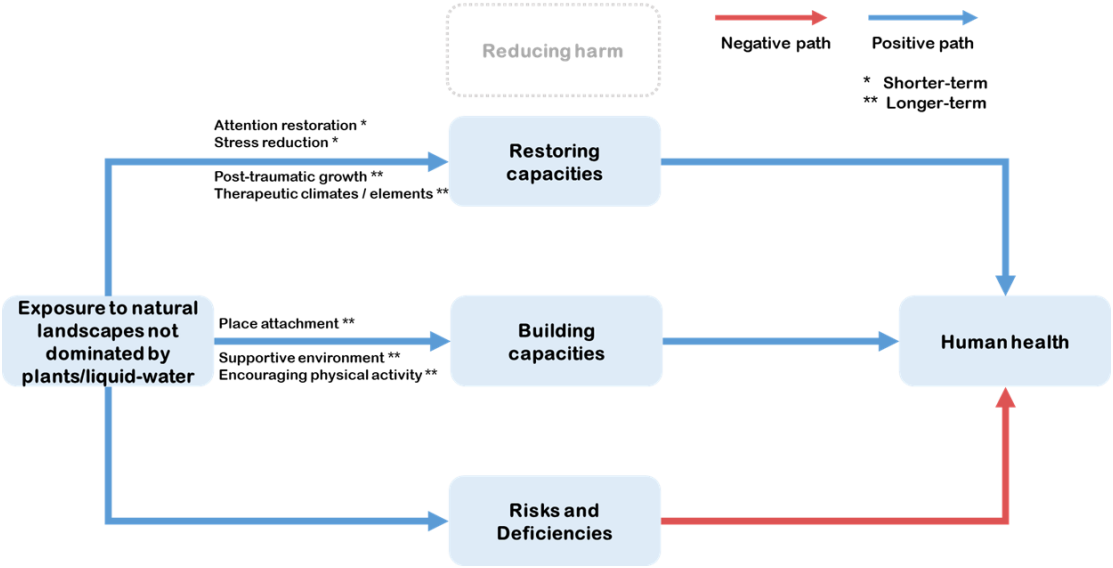


Figure 4. Hypothesized pathways linking exposure to natural landscapes, including those not dominated by plants ("greenspace") or liquid-water ("bluespace"), to human health. Notes: shorter-term vs. longer-term exposure detonated by * and ** respectively. Reducing harm is a common pathway in other nature-health research (Markevych et al., 2017) and retained to recognize it may emerge in future research on natural landscapes not dominated by plants/liquid-water despite little evidence for its role to-date.

3.2.1. Restoring capacities

Attentional resources can be seriously consumed in urban living, and residents usually face attentional depletion (Sullivan, 2018). Natural landscapes have been shown to help recover such resources. Attention restoration theory (ART) is a widely used theory for explaining the psychological benefits of shorter-term exposures to natural landscapes. ART describes how certain landscape characteristics can improve cognitive functioning through the restoration of involuntary attention (Kaplan, 1995). The four characteristics that facilitate attention recovery include being away (providing an escape from habitual activities), soft fascination (aspects of the environment that capture attention in a gentle and effortless manner), extent (the scope to feel immersed in the environment), and compatibility (the environment fits one's purposes) (Kaplan, 1995). ART does not assume restoration can be only facilitated by environments dominated by plants and liquid water, as these characteristics can exist in a wide range of environments. Polar and/or alpine landscapes, deserts, and caves may not be as fascinating as other natural landscapes due to the lack of desirable natural elements and a smaller number of colors and low-level features. Still, these landscapes can offer visitors with scenery that is different from their daily lives and more unique than plant or liquid-water-dominated landscapes, thus creating strong senses of being away from

everyday routines and worries (Pilotti et al., 2019). Several studies have also underlined the beauty of some deserts (e.g., Gutberlet, 2019); and polar spaces (Powell et al., 2012; Summerson & Lieser, 2018), and aesthetics is a key element of cave tourism (Kim et al., 2008). All of these landscapes may contain beautiful objects with low levels of movement and attract visitors' undirected/involuntary attention, in turn producing restorative directed/voluntary attention benefits.

Environmental stressors (e.g., crowding, noise, and air pollution) also dominate urban areas that house the majority of the world's population (Browning et al., 2022; Cohen et al., 2013). Stress reduction theory (SRT) describes how natural environments in which humans evolved may activate the parasympathetic nervous system in ways that reduce stress and autonomic arousal (Ulrich, 1983; Ulrich et al., 1991). Since plant and water-rich environments are not the only landscapes where humans evolved or still live (Hägerhäll et al., 2018; Zhang et al., 2021), this theory may also extend to the health benefits of solid-water-dominated landscapes, deserts, and caves. More specifically, SRT posits that human beings have rapid adaptive emotional responses to natural environments. Such rapid responses can facilitate subsequent approach-avoidance behaviors and the reduction or inhibition of stress. Because of their evolved adaptiveness, people tend to experience positive emotions and reduced physiological stress in resource-rich and safe, natural environments. By contrast, they tend to experience fear and dislike in response to dangerous environments or natural environments not rich in resources. Thus, deserts and polar areas might be expected to invoke aversion and fear. However, adaptiveness may not be perfectly sensitive to all types of nature. Research suggests that high-level semantics (meanings) of nature may contribute to its emotional benefits (Kotabe et al., 2017). Environments dominated by solid water and rock, which can be understood as "nature", might therefore still evoke more positive emotions than nature-poor environments (i.e., largely built environments).

Post-traumatic growth theory, which relates to recovery from a deficient state, may help explain the benefits of longer-term exposure to solid-water-dominated landscapes, caves, and deserts. This theory suggests that people who endure psychological struggles following adversity may see positive growth afterward. We placed this theory in the restoration dimension as it requires pre-induced psycho-physiological declines to generate compensation or super-compensation. Landscapes without drinkable water and plants are generally harsh for animals, including humans. Unlike visitors who briefly visit these landscapes for recreation, residents/travelers who take longer stays may experience multiple environmental stressors. For instance, snow and ice may make physical activities very physically and mentally challenging (Chapman et al., 2019; Larsson & Chapman, 2020). Dust may also cause respiratory distress in deserts (Goudie, 2014). Such stressors threaten visitors even if modern technologies (i.e., protective clothing, climate-controlled shelter, regular provision of food and water) have partially addressed resource constraints. But these stressors also present unique opportunities for personal growth. Successfully overcoming the challenges of over-wintering have been reported as a reason for the mental improvement in the Antarctic (Jenkins & Palmer, 2003). Overcoming stressors also appears to be a common reason for the observed positive effects on health/wellbeing among polar expedition members (Palinkas & Suedfeld, 2008; Zimmer et al., 2013). Blight and Norris (2018) have already explained some of the positive consequences of polar space exposure with this theory. Although we found no

scholars reporting post-traumatic growth in deserts, we posit that similar effects may exist since these landscapes are similar in their intensity of stressors and demands.

In addition to psychological aspects, some medical treatments for chronic respiratory and allergy symptoms are also based on landscapes' physical features, which helps patients to maintain or restore health. Specifically, caves generate unique health promoting mechanisms due to their unique climates. These climates may help to regulate the immune system and hormone secretion (Bilha & Simionca, 2013; Nagy et al., 2009). According to Freidl et al. (2020), the climates in caves may include five therapeutic features. The first is the high relative humidity (Lunghi et al., 2017), which can benefit the respiratory system. The second is cave aerosols, which may contain some health-promoting ions (e.g., Ca2+) that can treat infected areas in asthmatic lungs (Alföldy et al., 2002). The third is the absence of air pollutants resulting from caves' unique structure (Kertész et al., 2002). The fourth is radiation and ionization. Certain radon levels (a radioactive noble gas of natural origin commonly present in caves) may help treat pain symptoms caused by chronic degenerative diseases (Maier et al., 2021). The last is the lack of ozone due to no sunlight (Korzhe, 2017).

In Uyghur sand therapy, desert sands can deliver heat to the human body effectively and safely under proper procedures (Lina et al., 2005). Such haptic sensations and corresponding physiological responses can increase blood flow in major arteries and decrease platelet deposition (Han et al., 2019). Some practitioners have also surmised that the elements in desert sands, such as silicon dioxide and magnet particles, are physiotherapeutic materials of Chinese medicine that positively affect physiological responses and promote physical health (Niyazi-Aishan, 2002).

3.2.2. Building capacities

Supportive environment theory (SET) may help explain how novel natural landscapes can build health capacity among individuals exposed to them. Supportive environments refer to landscapes that are easy to understand and manage. SET suggests that people need such environments to maintain physical and mental health (Grahn & Stigsdotter, 2010). Although SET has been employed to explain the benefits of plant-dominated landscapes, it may also relate to the psychological benefits of deserts. One's perception of landscapes is not only bonded by genes but also fostered during the life course. For tourists who are unfamiliar with deserts, deserts may be places where "exciting" masks "relaxing," thereby activating the innate responses of the sympathetic nervous system (Terzano & Gross, 2020). By contrast, the millions of people around the world who grew up in deserts may find these ecosystems commonplace and familiar. Thus, a desert can be a supportive environment for local residents. Nazif-Munoz et al. (2020) argued that desert residents may be accustomed to the rocky natural elements and tend to feel safe within them and hence counteract acute social stressors. Indeed, many have written about the unique benefits afforded by prolonged exposure to nature in desert landscapes (Abbey, 1968).

It is unclear if SET applies to solid-water-dominated landscapes. One study revealed that some people who are accustomed to polar conditions might feel snow and ice are manageable parts of everyday life (Finlay, 2018). Such evidence comes from a study in Minnesota, which has only intermittent snow and ice, so it offers only indirect evidence to support the relevancy of SET.

Caves are special because there are very few cave residents in the world. China has villages that were settled in natural caves for long periods of history. It is reported that some people still living in these caves today are unwilling to move out because they are familiar with that environment (Zhou, 2019). We speculate that caves can also be supportive environments for these residents.

Relatedly, place attachment may explain some benefits acquired from familiar natural landscapes. Place attachment is comprised of multiple dimensions, including person, psychological, and place (Scannell & Gifford, 2010). Place attachment can occur in landscapes of varying significance, such as landscapes bonded with personal experiences, particularly in childhood (Riley, 1992), and it can help to build resilience and transformative capacity within these systems (Masterson et al., 2017). In "greenspace" research, place attachment has been described as a functional attachment associated with various recreational activities in a place, which partially explain why people prefer plants in their neighborhood (Zhang et al., 2015). For local residents, landscapes with abundant solid-state water or rocks and minerals may also provide places for recreational activities to happen, including in childhood. These landscapes usually lack noise and other disturbances due to limited traffic or human activities. Thus, youth may have positive experiences that foster attachment to such places. Place attachment has been empirically linked to health and wellbeing (Molcar, 2006; Rollero & De Piccoli, 2010), which can translate to positive health outcomes resulting from longer-term exposure.

Some longer-term health benefits could also be related to landscapes' physical features, especially if these features encourage physical activity. Similar to many landscaped dominated by plants or liquid-water, landscapes full of rocks or ice may offer places for physical activity and sports. Solid-water-dominated landscapes are ideal places for skating and skiing. These landscapes can motivate relevant physical activities among newcomers and locals alike and may therefore promote physical and mental health. More specifically, in addition to cardiovascular benefits, snow sports may be conducive to positive emotional arousal, social bonding, and feelings of accomplishment, particularly in the presence of others (Mirehie & Gibson, 2020). Desert landscapes are usually smooth and open, which may also provide some novel physical activity opportunities. Residents in Kenya reported that their desert landscape topography allowed freedom of movement and enhanced physical wellbeing (Dan et al., 2021). Such topographic elements are foundations of desert sports that benefit both locals and tourists (Abyar et al., 2014; Hashemi et al., 2020; Yan, 2014).

3.2.3. Risks and deficiencies

Despite the many possible health benefits of natural landscapes not dominated by plants and/or solid-water there are also many deficiencies and risks, which relate to what some scholars call ecosystem disservices (Oosterbroek et a., 2016). Snow and ice may limit mobility, evoke boredom, fear, and isolation, and cause concerns related to safety and vulnerability (Finlay, 2018). Snow and ice might also aggregate depression and seasonal affective disorder and even increase suicide risk (Leppämäki et al., 2002; Rind, 1996). Activities in ice and snow-covered alpine landscapes are also prone to falling injuries (Selig et al., 2012), frostbite (Ströhle, Rauch, et al., 2018), mountain sickness (Imray et al., 2010), and even lighting strikes (Ströhle, Wallner, et al., 2018). Activity in deserts can place people

at risk of dehydration, hyponatremia (electrolyte imbalance due to excessive water drinking), heat stroke, and even hypothermia (Elbaz et al., 2008; Krake et al., 2003; Shopes, 1997). Desert dust may also carry bacteria (Ruiz-Gil et al., 2020) and retreating lake beds may expose heavy metal depositions that threaten health (Han et al., 2004; Riches, 2019). In caves, excessive levels of radon may increase cancer risk (Maier et al., 2021). Many caves are inhabited by bats, and bats can be hosts for many diseases, which increases the risk of infections (Lottenberg et al., 1979; Willoughby et al., 2017). Such occurrences underline the necessity of risk management in these landscapes when planning health promotion environments.

Counterevidence to the potential health benefits of nature exposure in environments that are not dominated by plants or liquid-water also exists. A study of Texas college students reported that images of deserts were less restorative than images of other terrestrial biomes, including tundra and different types of forests (Han, 2007). Another study found U.S. adults reported decreased confidence in their ability to change negative habits and increased feelings of depletion and stress when shown a desert image compared to an image dominated by liquid water (Shalev, 2016). Such contradictory evidence may be related to human's inherent familiarity with resource-rich landscapes and the need to test responses among residents more accustomed to deserts.

Several health-promoting factors that are present in environments with abundant plants or liquid water may also not extend to other natural landscapes. Biological factors such as environmental microorganisms and negative oxygen ions, and beneficial volatile biogenic compounds (VOCs) generated by plants (Roviello & Roviello, 2021; Stanhope et al., 2020) may be nearly absent in polar landscapes, caves, and deserts. Climate regulation, aerosols, and negative ions generated by water movement and water-related organisms can also be absent in landscapes without liquid water (White et al., 2020).

3.3. Future research

The available evidence for health benefits of exposure to natural landscapes not dominated by plants/liquid-water is largely drawn from observational research prone to residual confounding and self-selection bias. Similar challenges are present in research on health benefits linked to other types of natural landscapes (Frumkin et al., 2017).

Further examinations should use more rigorous sampling techniques and study designs, such as following cohorts over time and conducting randomized clinical trials. Still, given the expense and challenges of these approaches, we recognize value in additional observational research given how few studies exist for each exposure-outcome pairing.

Consistent operationalizations of exposure are also needed to better compare findings across studies. We identified one attempt at quantifying natural rock/mineral cover (Nazif-Munoz et al., 2020; Olvera-Alvarez et al., 2021) and no attempts at quantifying snow or ice cover despite measures being available in remotely sensed datasets that are similar to what is used to quantify plant cover (Gao et al., 2010). We also identified no attempts at quantifying exposure to rocks/minerals or ice/snow cover using street view imagery. These measures would allow complementary or even improved exposure estimates given their ability to measure what can be seen at eye-level (Kang et al., 2020).

Future work is needed to validate and expand the mechanisms linking exposure to health outcomes. The mechanisms we presented are largely adapted from studies and theories based on plant-rich landscapes (Markevych et al., 2017; Marselle et al., 2021). Some of the arguments in favor of these mechanisms are also based on indirect evidence. Given how understudied this body of research is relative to other environmental exposures (e.g., air pollution, water quality), we anticipate undiscovered or under-discussed mechanisms will emerge. For example, while we didn't identify evidence for these natural landscapes reducing harmful exposures, future research could investigate this possibility. The mechanisms we presented are also likely to be refined or even invalidated as the quantity and quality of this body of literature grows.

Nature and health scholars should embrace the complexity of natural landscapes and their co-occurring exposures to multiple components (i.e., plants, water, and/or rocks/minerals). Few attempts have been made to measure vegetative and rock/mineral cover simultaneously (Nazif-Munoz et al., 2020; Olvera-Alvarez et al., 2021). We are also unaware of attempts to incorporate these two components at the same time as water (in its solid or liquid state) in a way that would present exposure to all three components concurrently. Such efforts would fill several gaps related to the health benefits of nature exposure, such as how much do the health benefits of different types of nature exposure overlap vs. diverge, and do natural landscapes with different components provide a multiplier effect whereby the total is greater than the sum of the individual parts? Additionally, the changing of the seasons are likely to modify what components are present at different times of year and across the lifecourse. For example, a high-alpine mountain landscape in a temperate climate is dominated by rocks – and perhaps even plants – in the summer and by snow and ice during much of the winter, spring, and fall seasons. Diurnal fluctuations in light levels across various landscapes (e.g., light pollution at night) might also influence health outcomes (Davies et al., 2018). For these reasons, we recommend time-varying exposure data rather than cross-sectional data to minimize exposure misclassification and account for the full range of experience with natural settings.

Finally, the utility of these landscapes in nature-based therapies and health promotion warrant critical examination. Speleotherapy and Uyghur sand therapy are examples of existing interventions with insufficient data on their recommended dosage, efficacy, and risk management. In contrast, therapies like forest-bathing or horticultural therapy are more mature and have many empirical research studies (Rosa et al., 2021) and practitioner-oriented articles and books written on their safe administration (Li, 2019; Miyazaki, 2021; Schuh & Immich, 2022). Ultimately, the landscapes we discussed pose greater risks and challenges than other natural landscapes. Risk-benefit calculations must be made before pursuing therapies in these landscapes at-scale and with the general population. The extent to which the possible health benefits of exposure outweigh the risks is perhaps the crux of the future research needs for these landscapes. We hope our contributions inspire research on the wide-ranging diversity of natural landscapes that exist, and how these benefits might be maximized into the future.

4. Conclusion

Our narrative review aimed to summarize and introduce the potential benefits of exposure to natural landscapes that are rarely studied in the literature focused on the nexus of nature and health. In doing so, we present a new and more comprehensive classification for types of health-promoting natural landscapes that moves beyond color-coding (i.e., "greenspace" and "bluespace") and focuses instead on natural components, including plants, water, and rocks/minerals. We also reviewed the extant literature on landscapes dominated by solid-state water (e.g., polar spaces) and rocks or minerals (e.g., deserts and caves) to reveal shorter- and longer-term effects of exposure. Despite some risks associated with visiting or living in these landscapes, we observed potential for beneficial psycho-physiological responses as well as physical, mental, and well-being outcomes, including resources for medical treatment. To connect the collected evidence to previous knowledge on plant-rich and other common-discussed natural landscapes, we proposed restorative and instorative mechanisms for enhancing health capacity on the basis of two frameworks from previous "greenspace" research (Markevych et al., 2017; Marselle et al., 2021). Further research is needed to build up the quantity and quality of literature on these landscapes, quantifying exposure and validating the possible mechanisms linking these landscapes to human health.

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