

Soil, soul, spirituality, and stewardship

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Soil, the most basic among all natural resources and essential to provisioning of numerous ecosystem services (ESs) that are critical for human well-being and nature conservancy, is prone to degradation because of land misuse and soil mismanagement. The ever-increasing impact of anthropogenic activities has raised environmental concerns since the 1960s (Carson 1962; Peterson 2001; Plumwood 2001; Kureethadam 2017; Moore 2017). However, threats to the environment are not only the anthropogenic impacts, but also a fundamental change in the relationship between humans and the terrestrial system with far-reaching and unintentional impacts on natural and social processes (Moyses and Soares 2019), along with exacerbated risks of soil degradation (figure 1).

It is argued that the finite soil resource is prone to risks of anthropogenic degradation, which are aggravated by the current and projected climate change (IPCC 2019). Human use directly affects 70% of the global ice-free land surface estimated at $1.31 \times 10^8 \text{ km}^2$ ($5.057 \times 10^7 \text{ mi}^2$). About 30% of ice-free land or $3.93 \times 10^7 \text{ km}^2$ ($1.517 \times 10^7 \text{ mi}^2$) may be affected by human-induced degradation and is undermining the well-being of two-fifths of humanity (~3.2 billion people), which may trigger mass human migration and increasing conflicts (IPCC 2019; IPBES 2018). Among principal causes of soil degradation are rapid expansion and unsustainable management of agroecosystems (e.g., crop lands and grazing lands).

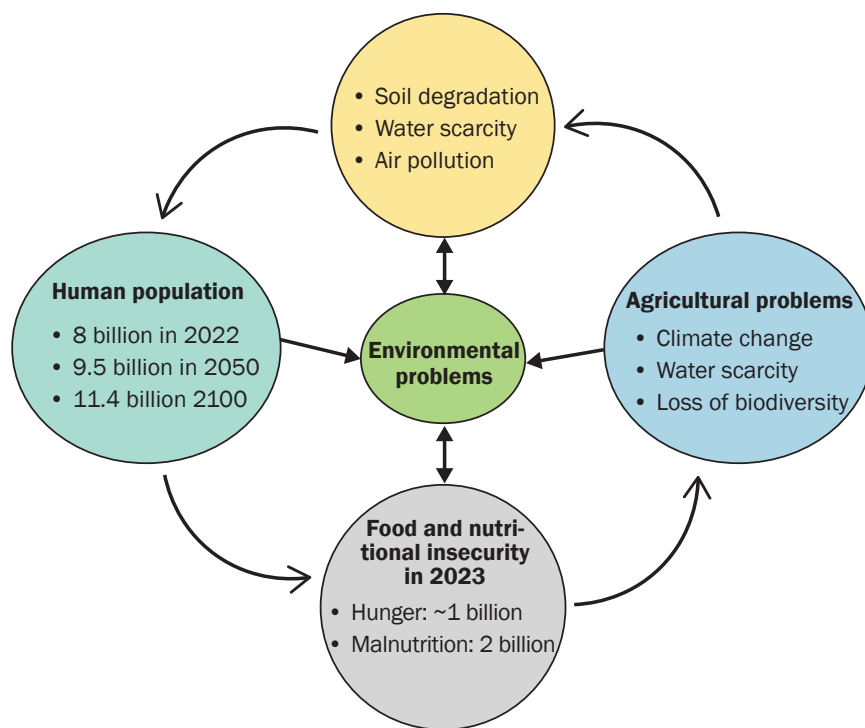
War extends beyond the confrontation between nations or communities—it

decimates an often-overlooked third party, nature, encompassing soil, vegetation, and wildlife. Modern warfare, involving heavy machinery and missiles containing heavy metals and other explosive devices, has severe adverse effects on soil properties and processes. Solokha et al. (2023) reported that areas affected by the Russian-Ukrainian war showed increased contents of heavy metals (manganese [Mn], iron [Fe], cobalt [Co], copper [Cu], cadmium [Cd], chromium [Cr], lead [Pb], and nickel [Ni]) in soils of the shelled areas compared to those of the nonshelled. Solokha and colleagues observed that shelling increased soil pollution, and intense fighting reduced greenness of the vegetation. Restoration of the war-polluted soil and healing of nature occur at decadal or generational scale. The toll on nature is staggering, and yet, the silent suffering of the environment remains largely ignored, deprived of its rightful acknowledgment and consideration.

Because soil is a major reservoir of fresh water, its degradation also leads to water scarcity, which is exacerbated in the global south. The drought/flood syndrome affected more than 3 billion people and caused economic damages of more than US\$780 billion worldwide over the two decades from 2001 to 2020 (UNESCO 2023). Zhang et al. (2023) reported that the Southern Hemisphere has dominated the declining trend in global water availability between 2001 and 2020, including in South America, southwestern Africa, and northwestern Australia. Soil degradation and human survival are codependent and inextricably connected. Recognizing this interdependence emphasizes the urgency of adopting sustainable land management practices as an imperative for safeguarding human well-being.

Figure 1

Links between human population, environmental issues, food insecurity, and agricultural problems.



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Thus, in addition to the focus on biophysical processes that affect soil health and its dynamics, attention must also be given to the soil-human relationship that leads to the care and stewardship of this finite and fragile but precious resource (Peterson 2016; Pigott 2021). More and more attention must be given to spiritual practices associated with biodynamics and site-specific practices, which pay attention to soil biota through both spirituality and scientific considerations (Steiner 1924). Religious beliefs and use of approaches that include spirituality may enable humanity to process their deep emotions and existential questions related to anthropogenic climate change (Pihkala 2018). Such an approach would also address eco-anxiety, which refers to descriptions of difficult emotions and mental states arising from environmental factors and human understanding about them (Pihkala 2018). Therefore, the objective of this article is to discuss the spiritual aspects in the context of the need for understanding the human-soil relationship to promote stewardship of the most essential among natural resources.

SOIL, SPIRITUALITY, AND STEWARDSHIP

The growing and complex problem of soil degradation, with its impact on human well-being and nature conservancy, may need more than just the biophysical or technological solutions. A broader approach may be necessary to address this issue. However, spiritual knowledge and practices do not comfortably fit with technoscientific and productivity accounts of soil health and its management (Pigott 2021). Despite the growing realization about the importance of spiritual elements to sustainable management of finite and fragile soil resources, there is a tendency to neglect discussion of these aspects. This article considers only the largest, Western thought-influencing religions, and in so doing limits its focus to Abrahamic and Vedic religions. Buddhism concepts may be similar to those of Vedic religions; however, North and South American Indigenous beliefs and those of African and other traditional cultures are not discussed.

The common phrase “from dust to dust” in the Biblical book of Genesis is respected by believers of Judaism, Christi-

anity, and Islam. This phrase highlights the basic concept that human beings originate from and return to the soil. Indeed, the idea of stewardship of soil is the common theme among all major world religions (Lal 2013). As a spiritual dimension of sustainable agriculture, soil is considered as a sacred resource (Van Wieren 2016). Thus, religion and religious values can also contribute to responsible stewardship of land in general (Hitzhusen et al. 2013) and of soil in particular (Lal 2013). In religious terms, stewardship means “caring for God’s creation.” In other words, civil title to ownership of a land does not mean that it can be manipulated as desired by the owner without any consideration beyond one’s own interests. Simply put, there is no such thing as absolute ownership of land because it belongs to God and no one else. However, ownership of land implies responsibility for judicious use and prudent care so that its ability to generate ESs is sustained in perpetuity. Stewardship also implies that ESs provisioned by soil are God’s gift for present and future generations, and that soil must be handed over to the future generation better than it was received by the present owner from previous generations (Lal 2013). Therefore, demands of the present generation must be appropriately adjusted so that needs for the coming generation are not jeopardized through land misuse and soil mismanagement.

These beliefs of Judeo-Christian ethics (Leopold 1987; Gore 1993; Wunderlich 2004) are in accord with Vedic scriptures, which state *vasudhaiva kutumbakam* or that “world is one family” (Lal 2022). These concepts imply that soil health, and its capacity to generate ESs, must be protected, restored, and enhanced (Hitzhusen et al. 2013).

SPIRITUAL AND ENVIRONMENTAL CRISIS

Environmental crisis is represented by the extent and severity of soil degradation affecting one-third of the planetary land areas (IPCC 2019), decline in quality and renewability of water (Gleick 1998), accelerated global warming (IPCC 2022), and extinction of species (Raven and Wagner 2021). The environmental crisis, widely identified as a spiritual crisis (Gore 1993; Thompson 2017; Wirzba 2023), is a long-term threat to planetary health and

nature’s well-being because of dualism between humanity and nature (White 1967). Indeed, the current environmental crisis is the canary in the mineshaft of modern society (Coates 2003).

If soil and environmental degradation are spiritual crises, the problems cannot be solved only by scientific, technological, economic, or political approaches (Ide et al. 2020). Spiritual and religious approaches are also critical to effectively addressing the basic problem that has plagued the planet and thus humanity since the transformation of natural landscapes to agroecosystems and that has been exacerbated since the onset of Industrial Revolution circa 1750. The problem has been aggravated by prioritizing human needs over nature rather than living in harmony and symbiosis with nature. Living in symbiosis with nature also implies that scientific and technological innovations are even more important and essential than ever before because Earth’s finite resources (e.g., soil, biodiversity, air quality, water renewability) must be protected, restored, and sustained forever.

In *Laudato Si’*, Pope Francis (2015) emphasized the importance of integral ecology and emphasized the need of seeking comprehensive solutions based on interactions within natural systems themselves and with social systems. Indeed, Pope Francis urged that humanity is not faced with two crises (environmental and social) but only with one complex but also harmonious crisis, which comprises both strongly interacting components. Therefore, any effective strategy must involve an integrated approach to combating poverty, restoring dignity, and protecting nature (Pope Francis 2015). It is thus futile to have a long list of problems, each with a separate list of solutions. Herein also lies the basis of Schwartz’s (2020) argument that “solar panels, electric cars and carbon taxes get nowhere close to addressing the underlying causes of our complex social-environmental challenges.” Adopting nature-friendly innovations is a step in the right direction only if social-environmental challenges are not ignored. It is not a question of either/or; both approaches are essential to addressing the complex issue. Indeed, humanity is in dire need of innovative strategies that are simultane-

ously holistic, systemic, comprehensive, and above all, nature-friendly.

Thus, there is a need to “emphasize religious virtues that favor sustainable resource use and key developments that have prompted fruitful dialogue between ecologists and religious believers” (Hitzhusen and Tucker 2013). Further, alliance between scientists and spiritual leaders may strengthen cooperation among them to promote stewardship of soil and other finite natural resources (Hitzhusen et al. 2013), including fresh water and biodiversity.

SOIL AS LIVING ENTITY

Rather than an inert material subject to human use, there is a growing understanding of the soil as a living entity. This increases human-soil affections through development of a sense of shared aliveness (Bellacasa 2019). As a living entity, soil has rights (Lal 2019) and intrinsic value such as that for sequestration of atmospheric carbon (C) (Lal 2013). Therefore, humans, as stewards of soils, have responsibilities to protect and restore soil’s intrinsic value both for human well-being and nature conservancy (Minami 2020a, 2020b). As is the case of all living beings, soil also breathes and uses air and water for performing its functions (Lovelock 1979; Miller 1995), which are critical to both humanity and nature. Soil is a habitat for a large proportion of terrestrial biodiversity, and there are more species in soil than are aboveground. Similar to the Clean Air Act (USEPA 2023b) and the Clean Water Act (USEPA 2023a), there is a strong need for a Soil Health Act (Lal 2021). Since soil biodiversity is critical for soil health, soil protection laws should account for global soil connections to protect and enhance soil biodiversity (Van Der Putten et al. 2023). Because soils are animated and enlivened, there is a growing need for earthly connectedness, which animates and reconnects the material world with the sense of looking at the soil beyond only human needs (Bellacasa 2019).

SOIL AND SOUL

A healthy soil is essential to nourishing all terrestrial life, and the risks of soil degradation are increasing both due to intensification of agro-ecosystems and climate

change. Therefore, the integration of spiritual ideas with those of scientific concepts is needed now more than ever before. It is precisely in this context that connecting soil to soul is essential to achieving this connection that will ultimately lead to mutual enhancement in both human well-being and nature conservancy. Clay is the soul of the soil, just as the organic matter content is the heart of soil health (figure 2). In addition to understanding the interaction between clay and the humic substances, understanding of the soil and soul relationship is critical to sustainable management of soil and using soil as a tool to address environmental issues such as climate change and water quality and renewability, as discussed below.

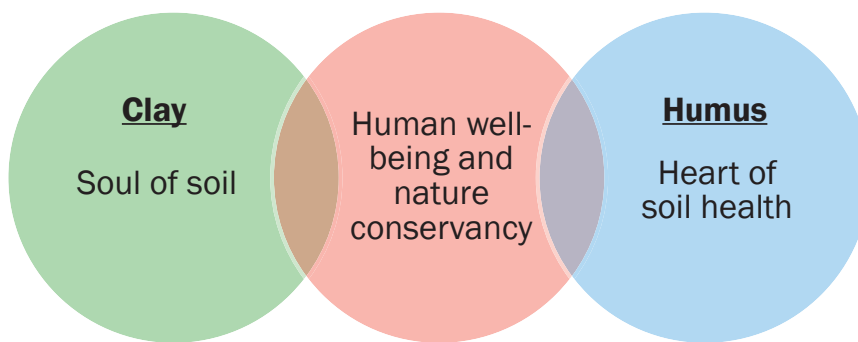
Soil Carbon Sequestration and Climate Change. The importance and awareness about the need for sequestering of atmospheric C in soil can be greatly enhanced by the understanding that clay is the soul and soil organic carbon (SOC) is the heart of soil health. Therefore, increasing the total soil C stock, comprising of both SOC and soil inorganic carbon (SIC), would strengthen both the soul and the circulatory system (elemental cycling through SOC dynamics), or heart, of soil health. Thus, sequestration of soil C comprising of an increase in SOC stock through creation of positive soil/ecosystem C budgets by input of biomass C in soil, and that of secondary carbonates through pedological

processes (Monger et al. 2015), are critical to enhancing soil physical health (i.e., structure). Formation of stable aggregates, which enhances pore continuity and stability, are essential to maintaining the circulatory systems comprising of gaseous diffusion, translocation of water and nutrients through a deep and a prolific root system. Therefore, the stewardship of soil as soul and sequestration of soil C are important, natural, and cost-effective strategies to adoption and mitigation of climate change (Monger et al. 2015; Lal et al. 2000; Lal 2023).

Water Quality and Renewability. Water scarcity and eutrophication are being aggravated by anthropogenic activities and climate change. Once again, Islam states clearly “do not waste water even if you live on a running river” (Lal 2008). Water can be conserved in the soil by reducing losses through evaporation and surface runoff. Improvements in SOC content, the heart of soil health, can enhance soil’s capacity to denature and filter pollutants. Indeed, water quality is more improved when it passes through the soil than over the soil surface. Risks of pedological and agronomic droughts can be reduced by increasing the green water (plant available water) storage in the root zone and not wasting the finite and precious freshwater resources as is highlighted in numerous scriptures.

Sustainable Development Goals of the United Nations Agenda 2030. Sustainable Development Goals (SDG) of the

Figure 2
Connecting humans with the soul and heart of soil health.



United Nations are not on track to be accomplished by 2030 (Lal et al. 2021). Therefore, the application of the ideas of stewardship may be important to put the SDGs on track for accomplishments by 2030. This is especially true for SDG #2 (zero hunger), SDG #3 (good health and wellbeing), SDG #6 (clean water and sanitation), SDG #7 (affordable and clean energy), SDG #13 (climate action), SDG #15 (life on land), and SDG #16 (peace, justice, and strong institutions). Stewardship and spirituality cut across these and other SDGs.

Soil and Biodiversity. Because soil is a habitat for a large proportion of terrestrial biodiversity, sustainable management of soil health is essential to enhancing and strengthening both aboveground and belowground biodiversity. The activity and species diversity of soil biota have an impact on soil health and creation of disease-suppressive soils, thus also affecting human health and well-being (Lal 2020). The One Health concept of the World Health Organization is based on the premise that “health of soil, plants, animals, people, environment, and planetary processes is one and indivisible.”

CONCLUSIONS AND RECOMMENDATIONS

Soil, the most basic among all natural resources and essential to human well-being and nature conservancy, is vulnerable to degradation, depletion, and pollution by anthropogenic activities. Despite advances in scientific understanding of processes and determinants of soil degradation processes, technological approaches have not been adequate to protecting and restoring soil health and its life support functions. Thus, more attention must be given to spiritual practices associated with biodynamics and site-specific practices, which pay attention to soil biota through both spirituality and scientific considerations. It is important to combine technical approaches with spiritual dimensions to protect, restore, and sustain soil health. Because soil degradation is also an ethical crisis, spiritual and religious approaches must be combined with scientific innovations to effectively address soil degradation, the most complex and challenging issue of the twenty-first century.

The integration of spiritual values from the world's major religions underscores the shared responsibility of humanity to care for the soil as a sacred resource. This article has only considered the big, Western thought-influencing religions, and is limited to Abrahamic and Vedic religions. Therefore, additional research is needed on other belief systems and on identifying ideas for successful spiritual approaches to environmental issues.

There is also a need for discussions on overlap and sharing of ideas among scientists and spiritual leaders, on how the conservation community can encourage or take the lead on these dialogues, and on identifying concrete outcomes that would make a difference for soil conservation and environmental sustainability.

World religions and spiritual beliefs are undergoing drastic changes, which may have strong effects on spiritual values. For example, the practice of Buddhism is in decline, Islam is on the rise, and the global number of nonbelievers is also increasing. At the same time, there are some emerging movements with clear positive impacts on stewardship (e.g., Save Soil by Sadhguru, founder and head of the Isha Foundation). It is important to know how these changes could affect stewardship values with regards to soil.

As the environmental crisis is also a spiritual crisis, an integrated approach that combines scientific advancements with spiritual and religious perspectives is critical. The call for a Soil Health Act reinforces the idea that soil, as a living entity, deserves legal protection. Without a voice of its own, stewardship and spirituality can play a critical role by advocating on behalf of soil and nature whose healing (restoration) will occur on a decadal or generational scale. As we confront these complex challenges, this comprehensive approach, encompassing technical solutions and spiritual dimensions, becomes imperative for safeguarding the well-being of both humans and nature.

REFERENCES

Bellacasa, de la, M.P. 2019. Re-animating soils: Transforming human-soil affections through science, culture, and community. *Sociological Review* 67(2):391-407.

- Carson, R. 1962. *Silent Spring*. Boston: Houghton Mifflin.
<https://www.rachelcarson.org/silent-spring>.
- Coates, J. 2003. Exploring the roots of the environmental crisis: Opportunity for social transformation. *Social Work and Ecology* 4(1).
- Francis. 2015. *Laudato Si'*. Encyclical letter of the Holy Father Francis on care for our common home. https://www.vatican.va/content/francesco/en/encyclicals/documents/papa-francesco_20150524_enciclica-laudato-si.html.
- Gleick, P.H. 1998. Water in crisis: paths to sustainable water use. *Ecological Applications* 8(3):571-579.
- Gore, A. 1993. *Earth in the Balance: Ecology and Human Spirit*. New York: Plume.
- Hitzhusen, G.E., G.W. Fick, and R.H. Moore. 2013. Theological and religious approaches to soil stewardship. In *Principles of Sustainable Soil Management in Agroecosystems*, Advances in Soil Science, eds. R. Lal and B.A. Stewart, 285-305. Boca Raton, FL: Taylor and Francis.
- Hitzhusen, G.E., and M.E. Tucker. 2013. The potential of religion for Earth's stewardship. *Frontiers in Ecology and Environment* 11(7):368-376.
- Ide, T., C. Frohlich, and J.F. Donges. 2020. The economic, political, and social implications of environmental crisis. *Bulletin of the American Meteorological Society* 101(3):E364-E367. <https://doi.org/10.1175/BAMS-D-19-0257.1>.
- IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services). 2018. *The IPBES Assessment Report on Land Degradation and Restoration*, eds. L. Montanarella, R. Scholes, and A. Brainich. Bonn, Germany: IPBES.
- IPCC (Intergovernmental Panel on Climate Change). 2019. *Climate Change and Land Use: A special report on climate change, desertification, land degradation, sustainable land management, food security and greenhouse gas flux in terrestrial processes*. Geneva, Switzerland: IPCC.
- IPCC. 2022. *Climate Change 2022, Adaptation and Vulnerability, Summary for Policy Makers*. Geneva, Switzerland: World Meteorological Organization.
- Kureethadam, J.I. 2017. *The Philosophical Roots of the Ecological Crisis: Descartes and the Modern World View*. Newcastle upon Tyne: Cambridge Scholars Publishing.
- Lal, R. 2013. Soil and Sanskriti. *Journal of the Indian Society of Soil Science* 61(4):267-274.
- Lal, R. 2019. Rights-of-Soil. *Journal of Soil Water Conservation* 74(4):81A-86A. <https://doi.org/10.2489/jswc.74.4.81A>.
- Lal, R., ed. 2020. *The Soil-Human Health Nexus*. Boca Raton: CRC Press.
- Lal, R. 2021. Feeding the world and returning half of the agricultural land back to nature. *Journal of Soil and Water Conservation* 76(4):75A-78A. <https://doi.org/10.2489/jswc.2021.0607A>.
- Lal, R. 2022. Sustaining soil for advancing peace: World is one family. *Journal of Soil and Water Conserva-*

- tion 77(3):43A-47A. <https://doi.org/10.2489/jswc.2022.0411A>.
- Lal, R. 2023. Farming systems to return land for nature: It's all about soil health and re-carbonization of the terrestrial biosphere. *Farming Systems* 1(1):100002. doi:10.1016/j.farmsys.2023.100002.
- Lal, R., J. Bouma, E. Brevik, I. Dawson, D.J. Field, B. Glazer, R. Hatano, et al. 2021. Soils and Sustainable Development Goals of the United Nations: An International Union of Soil Sciences perspective. *Geoderma Regional* 25(June 2021):e00398.
- Lal, R., J.M. Kimble, and B.A. Stewart, eds. 2000. *Global Climate Change and Pedogenic Carbonates*. Boca Raton, FL: Lewis/CRC Press.
- Leopold, A. 1987. *Sand County Almanac and Sketches Here and There*. New York: Oxford University Press.
- Lovelock, J.E. 1979. *Gaia: A New Look at Life on Earth*. New York: Oxford University Press.
- Miller, J.G. 1995. *Living Systems*. Niwot, CO: University Press of Colorado.
- Minami, K. 2020a. Seeking mental and physical health through integrated science between agriculture and medicine: Necessity and trends in Japan and Overseas. *Research Reports MOA Health Science Foundation* 23:15-28.
- Minami, K. 2020b. Soil is a living substance. *Soil Science and Plant Nutrition* 67(1):26-30. <https://doi.org/10.1080/00380768.2020.1827939>.
- Monger, C., R.A. Kraimer, S. Khresat, D.R. Cole, X. Wang, and J. Wang. 2015. Sequestration of inorganic carbon in soil and groundwater. *Geology* 43(5):375-378. <https://doi.org/10.1130/G36449.1>.
- Moore, J.W. 2017. The Capitalocene, Part I: On the nature and origins of our ecological crisis. *The Journal of Peasant Studies* 44(3):594-630. <https://doi.org/10.1080/03066150.2016.1235036>.
- Moyes, S.J., and R.C. Soares. 2019. Planetary health in the Anthropocene. *Health Promotion International* 34, Supplement 1:128-136. <https://doi.org/10.1093/heapro/daz012>.
- Peterson, A. 2001. *Being Human: Ethics, Environment and Our Place in the World*. Berkeley: University of California Press.
- Peterson, A. 2016. Religion, local community, and sustainable agriculture. In *Religion and Sustainable Agriculture: World Spiritual Traditions and Food Ethics*, eds. V. Shiva, Y. Deutscher et al., 233-249. Lexington, KY: University of Kentucky.
- Pigott, A. 2021. Hocus pocus? Spirituality and soil care in biodynamic agriculture. *Environment and Planning E: Nature and Space* 4(4):1665-1686. <https://doi.org/10.1177/2514848620970924>.
- Pihkala, P. 2018. Eco-anxiety, tragedy, and hope: Psychological and spiritual dimensions of climate change. *Zygon: Journal of Religion and Science* 53:545-569. <https://doi.org/10.1111/zygo.12407>.
- Plumwood, V. 2001. *Environmental Culture: The ecological crisis of reason*. London: Routledge.
- Raven, P.H., and D.L. Wagner. 2021. Agricultural intensification and climate change are rapidly decreasing insect biodiversity. *Proceedings of the National Academy of Sciences* 118(2):e2002548117. <https://doi.org/10.1073/pnas.2002548117>.
- Schwartz, A.W. 2020. *Philosophical Roots of the Ecological Crisis: The process-relational worldview and integral ecology*. Washington, DC: Georgetown University, Berkley Center for Religion, Peace and World Affairs. <https://berkeleycenter.georgetown.edu/responses/philosophical-roots-of-the-ecological-crisis-the-process-relational-worldview-and-integral-ecology>.
- Solokha, M., P. Pereira, L. Symochko, N. Vynokurova, O. Demyanyuk, K. Sementsova, M. Inacio, and D. Barcelo. 2023. Russian-Ukrainian war impacts on the environment: Evidence from the field on soil properties and remote sensing. *Science of the Total Environment* 902(2023):166122.
- Steiner, R. 1924. To all members: The meeting at Koberwitz and Breslau. *Anthropological Movement* 1:9-11.
- Thompson, P. 2017. *The Spirit of Soil: Agriculture and Environmental Ethics*, 2nd Edition. London: Routledge. <https://doi.org/10.4324/9781315559971>.
- UNESCO (United Nations Educational, Scientific, and Cultural Organization). 2023. *The United Nations World Water Development Report 2023: Partnerships and Cooperation for Water*. Paris, France: UNESCO World Water Assessment Programme.
- USEPA (US Environmental Protection Agency). 2023a. *History of the Clean Water Act*. <https://www.epa.gov/laws-regulations/history-clean-water-act>.
- USEPA. 2023b. *Summary of the Clean Air Act*. <https://www.epa.gov/laws-regulations/summary-clean-air-act>.
- Van Der Putten, W.M.H., R.D. Bardgett, M. Farfan, L. Montanarella, J. Six, and D.M. Wall. 2023. Soil biodiversity needs policy without borders. *Science* 379:32-34. doi: 10.1126/science.abn7248.
- Van Wieren, G. 2016. Soil as sacred religion: The spiritual dimensions of sustainable agriculture. In *Food Futures: Ethics, Science and Culture*, eds. I.A.S. Olsson, S.M. Araujo, and M.F.Vieira, 225-230. Wageningen: Wageningen Academic Publishers. https://doi.org/10.3920/978-90-8686-834-6_34.
- White, I. 1967. The historical roots of our ecological crisis. *Science* 155(3767):1203-1207.
- Wirzba, N. 2023. *The soil of spirituality: What agrarians can teach us about the life of faith*. LSRI Research Paper 2. Oxford: University of Oxford, Laudato Si' Research Institute.
- Wunderlich, G. 2004. Evolution of the stewardship idea in American country life. *Journal of Agricultural and Environmental Ethics* 17:77-93.
- Zhang, Y., C. Li, F.H.S. Chiew, D.A. Post, X. Zhang, N. Ma, J. Tian, et al. 2023. Southern Hemisphere dominates recent decline in water availability. *Science* 382:579-594.