



Research article

Old lessons for new science: How sacred-tree metaphors can inform studies of the public-health benefits of the natural environment

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ABSTRACT

Many studies have identified an association between exposure to the natural environment and improved public-health outcomes. However, much of this observational work lacks a theoretical foundation, so we look to the humanities for a stronger basis for green-health research, examining how trees have been used as religious metaphors and symbols for health and wellbeing. In particular, the tree of life, sacred trees, and other religious symbols provide a promising theoretical basis for green-health research. Based on this review, we propose the value of incorporating attributes such as vegetation species and size in exposure metrics, and considering the interactions between exposure attributes (e.g., species) and individual attributes (e.g., culture).

1. Introduction

Over the last 35 years, research has consistently shown that exposure to the natural environment is associated with a range of improved public-health outcomes from physical outcome such as birthweight [1], cardiovascular disease [2], and cancer [3] to mental-health and behavioral-health outcomes such as depression [4] and ADHD [5]. The majority of these studies are observational. This reliance on observational methods is understandable, given that the natural environment can be difficult, and expensive, to experimentally manipulate. In consequence, most experimental studies have focused on self-reported mental health [6] and intermediate biomarkers of health [7] rather than long-term health outcomes. However, one drawback of observational research is that unless the hypotheses being evaluated are carefully selected, and based on a clearly identified causal model, observational studies can become data-mining exercises that may detect spurious correlations without causal underpinnings. One way to avoid this is to make sure that hypotheses are well-grounded in the existing literature and theory. (In this context, we define theory as an *a priori* rationale for believing that trees and health are causally linked.) However, in the case of the natural environment and public health, much of the extant literature is itself observational, although recent papers are now using more sophisticated techniques—such as machine learning [8] and geographically-weighted regression [9]—to better understand the relationship between the natural environment and health. A small number of experimental studies have found a causal link between the natural environment and health, but these studies have often focused on short-term markers of stress or self-reported wellbeing [10], so they provide only modest theoretical support for observational research.

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One discipline that has provided plausible theoretical frameworks linking health and the natural environment is environmental psychology. For example, Attention Restoration Theory [11] posits that time spent in nature, as opposed to the built environment, is mentally restorative and reduces stress. Furthermore, numerous studies have shown that increased stress is a risk factor for a wide range of mental and physical health outcomes [12]. Place Attachment Theory [13] provides a framework for how people develop emotional connections to specific places. Although not limited to the natural environment, Place Attachment Theory explains how people may develop strong bonds with the natural environment, and other research has shown that strong connections to our environment—having a strong sense of place—is positively associated with health and well-being [14].

One way to bolster the theoretical links between trees and health is to examine metaphoric and other symbolic links between the two (by metaphor, we mean relational or attribute comparisons from a different semantic domain, and by symbol, we simply mean something that represents something else). Trees are persistently used across cultures to represent health and wellbeing, so we can draw some inference about the real-world relationships between them. This is because metaphors are more likely to be effective—encouraging inferences between the metaphor's source and target—if they are apt [15], and the aptness of a metaphor depends on individual experience of salience, and implied meaning, of the metaphoric link between source and target [16]. In other words, the ubiquity and persistence of trees-and-health metaphors and symbolism suggest that, across cultures, human experiences with trees readily invoke health and wellbeing. The use of trees to metaphorically represent health and wellbeing is paralleled by the empirical green-health literature, which shows that exposure to trees is associated with improvements in a rapidly expanding list of physical and mental-health outcomes [17].

Our reliance on metaphor to inform green-health research is consistent with frequent use of metaphor in the broader health literature. Indeed, Talley [18] observed that “metaphors shape ideas about what health is, what affects health, and what might be done to improve health”. For example, “body as a machine” is a popular metaphor proposed by Rene Descartes that provides a theoretical foundation for the biomedical model of disease distribution [19]. However, this model has received contemporary criticism, because it doesn't adequately account for the socio-cultural context of human health [20], nor does it prepare people for the entropic realities of ageing and death. More recently, eco-social theory better combines the social and environmental determinants of health. Krieger [21] metaphorically likened eco-social theory to a crossroads between the tree of life and the scaffolding of society.

The Bradford Hill criteria are a set nine principle in public health research that can be used establish causal evidence between a presumed cause and an observed effect [22]. The principles state that associations are more likely to be causal if they are larger, more consistent (observed by multiple scientists in different situations), more specific (few other explanations), temporally consistent (the cause occurs before the effect), exhibit a biological gradient (more of the cause leads to more of the effect), plausible, coherent (epidemiological and laboratory evidence are consistent), are supported by experimental evidence, and the existence of analogies between the presumed cause and the observed effect. In our case, the final criterion—the existence of analogies connecting trees and health—supports a potential causal relationship between trees and health. While we are concerned with metaphors rather than analogies, they share fundamental functions, using one thing to explain another. In combination with the evidence shown in observational studies [23,24], this provides support for our contention that tree-health metaphors are indicative of real-world connections between trees and health.

Given their wide use in health research and practice, we propose using metaphor and symbolism to inform and guide green-health research. In identifying green-health metaphors and symbols we look to the humanities and traditions outside science. Casting such a wide net is supported by interdisciplinary science, which has repeatedly shown that research effectiveness can be enhanced by the integration of multiple disciplines [25]. We chose to focus on religious texts and traditions to gain insights into long-standing and well-documented cultural understandings of human relationships with nature. Specifically, we examine how trees—an important component of the natural environment and important motifs across many religious traditions [26]—have been used as metaphors and symbols for health and wellbeing in religion for millennia.

Our choice to focus on symbolic and metaphoric links between the natural environment and health is a deliberate one. Symbols and metaphors can be used to effectively explain ideas and make connections between disciplines [27]. In addition, metaphors can serve as a way of creating and refining causal models that are useful for interdisciplinary research [27,28]. Finally, Krieger [29] notes that “metaphor spark connections in our pattern-seeking minds”.

In focusing on symbolic and metaphoric links between trees and human health in different religious traditions, we aim to answer two questions. First, do these symbols and metaphors provide context and support for empirical studies of the public-health benefits of nature. Second, can these symbols and metaphors provide specific guidance on the design of green-health research.

In looking to the humanities for insights into how to conduct science, we are inspired by C.P. Snow's influential “Two Cultures” essay [30], which asserted that there are important lessons to be learned at the intersection of the arts and sciences, but we are missing out on these lessons, because the two traditions cannot communicate with each other effectively. In a call to action, Snow noted that “... we are letting some of our best chances go by default. The clashing point of the two subjects, two disciplines, two cultures—of two galaxies, so far as that goes—ought to produce creative chances. In the history of mental activity that has been where some of the breakthroughs came.”

2. Origins of tree health metaphors and symbols

Tree metaphors and symbols are among the oldest in human history. Indeed, they are so ancient that it is not clear whether they arose independently in different religious traditions or from a common origin [31]. Certainly, by the fourth millennia BCE the tree-of-life symbol had appeared in Mesopotamia, and by the second millennia BCE it was also present in Egypt, Greece, and the Indus Valley [31]. A closely related tree symbol, the cosmic tree, had also appeared by this time. The cosmic tree is typically shown linking

the underworld, the earth, and the heavens [32].

The Egyptians, in particular, frequently used trees as metaphors for health and rejuvenation, and many Egyptian gods were associated with specific trees. For example, Nut, the goddess of the sky, was associated with a Sycamore tree. In consequence, sycamores are often planted in graveyards, and sycamore wood is used for coffins. Because of this association with death and rebirth, Nut and sycamore trees appear in the Egyptian Book of the Dead, which contains a series of spells intended to help the reader navigate the underworld and arrive at the afterlife [33].

Another example of trees being associated with life and rebirth is the death of Osiris, the god of the underworld. After he dies a huge tree grows out of his tomb, and Osiris is reborn from the trunk. Other tree references are found in The Instruction of Amenemope, an Egyptian text (1000-600 BCE) consisting of 30 aphorisms giving advice on how to live successfully [34].

Greek mythology also uses trees as metaphors for health and wellbeing. For example, when King Cecrops established the city of Attica (subsequently Athens), he held a competition between Poseidon and Athena to see who would provide the greatest gifts and, therefore, be named the patron of the city. Poseidon created a salt-water spring, whereas Athena planted Greece's first olive tree. Athena won, and the city was named in her honor [[35] 8.55].

In these early examples and the ones reviewed in the following sections, cultural and religious traditions specify not just generic trees, but particular species of trees that have served as metaphors and symbols for health outcomes, especially related to birth and longevity. They also suggest culturally specific relationships to trees. Table 1 provides examples of the species that have been associated with beneficial health outcomes across a global range of cultural and religious traditions, spanning millennia. These examples are expanded upon in the following sections. Overall, the cultural and ecological specificity of these traditions suggest a theoretically rich and practically consequential relationship to human health.

3. Abrahamic religions

3.1. Judaism and christianity

Judaism is one of the world's oldest monotheist religions and represents a covenant between God and the people of Israel. Specifically, God gave Israel to Isaac, the son of Abraham, as a reward for Abraham's faith in one God. Jewish scripture includes the Hebrew Bible (Tanakh), which is split into three parts: the Torah, the Nevi'im, and the Kethuvim. These texts were later supplemented by oral traditions such as the Talmud and Midrash [36].

Christianity was originally a sect of second-temple Judaism but diverged in the first century due to irreconcilable theological differences [37].

The Bible contains perhaps the most well-known tree-health metaphor: the tree of life. Although trees are mentioned many times in the Bible, the tree of life is explicitly mentioned in only three books: Genesis, Proverbs, and Revelation. In addition, the tree of life is alluded to in Psalms and Ezekiel.

Two trees, the tree of life and the tree of knowledge, are mentioned by name in Genesis. However, many other trees were also created for two purposes: food and aesthetics (Genesis 2:9). That God created trees for the purpose of being beautiful is unusual. Indeed, beauty is not mentioned as a rationale for other parts of creation.

Table 1
Examples of important or sacred species of trees symbolizing health or well-being in religious traditions.

Religious/cultural tradition	Tree-health metaphors, symbols, stories, and practices	Important or sacred species	Related health and wellbeing outcomes
Judaism and Christianity	<ul style="list-style-type: none"> • Tree of life • Tree of knowledge • Tree of the Virgin • Tree pilgrimages 	<ul style="list-style-type: none"> • Olive (<i>Olea</i>) • Fig (<i>Ficus</i>) • Sycamore (<i>Ficus sycomorus</i>) 	<ul style="list-style-type: none"> • Promotes healing • Promotes longevity [92]
Islam	<ul style="list-style-type: none"> • Quaranic account of Jesus' birth • Sacred trees 	<ul style="list-style-type: none"> • Tuba tree (<i>Derris</i>) • Lote tree (<i>Ziziphus lotus</i>) • Mbeb tree (<i>Sterculia setigera</i>) • Palm tree (<i>Areca</i>) • Doum tree (<i>Hyphaene thebaica</i>) 	<ul style="list-style-type: none"> • Promotes longevity • Promotes maternal health [93]
Hinduism	<ul style="list-style-type: none"> • Specific sacred trees • Sacred species; trees as the embodiment of a god • Tree of life/creation • Tree worship rituals; pilgrimages 	<ul style="list-style-type: none"> • Peepal (<i>Ficus religiosa</i>) • Neem (<i>Azadirachta indica</i>) • Banyan (<i>Ficus benghalensis</i>) • Wood apple (<i>Aegle marmelos</i>) • Amla (<i>Phyllanthus emblica</i>) 	<ul style="list-style-type: none"> • Promotes fertility [94] • Promotes longevity
Buddhism	<ul style="list-style-type: none"> • Meditation under trees • Specific sacred trees • Maha-Bodhi tree; tree pilgrimages • Trees present at birth/death 	<ul style="list-style-type: none"> • Sal tree (<i>Shorea robusta</i>) • Jambu tree (<i>Syzygium samarangense</i>) • Amra tree (<i>Spondias pinnata</i>) • Peepal tree (<i>Ficus religiosa</i>) • Peepal (<i>Ficus religiosa</i>) 	<ul style="list-style-type: none"> • Promotes favorable birth outcomes [1] • Promotes mental health [95]
Sikhism	<ul style="list-style-type: none"> • Tree of life 	<ul style="list-style-type: none"> • Peepal tree (<i>Ficus religiosa</i>) • Peepal (<i>Ficus religiosa</i>) 	<ul style="list-style-type: none"> • Promotes longevity
Norse Mythology	<ul style="list-style-type: none"> • Yggdrasil • Fruit from sacred trees 	<ul style="list-style-type: none"> • Ash tree (<i>Fraxinus excelsior</i>) 	<ul style="list-style-type: none"> • Promotes maternal health • Promotes healing

After eating from the tree of knowledge, God expels Adam and Eve from Eden, because He is concerned that if Adam and Eve were to also eat (or perhaps continue to eat) from the tree of life, then they would become “like one of us.” (Genesis 3:22).

The tree of life next makes an appearance in Proverbs where it is used somewhat differently. It is no longer a simple metaphor for eternal life. Rather, it appears to have become so well accepted that it is a dead metaphor with a literal meaning. Rather than a tree being used as a metaphor to understand immortality, the tree of life itself is now a metaphor for the reward and blessing of a life lived in the pursuit of wisdom. Perhaps, the most well-known evocation of the tree of life is in Proverbs (3:18):

“She is a tree of life to those who lay hold of her; those who hold her fast are called happy”.

In Judaism, this verse is recited as the Torah is put away in the ark (an ornate cabinet that stores the Torah scrolls used in public worship). In this use, wisdom and the Torah are explicitly conflated.

In Psalms, the tree of life is also used to denote the wisdom and the reward for following the word of God (1:1–3). The explicit phrase “tree of life” is not used, but the parallels to Genesis (eternal life) and Proverbs (wisdom) are clear. A similar evocation of trees representing the word of God is also seen in Ezekiel.

In Christianity, the final four Biblical references to the tree of life come in the Book of Revelation. In three of these references, the tree of life is part of a simile (2:7, 22:14, 22:19). In the one case where the tree of life is described directly (22:2), it is almost identical to the description of a paradisiacal tree of life in Ezekiel (47:12) and clearly inspired by the tree of life described in Genesis, the first book of the Bible (Fig. 1). This demonstrates that despite only being mentioned explicitly 11 times in the Bible, the tree of life is an enduringly important metaphor [38].

Beyond textual references, the tree of life has influenced Jewish culture and practices. In particular, in the Jewish mystical tradition, Kabbalah, the tree of life is represented as a series of 10 nodes linked by 22 lines. The spheres symbolize aspects of God or the human mind, while the lines represent relationships [39].

In addition to the Biblical canon, the tree of life appears in the biblical apocrypha. For example, 1 Enoch contains several references to a tree that has clear parallels with the tree of life in the Bible. The fruits of this tree are reserved for the elect, and those who eat the fruit: “... shall live a long life on earth” (verses 4–6).

In the first two centuries CE, Gnosticism flourished, which was a religious tradition that emphasized personal spiritual knowledge over orthodox teachings and believed that salvation came through direct knowledge of the divine (gnosis). There is ongoing debate about whether Gnosticism should be considered a separate religion or a Christian sect [40], because Gnosticism, Christianity, and Judaism influenced each other during the early years of the Christian church. Gnostic texts contained references to both the tree of life and the tree of knowledge (Gospel of Philip section 75). However, most texts emphasized the importance of the tree of knowledge over



Fig. 1. The Tree of life from the book of Revelation c. 1892. “On either side of the river was there the tree of life which bare twelve manner of fruits” (Revelation 22:2) (Library of Congress, Prints & Photographs Division, reproduction number LC-DIG-pga-03638). *REPRODUCE IN COLOR.*

the tree of life, which is consistent with a religious tradition centered on personal knowledge of God [41]. However, Gnosticism was eventually denounced as heretical by the early Christian church and many Gnostic texts were destroyed [42].

Compared to other religions, sacred healing trees are not as common in Christian traditions, although there are a few notable exceptions. The Garden of Gethsamane, where Jesus went to pray after the Last Supper, is a major pilgrimage site. Eight olive trees (Fig. 2) are found there that date back at least 800–900 years, making them some of the oldest living broad-leaved trees in the world [43].

The Tree of the Virgin at Matarea is located just north of old Cairo. The tree is believed to be a resting place for the Virgin Mary on the flight to Egypt (Joseph had a dream that Herod would kill Jesus, so Mary and Joseph fled to Egypt with the infant). This journey is described in Matthew as well as several of the New Testament apocrypha. For example, in the Gospel of Pseudo-Matthew (chapter 20), Mary rested there and bathed Jesus in the water that sprang from the tree [44]. The original “Tree of the Virgin” fell in the 17th century, and has since been replaced multiple times [45]. The tree remains a pilgrimage site for Coptic Christians who believe the water has healing properties.

3.1.1. Islam

Islam is a monotheist Abrahamic religion that was founded by the prophet Muhammad (570–632 CE) in Mecca, which is located on the Arabian Peninsula in current day Saudi Arabia. After Muhammad’s death, in 632, there was a violent successional disagreement that led his followers to split into two groups. This sectarian divide (Sunni and Shia) persists to this day [46].

A number of sacred trees—representing health, wellbeing, and wisdom—appear in the Quran, the hadith (the saying of the prophet Mohammad), and Islamic literature inspired by the Quran. One of the most notable is the paradisiacal Tuba tree. Although Tuba isn’t mentioned as a tree by name in the Quran, but instead in the context of blessedness (Surah 13:29), the Tuba tree has become a major element in Islamic literature that has parallels with the paradisiacal tree of life described in Revelation. For example, the tree is described in detail in *The Ilkhanid Book of Ascension* [47] a thirteenth century book of literature inspired by Mohammad’s ascension to heaven. The tree is fastened to the leg of God’s throne, and it provides everything a paradise dweller might need (the tree of life described in Revelation 22:2 is also in the throne room of God). Of particular interest, given our focus on health and wellbeing, it bestows eternal life.

Another notable sacred tree is the lote tree of the farthest boundary (Surah 53:14) that marks the boundary of the seventh heaven. Muhammad encounters the lote tree (*Ziziphus lotus*) on his night journey and ascension to heaven. Even the Archangel Gabriel, who accompanied Mohammad, cannot pass the lote tree. Therefore, the tree can be seen as a metaphor for the limited human knowledge of the divine. The lote tree of the boundary has some similarities with the tree of knowledge in Genesis and with the tree of life in Proverbs, which is used as a metaphor for wisdom.

The lote tree is native to the Arabian Peninsula where Muhammad lived. It may also be the lotus tree of Greek mythology that Odysseus encounters on the island of the lotus eaters. The residents of the island eat the fruit of the lotus tree, which puts them in a deep, apathetic sleep.

Notably, the Quran also contains descriptions of a tree, Zaqqum, growing in hell (Surah 37:62–68). Zaqqum stands in stark contrast to the paradisiacal tree, Tuba. Indeed, rather than the fruit offering eternal life, eating the fruit will be like “a mixture of scalding water” (Surah 37:67).

A tree figures prominently in the Quranic account of Jesus’ birth. Mary goes into labor under a palm tree. In pain, she cries out to God, who causes a stream of water to come out of the tree and also tells her that if she shakes the trunk of the palm that ripe dates will fall (Fig. 3). Both the water and dates provide comfort to Mary. This account is reminiscent of the Greek myth of the birth of the twins Apollo and Artemis on the island Delos. Their mother found comfort during labor by leaning against the trunk of a palm tree [48].

Quranic trees have continued to influence Islamic literature, culture, and practices. For example, in 1887, Cheikh Ahmadou Bamba Mbacké, a Muslim mystic, was guided by God to a giant mbeb tree (*Sterculia setigera*) in rural Senegal. He was inspired to found a city,



Fig. 2. Mount of Olives and Gethsemane. Tree of Agony. Monk picking olives, c. 1920–1933. (Library of Congress, Prints & Photographs Division, reproduction number LC-DIG-matpc-02533). *REPRODUCE IN BLACK AND WHITE.*



Fig. 3. Maryam (Mary) at the palm tree with baby ʿĪsā (Jesus), from *Stories of the Prophets (Qīṣaṣ al-anbiyā)*, by Ishaq ibn Ibrahim al-Nishapuri, c. 1570 CBL Per 231.227 (© The Trustees of the Chester Beatty Library, Dublin). *REPRODUCE IN COLOR.*

and religious center, on that spot called Toubā after the heavenly Tuba tree [49].

In the short story “The doum tree of Wad Hamid,” the Sudanese writer Tayeb Salih, describes a doum tree (*Hyphaene thebaica*), which serves as a tomb for Wad Hamid, a former enslaved person who was considered to be one of God’s holy saints. The tree is revered for its healing properties; when the government tries to develop their village and interrupt their sacred practices related to the tree, the villagers revolt. Twenty villagers are arrested for protesting the new government’s development proposals, but ultimately the entire government is overthrown [50].

In summary, trees are widely used in Abrahamic religions to metaphorically represent health and wellbeing. In Christianity and Judaism, the tree of life is one of the most iconic metaphors. It appears in the first and last books of the Bible as well as the biblical apocrypha. In Islam, trees are also used as metaphors for health and wellbeing in the Quran, the hadith, and later Islamic literature inspired by the Quran. These trees include the Tuba tree, and the lote tree of the furthest boundary.

3.2. Religions of Northern India: Hinduism, Buddhism, and Sikhism

3.2.1. Hinduism

Hinduism arose approximately 4000 years ago among the Vedic people, who were nomads living in the Punjab region of Northern India. The Vedic people were culturally and ethnically distinct from the earlier Indus Valley Civilization that flourished further south between 3300 and 1300 BCE [51].

The earliest Hindu religious text is the Rig Veda, which consists of 1028 poems grouped into 10 mandalas. The Rig Veda was originally passed down orally but was written down (in Sanskrit) between 1700 and 1500 BCE. The Rig Veda was followed by three more Vedic texts (Yajur Veda, Samma Veda, and Atharva Veda) between 1200 and 900 BCE. Additional groups of Hindu texts were written later including the Upanishads, 800-200 BCE, and the Puranas, 350-1500 CE [51].

Trees are mentioned many times in Hindu texts (for example, see Bhagavad Gita 17.1-4; Katha Upanishad 6.4; Padma Purana 1.58.15-16; Skanda Purana 6.247.39; Maitri Upanishad 6.4), and tree worship is an important element of contemporary Hindu religious practice. The polytheism of popular Hinduism allows for the divine to be embodied in a wide range of physical objects [52]. This concept has important implications for the role of trees in Hinduism. Not only are there multiple gods in Hinduism, but these gods may be embodied by a wide range of physical objects. These objects can be manmade (murti-rupa), such as shrine, or may be a natural object (prakriti-rupa) such as tree. Therefore, to some degree, the choice of object to worship is a matter of personal preference as many objects could be the embodiment of a specific god or a unified divinity [52].

Puranic texts identify five species of trees (Panchavaiti) as being particularly sacred: peepal (*Ficus religiosa*), neem (*Azadirachta indica*), banyan (*Ficus benghalensis*), wood apple (*Egle marmelos*), and amla (*Phyllanthus emblica*). Of these five, the peepal, neem, and banyan are especially significant, with the peepal being the most important of all. Indeed, Vedic texts explicitly refer to the peepal tree as the tree of life or the tree of creation (jivana-taru) and the tree of knowledge (brahma-taru) [53]. In addition, all sacred trees are regarded as wish fulfilling (kulpa-vriksha), and specific trees are worshipped for long life and fertility [54]. Hindu temples are often built around a tree that was already an object of worship. Narayanan [54] describes that “almost every temple in South India dedicated to the gods Shiva or Vishnu, or to a manifestation of the goddess, has a sthala vriksha, a special tree regarded as sacred to that area. This ‘official’ tree is usually a grand old specimen ... [and] symbolizes all trees and reminds pilgrims that all trees are worthy of respect.”

Although certain gods are associated with particular trees—the peepal tree and Vishnu, for example—these associations are not rigid or exclusive. Indeed, sometimes different parts of a tree are associated with different gods.

The Somvati Amavasya Vrat is a story and ritual that describes how a woman, Gunavati, brings back her husband, Rudrasharma, from the dead. The ritual involves walking around a peepal tree 108 times under a new moon while reciting a mantra describing the beauty of the peepal tree [52].

Although the peepal is the most revered tree in Hinduism, neem and banyans are also important. The neem tree is widely viewed as being the embodiment of the goddess Devi, and neem trees are sometimes ceremonially married to a peepal tree (representing Vishnu). At temples that feature a “married” pair of trees, platforms are often built around the two trees. Walking around a pair of neem and peepal trees is thought to promote fertility [55].

Banyan trees are associated with long life and immortality due, at least in part, to their unusual structure. Aerial roots hang down from the tree’s branches, and new stems grow from these roots. In consequence, a single tree can cover a very large area, and a tree can flourish even after the original stem dies. For example, a banyan tree at the Royal Botanical Gardens in Kolkata covers 1.5 ha (Fig. 5).

Because of the banyan’s unusual structure, it is used as a symbol for immortality and renewal. For example, the Matsya Purana describes a great flood that will end all life on earth with the exception of one banyan tree called the Akshaya Vata. At the world’s end, and before its renewal, Vishnu takes the form of a baby lying on a leaf of the tree. Three existing banyan trees in India are claimed to be the Akshaya Vata, and all three are sites of pilgrimage. In particular, these trees are seen as auspicious places to perform the shraddha ritual, which honors and aids dead relatives [56]. Indeed, the ritual claims to bring immortality to the person performing the ritual as well as their ancestors.



Fig. 4. The Sacred Bodhi Tree by Ernst Haeckel, published in *The Open Court* by Paul Carus, 1887 (scan by the Internet Book Archive) **REPRODUCE IN BLACK AND WHITE.**

3.2.2. Buddhism

Buddhism began in the same region as Hinduism, and Buddhist philosophy was, to a significant degree, a reaction against the ritual violence that played a central role in Hinduism during Buddha's lifetime [51]. The horse sacrifice, for example, was an important element of the Rig Veda [57]. Interestingly, the non-violence of Buddhism influenced subsequent Hindu texts [58]. Jainism arose around the same time in Northern India, and, like Buddhism, it was also a "renouncer" religion that embraced asceticism over Hindu ritual violence [59].

Trees are a common symbol in Buddhist philosophy and played an important part in Buddha's life. For example, Buddha was born in a grove of sal trees (*Shorea robusta*); he first meditated under a jambu tree (*Syzygium samarangense*); he practiced asceticism under an amra tree (*Spondias pinnata*); he achieved enlightenment under a peepal tree, and later in life he did much of his teaching in Deer Park under a tree [52]. Finally, when approaching death, Buddha requested that his deathbed be placed between two sal trees, the same species of tree that had been present at his birth [60]. These examples show trees were associated with birth (fertility), knowledge, and ultimately death and rebirth.

Trees also feature prominently in Buddha's previous births, which are recounted in the Jataka stories. Indeed, Buddha appeared at least 30 times as a tree god. For example, in one Jataka story he took the form of a tree god, so that he could preach non-violence to all living things [61]. Trees also featured prominently in the enlightenment of Buddha's previous births. In "The Seven Buddhas" frieze at the Sanchi Stupa Buddhist complex in India, for example, four of the seven Buddhas depicted are shown under the trees where they achieved enlightenment. Again, this shows a connection between trees, knowledge, and enlightenment.

The peepal under which Buddha gained enlightenment is called the Maha-Bodhi tree (Fig. 4) and is a major pilgrimage site for Buddhists (it is located in Bodhi Gaya in northeastern India). The current Maha-Bodhi is not the original tree under which Buddha sat. Rather, it's a cutting from a tree called the Jaya Sri Maha Bodhi in Anuradhapura Sri Lanka [62]. This Jaya Sri Maha Bodhi was a cutting from the original Maha-Bodhi tree and was planted in 288 BCE when Buddhism was introduced into Sri Lanka by King Ashoka [63]. The Jaya Sri Maha Bodhi is thought to be the oldest human-planted tree in the world [55].

Although trees feature prominently in both Buddhism and Hinduism, there are important differences in how the two religions view trees. Buddhists revere peepal trees in general—and the Maha-Bodhi tree, in particular—but they do not worship them, as they view peepal trees as sacred but not the embodiment of a god as the Hindus do.

3.2.3. Sikhism

Sikhism is a monotheistic religion that began in the Punjab region of India in the 15th century CE. Sikhs follow the teachings of Guru Nanak (1469–1539) and nine subsequent gurus [64].

In Sikhism, tree metaphors are widely used to represent, among other things, the Divine, Guru Nanak (the founder of Sikhism), the human body, and immortality. In addition to these tree metaphors, there is an explicit tree of life in Sikh scripture, Guru Granth Sahib Ji. Trees are also used as a reminder of the ephemeral nature of life: "People fall in love with the shade of the tree and they lament when it disappears." (Rag Gauree, Guru Granth Sahib Ji).

In 2019, Sikhs launched an initiative to plant one million trees to mark the 550th anniversary of the birth of Guru Nanak [65].

In summary, in religions of Northern India, trees are frequently used as metaphors and symbols for health, wellbeing, and knowledge. Buddhist texts make frequent use of trees as symbols and metaphors for health, knowledge, and enlightenment. The Maha-Bodhi tree, under which Buddha gained enlightenment is an important pilgrimage site for Buddhists. Tree worship is an important part of Hindu practice, and many Hindu temples are built around a large tree. Peepal, neem, banyan, wood apple, and amla trees are especially revered by Hindus, with the peepal tree being the most important of all. In Sikhism, trees are also imbued with meanings related to immortality and the human body.



Fig. 5. The great banyan tree in the Kolkata Botanical Garden (photo by Mike Prince) REPRODUCE IN COLOR.

3.3. Norse mythology

In Norse mythology, a giant ash tree, Yggdrasil (Fig. 6), acts as the earth's axis and points towards the North Star. Its branches stretch out over heaven and earth, and its three great roots link together the realms of the gods, giants, and the dead [66]. It is, therefore an example of a cosmic tree [67].

Yggdrasil has the power of healing, and its fruits feed the gods and aid women in childbirth. This theme of fruit of sacred trees helping women in labor is also present in the Old Norse poem, *Flöjsvinnsmál* [68].

As Christian missionaries proselytized Northern European countries in the 10th and 11th centuries, Yggdrasil became partially incorporated into Christian traditions. For example, European stave churches, timber structures erected in the early days of Christianity, contain iconography inspired by Yggdrasil [66]. However, in other cases, attachment to specific trees was seen as a threat to Christianity, so the trees were destroyed. For example, in the 8th century, Saint Boniface cut down a large oak tree (called the Thunder Oak) that was dedicated to the god Thor in the village of Geismar in modern-day Germany [69]. Also in the 8th century, Charlemagne destroyed Irminsul, which was a tree trunk venerated by the local Saxon population. The destruction of the tree may have been partly an act of retribution for the destruction of a church by the Saxons [70]. These acts carried deep meanings because of Yggdrasil's important symbolism in Norse culture.

4. Discussion

4.1. Religious perspectives on human relationships with nature

Tree-health metaphors and symbols vary widely among religions reflecting fundamentally different beliefs about people's place in the natural world. For example, in Christianity, Judaism, and Islam, humans are seen as distinctly separate from the rest of creation, because they are the only part of the natural world with souls. This view has parallels in scientific disciplines that draw a sharp distinction between humans, who have consciousness, and the rest of the natural world. Descartes, for example, viewed animals as no more than complex machines [71].

In contrast, many non-Abrahamic religions are influenced by animism—the belief that other elements of the natural world have souls. These religious traditions do not view humans as being distinct from the rest of nature. Rather, humans, animals, and plants are interconnected and coequal parts of the natural world [72]. This perspective aligns with contemporary interdisciplinary frameworks that emphasize the interconnectivity of human and non-human actors and processes within intertwined social-ecological systems [73]. Divergent beliefs about people's place in the natural world across religious traditions encourage us, when developing theory and designing research, to consider how these diverse beliefs affect people's interactions with the natural world, and the outcomes of these practices for human health.

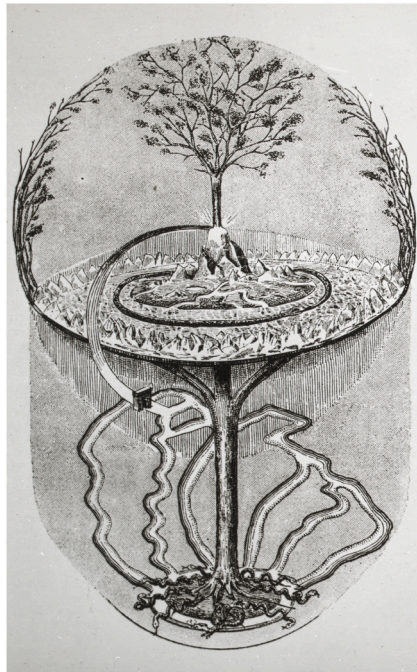


Fig. 6. The cosmic ash tree Yggdrasil, photograph of 19th century engraving from Finn Magnussen, *Eddalaren* (Library of Congress, Prints & Photographs Division, reproduction number LC-DIG-ppmsca-16360). **REPRODUCE IN BLACK AND WHITE.**

4.2. How tree-and-health metaphors can inform green-health theory

As shown in our review, symbolic and metaphoric connections between trees and human health are present across all major religions. Indeed, the historian of religions, Mircea Eliade, noted that “at the heart of the universe, there is always a tree—the tree of eternal life or knowledge.” [74]. Our review establishes the consistent focus on wellness, longevity, fertility, enlightenment, and power in tree-health metaphors (Table 1). The prevalence of these metaphors and symbols across time and space emphasizes that nature is central to what it means to be human and to be alive. By extension, something so fundamentally connected to our humanity cannot be eliminated or lost without cost.

A link between trees and health is also consistent with several important concepts in the psychology literature. For example, trees can inspire awe, and the experience of awe is associated with better physical and mental health [75]. In addition, exposure to the natural environment is associated with increases in self-transcendence [76], and self-transcendence is positively associated with health and well-being [77]. Finally, exposure to nature is associated with improved self-reflectance [78], and there is a well-established link between self-reflectance and improved mental health [79].

What does the widespread use of tree-and-health metaphors and symbols in the world’s religions mean for contemporary green-health research? We contend that they provide theoretical support for hypothesized links between the natural environment and health. It is not a coincidence that trees have been repeatedly used as a metaphoric lens through which to understand health and wellbeing. This does not mean that exposure to trees will, in all cases, improve health outcomes. However, the metaphoric and symbolic links between trees and health do provide a theoretical foundation from which it is reasonable to explore the health benefits of nature. And these metaphoric links increase the probability that any empirical associations that are discovered between the natural environment and health are causal.

We contend that the metaphoric and symbolic links between trees and health support rather than supersede existing theoretical models linking the natural environment and health. In particular, our review offers insights about why the experimental literature has shown that exposure to the natural environment can improve short-term markers of stress and self-reported measures of wellbeing [10]. For example, these outcomes could be related to the exercise of cultural practices and the relationships with trees those practices support. Furthermore, our review suggests similar potential insights into research that has identified plausible mechanisms linking exposure to the natural environment and improved health [80]. Future research that builds on this article’s insights could help develop, test and refine theory that underpins green-health research, and direct the iterative study of religious traditions to inform those theoretical foundations. This review is intended as a starting point to help encourage such theoretical development through green-health study design.

In summary, we contend that by looking beyond the confines of science, sacred-tree metaphors broaden the theoretical foundation of green-health research. They do this by demonstrating that trees are a universal symbol and metaphor for health and well-being. It is no accident that the world’s religions repeatedly reach for trees as a way of representing health. In consequence, contemporary green-health research can be both bolstered and guided by the metaphor of the life-giving tree.

4.3. How tree-and-health metaphors can inform green-health study design

In addition to strengthening the theoretical underpinnings of green-health research, our review provides guidance on how to design and implement green-health studies. The first lesson is that specifics matter. As summarized in Table 1, the trees featured are seldom simply generic trees and rather typically are specific species. Peepal trees are sacred to Hindus, for example. In extreme cases, individual trees can have special significance: the Maha-Bodhi tree is revered by Buddhists, for example. More generally, trees are often revered for their size and age [81]. For example, in South India most temples dedicated to Shiva or Vishnu are centered around a large tree (sthala vriksha). The cosmic ash tree Yggdrasil was large, as it was the axis on which the world turned (Fig. 6). Finally, studies have shown that across cultures people prefer tall trees with large spreading crowns [82,83]. It’s possible that different tree structures inspire different human emotions. Tall trees may be especially good at provoking awe, whereas trees with large, spreading crowns may provide a sense of safety, but the linkage of tree structure and specific human emotions awaits confirmation by future research.

Unfortunately, most extant studies of trees and health use total tree cover as an exposure metric [84,85]. This approach implicitly assumes that tree size doesn’t matter. If five small trees have the same crown area as one large tree, then it is assumed that the five small trees will have the same impact on health as the one large tree. However, given that large trees are so often used to metaphorically or symbolically link trees and health, our review suggests that this assumption is likely not sound. An alternative approach would be to divide trees into size categories and then calculate total canopy cover in each size category. This approach would reveal whether the biggest trees have a disproportionately large impact on health.

Total tree canopy also does not account for tree species. Given that many trees-and-health metaphors are species specific, we suggest that future studies begin by identifying tree species that have been metaphorically or symbolically linked with the health outcome under study. Scientists could then create separate exposure metrics for these tree species.

In summary, at a minimum, studies of the health impact of trees and plants should include information on vegetation species and size, as these are likely part of the mechanisms through which trees and plants influence health. However, the most commonly used metrics in green-health studies aren’t able to do this. For example, a 2018 review and metaanalysis of green-health research included 113 observational studies [86], 26 of which used the normalized difference vegetation index (NDVI) as an exposure metric, and 39 used land-use data. NDVI is an index of photosynthetic activity that is typically derived from satellite data. NDVI cannot distinguish between different species of vegetation. Indeed, a single NDVI acquisition cannot even distinguish between deciduous and evergreen trees [87]. In addition, NDVI cannot distinguish between a single large tree and a group of small trees with similar photosynthetic

activity. Finally, single NDVI acquisitions tell us nothing about vegetation age.

In common with NDVI, most sources of land-use data provide little information on vegetation species, age, and size. For example, the National Land Cover Database, the most commonly used land-cover data in the US, categorizes all forest cover as deciduous, evergreen, or mixed. In addition, land-cover data do not provide information on size of individual trees. Furthermore, the quality of the natural environment may influence the effectiveness of the “dose”. In a study that objectively assessed the quantity as well as the quality of exposure to greenspace, quality explained significant variability in health after accounting for quantity [88]. This suggests that future studies could fruitfully focus on developing and utilizing more detailed exposure metrics linked to the hypothesized conceptual model. In part, this could be achieved using higher resolution remotely-sensed data such as LiDAR [89], which is a remote-sensing technique that uses a scanning laser to create high-resolution, three-dimensional images of target landscapes. However, remotely sensed data have their limits, so primary-data collection may be necessary. This would increase the cost of studies and may limit sample sizes. Nonetheless, our review of religious tree metaphors and symbols suggests that more detailed exposure data may provide valuable insights into the health benefits of exposure to nature.

An additional lesson that we can draw from our review is that the health benefits of exposure to nature depend on the attributes of the natural scene and the characteristics of the person being exposed to the scene. For example, if a person is from a culture or religion that venerates a species of tree as sacred, then they will likely have a different response to that tree than someone who lacks those cultural or religious ties. In other words, the health benefits of generic tree planting may be quite different to the health benefits of planting or retaining trees that have special cultural or religious significance for a particular population. Similarly, a person’s age may also mediate their experience with trees. Somebody who has lived in a house next to a tree for 50 years, would likely experience more negative health consequences, if that tree were to die, compared to someone who just moved in the year prior. Therefore, studies should, where possible, collect detailed data on study participants, and evaluate interactions between attributes of the natural exposure and attributes of participants. These could include individual-level data—race, or religious affiliation, for example—or population-level data describing customary practices. A handful of green-health studies have shown that the protective effect of greenness is greater for people with lower socioeconomic status [84,90]; however, these studies didn’t examine the interaction between socioeconomic status and specific attributes of the green exposure. One obvious interaction would be between vegetation species and religious practices, but vegetation species may interact with individual or population-level characteristics in other ways. For example, natural scenes with greater species diversity may promote immune maturation, and this effect may vary depending on an individual’s socioeconomic stressors.

Because metaphors influence the way we understand and interact with the world, trees that are used as religious metaphors or symbols for health may provide additional health benefits to a religiously observant person compared to a non-believer. However, religious belief is not a prerequisite for deriving health benefits from trees, because the fundamental relationship between trees and human well-being predates any particular religious belief or practice. However, the specifics of these ancient metaphors and symbols provide invaluable insight into how the natural environment can be used to improve our health even in modern settings.

To show how these lessons could be applied in practice, let us consider the design of a longitudinal study into the relationship between the natural environment and human mortality rates at the Census tract level. A handful of studies have looked at this question [91], and all but one measured exposure to the natural environment using NDVI. However, NDVI allows no context for metaphoric or symbolic links to health. It is simply a measure of photosynthetic activity. Our review suggests that it would be better to measure people’s exposure to trees rather than a broad greenness index. However, simply measuring tree canopy may not be sufficient. Our review suggests that the species and size of trees that a person is exposed to is also important. Therefore, we would categorize every tree in the sample as either small, medium, or large. The specific cut offs between each category would depend on the size distribution of trees in the sample. In addition, each tree species would be assigned to one of the following three categories: species has been metaphorically linked to longevity, species has been metaphorically linked to improvements in any health outcome, species has no metaphoric links with health. Combining the three size categories and the three species categories would give a total of nine size-species categories (large trees that have been metaphorically linked to longevity, for example). Next, we would measure the total crown area of each size-species category in each Census tract. Regression analysis would then be used to find the association between mortality rate and the nine size-species variables.

Our review suggests that people of different religious and cultural backgrounds may respond differently to trees. Therefore, the regression analysis would also include interaction terms between tree variables and variables describing religious affiliation in each Census tract. This type of interaction brings us back to Nancy Krieger’s eco-social model of disease that we discussed in the introduction, that stresses the interaction of the social and ecological determinants of health and likens them to a crossroads between the tree of life and the scaffolding of society.

5. Conclusion

In the introduction to this paper, we ask two questions. First, do sacred tree symbols and metaphors provide context and support for empirical studies of the public-health benefits of nature? Second, can these symbols and metaphors provide specific guidance on the design of green-health research? Our review suggests that the widespread presence of sacred tree symbols and metaphors in the world’s religions show that contact with nature is fundamental to the human condition, and absent this contact, our health and wellbeing will suffer. Therefore, sacred tree symbols and metaphors contribute to the theoretical foundation for the empirical study of the relationship between exposure to the natural environment and health. Our review also provides specific guidance on how green-health studies should be designed. In particular, the natural environment is not a homogenous green monolith. Rather, the health benefits experienced from exposure to nature will depend upon the specifics of the natural scene that a person is exposed to. In

addition, the health benefits of exposure to a natural scene are not solely a function of that scene's physical attributes. Rather, they are a function of the interaction between that natural scene and the individual characteristics of the person being exposed.

Data availability statement

No data was used for the research described in the article.

CRedit authorship contribution statement

Geoffrey H. Donovan: Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Investigation, Conceptualization. **Monika Derrien:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Kendra Wendel:** Writing – review & editing, Writing – original draft, Methodology, Investigation. **Yvonne L. Michael:** Writing – review & editing, Writing – original draft, Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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