Sustainable Development through Soil Health: An Indonesian Perspective in the Era of Society 5.0

Peni Agustijanto[*,1,2], Norbertus Citra Irawan[3], Haryuni[3]

1 Cocoa-Coffee Program Director Rikolto Southeast Asia, Denpasar, Bali, Indonesia
2 Cocoa Program Manager Rikolto Indonesia, Denpasar, Bali, Indonesia
3 Tunas Pembangunan University, Surakarta, Indonesia

* E-mail: peni.agustijanto@rikolto.org

ABSTRACT

This research addresses a critical gap in our current understanding of the intricate interplay between soil biodiversity and human health. The primary objective of this study is to elucidate the profound implications of healthy soil ecosystems for human well-being and nutrition. The research explores several critical facets of the relationship between soil biodiversity and human health, including the connections between soil biodiversity and the production of nutrient-rich food, the intriguing correlations between soil and gut microbiomes, and the role of soil biodiversity in the bioremediation of contaminants. The study employs a literature review methodology to analyze existing scholarly works and synthesize relevant information systematically. The findings underscore the critical importance of implementing sustainable soil management practices and policy initiatives to preserve and enhance soil biodiversity to promote human health and environmental sustainability. Furthermore, this research highlights the need for further exploration into the nuanced mechanisms underlying this relationship, ultimately guiding the development of evidence-based policies and practices that foster human well-being through preserving and enhancing soil biodiversity.

KEYWORDS
good agricultural practices; society 5.0; soil biodiversity; soil health; sustainable development

1. INTRODUCTION

Sustainable development is now a global imperative, recognizing the intricate links between environmental health, social equity, and economic progress (Linnerud et al., 2021). In Indonesia, a nation renowned for its biodiversity and culture, achieving sustainable development is both an urgent need and a promising opportunity (Sasmito et al., 2023). As we navigate the 21st century, marked by rapid technological advances and societal shifts, the “Society 5.0” concept emerges as a guiding framework to leverage innovation for addressing pressing challenges (Tavares et al., 2022).

Like many others, a paramount challenge for Indonesia is soil degradation (Rai, 2022). Soil degradation, characterized by dwindling quality, reduced biodiversity, and imbalances in organic and inorganic elements, threatens food security, ecosystem resilience, and sustainability (Ayub et al., 2020). A comprehensive understanding of soil health within sustainable development is vital to address this (Lehmann, Bossio, et al., 2020).

Indonesia’s diverse landscapes face significant soil degradation due to rapid agricultural expansion, deforestation, industrialization, and urbanization (Hossain et al., 2020). These factors erode soil quality, diminish fertility, and decrease diversity in organic and inorganic components (Javed et al., 2022). These impacts collectively impair the ability of Indonesian soils to support agriculture, combat climate change, and sustain the populace (Octavia et al., 2022).

While the consequences of soil degradation are well-documented, a research gap exists concerning Indonesia’s mechanisms and strategies to restore soil health holistically (Young et al., 2022). Existing studies often focus on singular aspects, neglecting soil health’s multi-dimensional nature and its role in broader sustainability goals (Sowińska-Świerkosz et al., 2023). Thus, comprehensive research is needed to assess Indonesian soils’ current state and propose sustainable solutions that align with Society 5.0 principles (Prihadyanti & Aziz, 2022).

This study investigates soil health in Indonesia, considering degradation dimensions, the diversity of organic and inorganic components, and their interactions. It aims to identify drivers of soil degradation in Indonesia and propose a sustainable soil management framework aligning with Society 5.0. The study bridges the gap between science and practical solutions through interdisciplinary methods, fostering a holistic understanding of soil health within the sustainable development context. The research holds substantial promise for policymakers, land managers, farmers, and environmentalists. By elucidating Indonesia’s soil dynamics and proposing innovative solutions, it can inform evidence-based policies and practices promoting sustainable land use, food security, and environmental mitigation.

2. METHODOLOGY

This manuscript employs a literature review methodology to explore the dynamic interplay between sustainable development and soil health in Indonesia, specifically within the paradigm of Society 5.0. The investigation encompasses agricultural practices, environmental policies, and technological interventions. In addition to synthesizing existing knowledge and identifying gaps, the review is supported by pertinent literature, aiding in a comprehensive analysis. The systematic literature review adopts a methodical approach, defining specific search criteria, utilizing reputable databases, and establishing clear inclusion/exclusion criteria (Krnic Martinic et al., 2019). This method ensures the selection of relevant publications, contributing to a thorough and focused examination of the relationship between sustainable development and soil health in the context of societal and technological evolution.

3. RESULTS AND DISCUSSION

3.1. Soil Biodiversity

Ensuring biodiversity in the soil is crucial for upholding a robust quality assurance system in the market and, consequently, delivering products of superior quality (Krauss & Krishnan, 2022). The diverse microbial communities and organisms within the soil are a key indicator of soil health, influencing crops' nutritional content and overall vitality (Naz et al., 2022). This biodiversity enhances ecosystems' resilience and contributes to producing healthier and more nutritious agricultural products (De Garine-Wichatitsky et al., 2021). In the context of market demands and quality standards, a flourishing soil microbiome becomes integral to sustainable agriculture (Jayaraman & Dalal, 2022). By recognizing the link between soil biodiversity and product quality, stakeholders can implement practices that support a thriving ecosystem, fostering environmental sustainability and producing goods that meet high-quality standards in today's competitive markets (Hou et al., 2020).

Producers play a pivotal role in the agricultural landscape, where their activities encompass cultivating and producing a wide range of farm products (Bethwell et al., 2022). These products form the backbone of our food supply, ranging from staple crops like rice and wheat to various fruits, vegetables, and livestock (Yu & Pedroso, 2023). Producers engage in many tasks, from sowing seeds and tending to crops to raising animals and harvesting their produce (Agathokleous et al., 2021). Their efforts are aimed to meet the demand for food and ensure the quality, safety, and sustainability of these products. In today's increasingly complex agricultural sector, producers face the challenge of balancing productivity with environmental stewardship as consumer preferences evolve toward healthier and more sustainable choices (Naamala & Smith, 2020). Consequently, modern agricultural producers must adopt innovative and environmentally responsible practices to produce products that satisfy the market's needs and contribute to the planet's well-being and its inhabitants (Ghobakhloo et al., 2021).

Guarantee systems are integral in ensuring the quality and sustainability of agricultural products (Mondejar et al., 2021). These systems involve the development of specific indicators that serve as prerequisites for maintaining product quality and supporting environmental conservation (Ikram et al., 2021). These indicators encompass various criteria, from pesticide use and soil health to water management and biodiversity preservation (Guo, 2021). By establishing these indicators as stringent requirements, guarantee systems aim to create a framework where agricultural practices align with product quality and environmental stewardship (Albaladejo et al., 2021). This dual focus benefits consumers and improves ecosystems' long-term health (Keesstra et al., 2018).

In the modern market, consumers are increasingly discerning regarding their food choices (Ballco & Gracia, 2022). The market serves as the platform for informed consumers to prioritize health and sustainability (R. Wang et al., 2023). These intelligent consumers are keenly aware of the significance of their choices in influencing agricultural practices (Mesías et al., 2021). They seek products that satisfy their nutritional needs and align with their values and principles, such as supporting eco-friendly and ethical production methods (Saraiva et al., 2021). In this dynamic marketplace, producers and guarantee systems are incentivized to meet the evolving demands of these discerning consumers, thus driving positive changes in the agricultural sector (Chalupová et al., 2020).

Agriculture has historically played a fundamental role in meeting the nutritional needs of humanity, with soil serving as its cornerstone (Toor et al., 2021). The ground provides the essential nutrients and support necessary for the growth of crops and the raising of livestock (Sekaran et al., 2021). However, it is crucial to recognize that the sustainability of agriculture is inextricably linked to soil health (Irawan et al., 2023). Soil degradation can compromise the ability of agriculture to fulfill human nutritional needs (Nunes et al., 2020). Therefore, it becomes imperative to implement practices that maintain and enhance soil health, ensuring the continued provision of nutritious food for the global population (Kopittke et al., 2019). In essence, the nexus between agriculture, soil health, and human nutrition underscores soil's vital role in sustaining human life and well-being (Ruppel, 2022).

3.2. Soil and Agriculture

Soil is an intricate and dynamic composition of various elements, including organic matter, minerals, gases, liquids, and many organisms, all coexisting to sustain life on our planet (Mohanty et al., 2021). Earth's expansive body of soil, often called the "pedosphere," is the foundational bedrock for numerous vital functions indispensable to the natural world (Lybrand, 2023). Understanding these functions is critical to appreciating soil's profound role in our environment (Wang et al., 2020).

The foremost function of soil is to serve as a nurturing medium for plant growth (Rajput et al., 2022). Its physical structure and chemical composition support many plant species, enabling their roots to anchor securely and access vital nutrients and water (Kalaivanan et al., 2023). In essence, soil acts as Earth's green cradle, facilitating the growth of vegetation that forms the basis of terrestrial ecosystems, making it a fundamental component of our biosphere (Johnson et al., 2022).

Moreover, soil plays a pivotal role in Earth's hydrological cycle (Reichstein & Carvalhais, 2019). It serves as a reservoir for water, storing and releasing it as needed. Soil regulates the flow of water and purifies it as it percolates through, removing impurities and ensuring groundwater quality (Irawan, 2023a). This function is vital for maintaining the availability of freshwater resources and sustaining life both above and below the ground (Baggio et al., 2021).

Beyond its roles in plant growth and hydrology, soil profoundly influences Earth's atmosphere (Singha & Navarre-Sitchler, 2022). It modifies atmospheric composition through processes like carbon sequestration and the release of greenhouse gases (Yoro & Daramola, 2020). Soil's ability to capture and store carbon is of particular significance in the context of climate change mitigation (Bossio et al., 2020). Furthermore, soil and atmosphere interactions are crucial in weather patterns and climate regulation (Coban et al., 2022).

Lastly, soil is a dynamic habitat for a diverse range of organisms (van Leeuwen et al., 2019). From microscopic bacteria to larger mammals, countless species find their homes and sustenance within the soil's complex microcosm (Höss et al., 2021). These organisms contribute to soil fertility, nutrient cycling, and overall ecosystem health, making soil a thriving hub of biodiversity (Sofo et al., 2022). In essence, the multifaceted functions of soil encompass its role as a nurturing medium, a hydrological regulator, an atmospheric influencer, and a bustling habitat, collectively making it an indispensable component of Earth's intricate web of life (Dharmawan et al., 2023).

3.3. Principles of Soil in Crop Production and Good Agriculture Practice

Crop production is a cornerstone of global agriculture, serving as the primary source of food, fiber, and various essential products (Aly & Borik, 2023). It encompasses cultivating and harvesting crops like grains, fruits, vegetables, and legumes (Rejekiningrum et al., 2022). Crop production success is contingent upon adherence to guidelines known as Good Agriculture Practices (GAPs) (Sun & van der Ven, 2020). These practices are principles and methods designed to optimize crop yield, minimize environmental impact, and ensure the safety and quality of agricultural products (Richard et al., 2022). GAPs encompass various aspects of farming, from soil management to pest control, irrigation, and post-harvest handling (Singh et al., 2022). By following GAPs, farmers can enhance their crop production processes' sustainability, efficiency, and safety (Ashraf et al., 2021).

Land and soil management are pivotal components of sustainable agriculture (Visser et al., 2019). Adequate land and soil management strategies are essential for maintaining soil fertility, preventing erosion, and preserving ecosystem health (Mehmet Tuğrul, 2020). General land and soil management principles include crop rotation, conservation tillage, cover cropping, and applying organic matter such as compost or manure (Khmelevtsova et al., 2022). These practices help improve soil structure, enhance nutrient retention, and reduce the need for chemical inputs (Sarkar et al., 2020). Furthermore, land requirements for agriculture must be carefully considered to balance food production with environmental preservation (Serra-Majem et al., 2020). Responsible land use planning ensures that agricultural expansion does not lead to deforestation, habitat destruction, or soil degradation, promoting a more sustainable and harmonious coexistence between agriculture and the environment (Hariram et al., 2023).

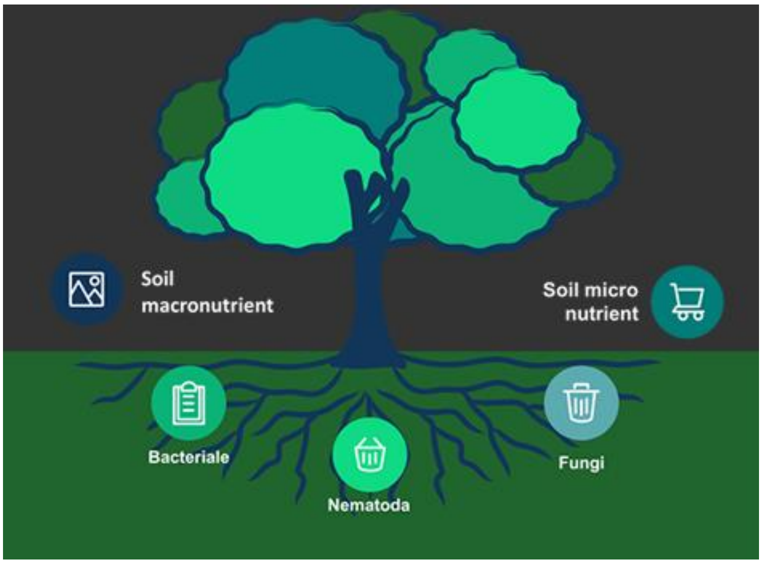

Figure 1. General principles of the sustainable management system

Crop production, guided by Good Agriculture Practices, is the linchpin of food security and livelihoods worldwide (Tirado et al., 2022). Adequate land and soil management, based on general principles, is essential for maintaining the health and productivity of agricultural ecosystems (Teague & Kreuter, 2020). Balancing land requirements for agriculture with broader environmental concerns is crucial for ensuring that agriculture remains a sustainable practice that can meet the growing demands of a global population while safeguarding the planet's natural resources (Movilla-Pateiro et al., 2021).

A sustainable management system in agriculture is rooted in a profound respect for nature's intricate systems and cycles (Irawan, 2023b). It encompasses the careful stewardship and enhancement of vital elements like soil, water, and air, as well as the health of plants and animals while maintaining a delicate balance between them (Almusaed et al., 2023). Central to this approach is a comprehensive soil management plan that involves a thorough assessment and thoughtful management of soil resources (Debeljak et al., 2019). This process entails identifying and implementing measures to increase soil organic matter, enhance on-farm nutrient recycling, and optimize soil moisture levels (McLennon et al., 2021). Farmers aim to preserve or enhance soil fertility and nutrient content through these practices, ultimately ensuring the long-term productivity and sustainability of agricultural systems (Richard et al., 2022). Such an integrated approach safeguards the environment and contributes to improved crop yields, healthier ecosystems, and a more resilient agricultural sector (Bindraban et al., 2020).

3.4. Soil Biodiversity Benefit

Soil biodiversity offers many benefits that ripple through our environment and well-being. Firstly, healthy soil, rich in biodiversity, is a linchpin for ecosystem health (Polistina, 2022). A diverse community of soil microorganisms and macroorganisms work in tandem to maintain nutrient cycles, support plant growth, and safeguard against soil-borne diseases (Afridi et al., 2022). This intricate web of life beneath our feet contributes to terrestrial ecosystems' overall vitality and resilience (Li et al., 2022). Moreover, soil is a crucial medium for plant growth, providing essential nutrients and physical support (Tauqeer et al., 2022). The diversity of soil organisms contributes to nutrient availability and soil structure, which, in turn, sustains healthy plant life and drives agricultural productivity (Saleem et al., 2019).

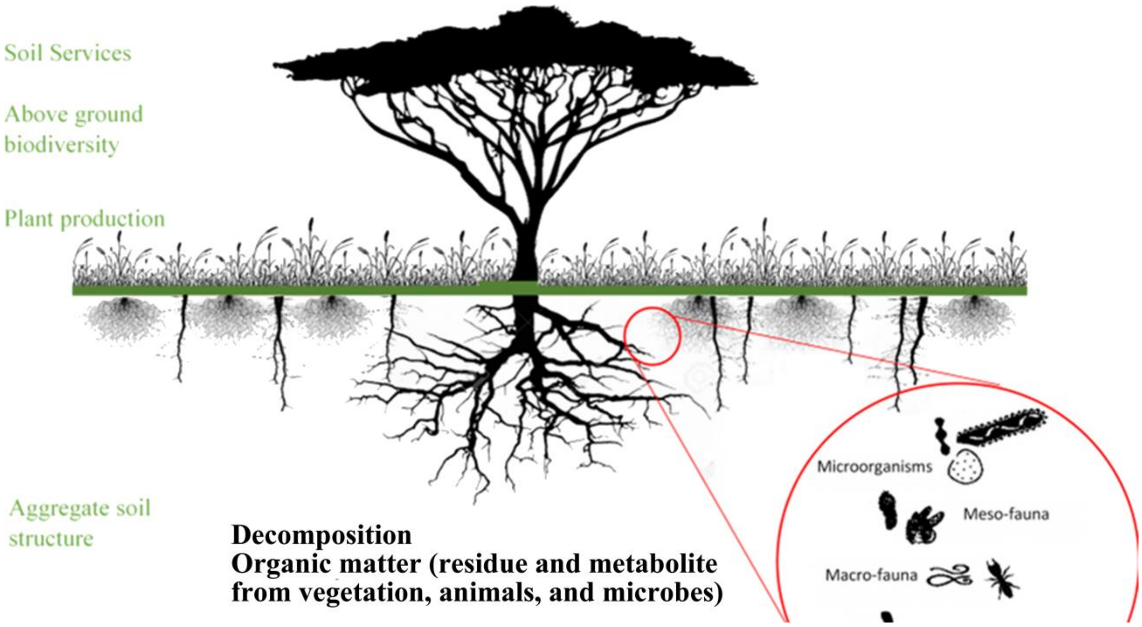

Figure 2. Soil biodiversity benefit

The impact of soil biodiversity extends beyond ecosystems and agriculture, directly affecting human health and our food quality. Soil teeming with diverse life produces crops that are more abundant and nutritionally superior (Anderson et al., 2023). Nutrient-rich food, in turn, promotes human health and well-being (Irawan et al., 2023). Furthermore, soil biodiversity plays a pivotal role in water purification (Bach et al., 2020). As water percolates through the soil, diverse communities of microorganisms help filter out impurities and contaminants, effectively purifying the water (Mwamburi, 2022). This natural purification process enhances the quality of groundwater and surface water, benefiting both ecosystems and human populations (Szklarek et al., 2022). Finally, soil biodiversity is crucial in climate change mitigation and adaptation (Morecroft et al., 2019). One effective mitigation strategy involves increasing the organic matter content in the soil (Lehmann et al., 2020). This strategy not only sequesters carbon, mitigating greenhouse gas emissions but also enhances soil structure and water-holding capacity, aiding in adaptation efforts to combat the impacts of climate change (Gonzalez-Sanchez et al., 2021). In essence, the richness of soil biodiversity underscores its fundamental role in sustaining the health of our ecosystems, our food supply, the quality of our water, and our collective endeavors to address climate change challenges (Shostak, 2022).

3.5. Soil Biodiversity and Human Health

The intricate relationship between soil biodiversity and human health underscores the profound influence of our environment on our well-being (Were et al., 2022). This connection can be dissected into several key facets that highlight soil biodiversity's vital role in shaping our health and nutrition (Lazarova et al., 2021). The intricate world of soil biodiversity is a vital but often overlooked component of our ecosystem that profoundly impacts human health (Costantini & Mocali, 2022). Soil is a complex living system, teeming with many microorganisms, fungi, insects, and other organisms that interact in ways critical to soil health (Yatoo et al., 2020). These tiny organisms are crucial in nutrient cycling, decomposition, and soil structure formation (Dai et al., 2021). Consequently, soil biodiversity directly influences the quality of the food we grow and consume, thus, our overall well-being (Bach et al., 2020).

Nutrient-rich soil contributes to the production of nutrient-dense food (Barker & Stratton, 2020). Firstly, the diversity of life within healthy soil cultivates an environment where an array of nutrients becomes readily available to plants (Ikkonen et al., 2021). As a result, crops grown in such soil tend to be not only more abundant but also more nutritionally rich (Montgomery & Biklé, 2021). This direct correlation between soil biodiversity and the quality of agricultural products underscores the critical importance of maintaining diverse soil ecosystems for human health (de Graaff et al., 2019). Nutrient-dense food, in turn, contributes to improved human health, providing essential vitamins and minerals that are vital for our well-being (Gbenga-Fabusiwa et al., 2022).

The Gut Microbiome Connection. Another intriguing aspect of the soil-human health relationship is the correlation between soil microbiomes and the human gut microbiome (Maji et al., 2022). Emerging research suggests that exposure to diverse soil microbiota may positively impact the composition of our gut microbiome (Blum et al., 2019). A balanced and diverse gut microbiome is increasingly recognized as a critical factor in maintaining human health, influencing aspects ranging from digestion to immunity (Gomaa, 2020). The intricate connection between soil and gut microbiomes highlights how soil biodiversity can indirectly shape our internal ecosystems, potentially influencing our susceptibility to various health conditions (Sbihi et al., 2019).

Soil Bioremediation and Environmental Health. Additionally, soil biodiversity plays a critical role in bioremediation, a process where certain microbes, macro-, and microfauna contribute to reducing soil contamination (Tegene & Tenkegna, 2020). This environmentally beneficial process supports healthier soil ecosystems and has implications for human health by mitigating exposure to harmful contaminants (Urra et al., 2019). Bioremediation is a powerful tool for improving environmental and human health by harnessing the natural cleaning abilities of soil organisms (Kour et al., 2021).

The correlation between soil biodiversity and human health is intricate and emphasizes the crucial role of preserving and enhancing soil ecosystems (Saleem et al., 2019). This connection manifests in various ways, ranging from the nutritional quality of food produced in diverse soils to the intricacies of the gut microbiome (Trivedi et al., 2021). Soil serves as the fundamental source of nutrients for plants, and the richness of its biodiversity directly influences the nutritional content of crops consumed by humans (Yadav et al., 2021). Furthermore, the intricate relationship extends to soil bioremediation, where diverse microbial communities contribute to detoxifying soil contaminants (Wang et al., 2022). This interplay serves as a poignant reminder of the profound connection between humans and the natural world, highlighting the far-reaching implications of soil health on our overall well-being (Martin et al., 2020). Recognizing and fostering soil biodiversity not only ensures the sustainability of ecosystems but also holds the potential to positively impact human health, making it imperative to prioritize the preservation and enhancement of soil ecosystems in our pursuit of holistic well-being (Yin et al., 2022).

4. CONCLUSION

The correlation between soil biodiversity and human health is complex and multi-dimensional. Maintaining healthy soil ecosystems, known for nutrient-rich content, contributes to the production of nutritious food, positively impacting human health and nutrition. The fascinating link between soil microbiomes and the human gut microbiome underscores the potential influence of soil biodiversity on our internal ecosystems. Additionally, soil biodiversity plays a crucial role in bioremediation, with environmental and human health implications by reducing soil contamination. These findings emphasize the interconnectedness of our environment and health, underscoring the importance of preserving and enhancing soil ecosystems. Promoting organic farming methods, minimizing soil disturbance, and reducing chemical inputs can help maintain and enhance soil biodiversity. Public awareness campaigns can also educate individuals about the importance of healthy soil for their well-being. Policy initiatives should promote sustainable agricultural practices, prioritizing soil health and biodiversity. Incentives for farmers adopting environmentally friendly practices can be a practical approach. Policymakers should also consider integrating soil health assessments into broader environmental and health policies to ensure a holistic approach to well-being. While significant progress has been made in understanding the link between soil biodiversity and human health, further research is needed to explore the nuances of this relationship. Long-term studies assessing the impact of soil management practices on human health outcomes and in-depth investigations into the mechanisms connecting soil and gut microbiomes are essential for comprehensive insights. Such research will aid in developing evidence-based policies and practices that promote human health through preserving and enhancing soil biodiversity.

REFERENCES

Afridi, M. S., Javed, M. A., Ali, S., De Medeiros, F. H. V., Ali, B., Salam, A., Sumaira, Marc, R. A., Alkhalifah, D. H. M., Selim, S., & Santoyo, G. (2022). New opportunities in plant microbiome engineering for increasing agricultural sustainability under stressful conditions. *Frontiers in Plant Science*, *13*. https://doi.org/10.3389/fpls.2022.899464

Agathokleous, E., Zhou, B., Xu, J., Ioannou, A., Feng, Z., Saitanis, C. J., Frei, M., Calabrese, E. J., & Fotopoulos, V. (2021). Exogenous application of melatonin to plants, algae, and harvested products to sustain agricultural productivity and enhance nutritional and nutraceutical value: A meta-analysis. *Environmental Research*, *200*, 111746. https://doi.org/10.1016/j.envres.2021.111746

Albaladejo, J., Díaz-Pereira, E., & de Vente, J. (2021). Eco-Holistic Soil Conservation to support Land Degradation Neutrality and the Sustainable Development Goals. *CATENA*, *196*, 104823. https://doi.org/10.1016/j.catena.2020.104823

Almusaed, A., Almssad, A., Alasadi, A., Yitmen, I., & Al-Samaraee, S. (2023). Assessing the Role and Efficiency of Thermal Insulation by the "Bio-Green Panel" in Enhancing Sustainability in a Built Environment. *Sustainability*, *15*(13), 10418. https://doi.org/10.3390/su151310418

Aly, A. A., & Borik, Z. M. (2023). Food crops, growth and productivity as an important focus for sustainable agriculture. In *Plant Small RNA in Food Crops* (pp. 3–23). Elsevier. https://doi.org/10.1016/B978-0-323-91722-3.00002-6

Anderson, A. J., Britt, D. W., & Dimkpa, C. O. (2023). Nano–microbe interaction and implications for soil health and plant vigor: dialogs in the rhizosphere. In *Nano-Enabled Sustainable and Precision Agriculture* (pp. 293–353). Elsevier. https://doi.org/10.1016/B978-0-323-91233-4.00013-2

Ashraf, S. A., Siddiqui, A. J., Elkhalifa, A. E. O., Khan, M. I., Patel, M., Alreshidi, M., Moin, A., Singh, R., Snoussi, M., Adnan, M., Abd Elmoneim, O. E., Khan, M. I., Patel, M., Alreshidi, M., Moin, A., Singh, R., Snoussi, M., & Adnan, M. (2021). Innovations in nanoscience for the sustainable development of food and agriculture with implications on health and environment. *Science of The Total Environment*, *768*, 144990. https://doi.org/10.1016/j.scitotenv.2021.144990

Ayub, M. A., Usman, M., Faiz, T., Umair, M., ul Haq, M. A., Rizwan, M., Ali, S., & Zia ur Rehman, M. (2020). Restoration of Degraded Soil for Sustainable Agriculture. In *Soil Health Restoration and Management* (pp. 31–81). Springer Singapore. https://doi.org/10.1007/978-981-13-8570-4_2

Bach, E. M., Ramirez, K. S., Fraser, T. D., & Wall, D. H. (2020). Soil Biodiversity Integrates Solutions for a Sustainable Future. *Sustainability*, *12*(7), 2662. https://doi.org/10.3390/su12072662

Baggio, G., Qadir, M., & Smakhtin, V. (2021). Freshwater availability status across countries for human and ecosystem needs. *Science of The Total Environment*, *792*, 148230. https://doi.org/10.1016/j.scitotenv.2021.148230

Ballco, P., & Gracia, A. (2022). Tackling nutritional and health claims to disentangle their effects on consumer food choices and behaviour: A systematic review. *Food Quality and Preference*, *101*, 104634. https://doi.org/10.1016/j.foodqual.2022.104634

Barker, A. V., & Stratton, M. L. (2020). Nutrient density of fruit crops as a function of soil fertility. In *Fruit Crops* (pp. 13–31). Elsevier. https://doi.org/10.1016/B978-0-12-818732-6.00002-2

Bethwell, C., Sattler, C., & Stachow, U. (2022). An analytical framework to link governance, agricultural production practices, and the provision of ecosystem services in agricultural landscapes. *Ecosystem Services*, *53*, 101402. https://doi.org/10.1016/j.ecoser.2021.101402

Bindraban, P. S., Dimkpa, C. O., White, J. C., Franklin, F. A., Melse-Boonstra, A., Koele, N., Pandey, R., Rodenburg, J., Senthilkumar, K., Demokritou, P., & Schmidt, S. (2020). Safeguarding human and planetary health demands a fertilizer sector transformation. *Plants, People, Planet*, *2*(4), 302–309. https://doi.org/10.1002/ppp3.10098

Blum, W. E. H., Zechmeister-Boltenstern, S., & Keiblinger, K. M. (2019). Does Soil Contribute to the Human Gut Microbiome? *Microorganisms*, *7*(9), 287. https://doi.org/10.3390/microorganisms7090287

Bossio, D. A., Cook-Patton, S. C., Ellis, P. W., Fargione, J., Sanderman, J., Smith, P., Wood, S., Zomer, R. J., von Unger, M., Emmer, I. M., & Griscom, B. W. (2020). The role of soil carbon in natural climate solutions. *Nature Sustainability*, *3*(5), 391–398. https://doi.org/10.1038/s41893-020-0491-z

Chalupová, M., Rojík, S., Kotoučková, H., & Kauerová, L. (2020). Food Labels (Quality, Origin, and Sustainability): The Experience of Czech Producers. *Sustainability*, *13*(1), 318. https://doi.org/10.3390/su13010318

Coban, O., De Deyn, G. B., & van der Ploeg, M. (2022). Soil microbiota as game-changers in restoration of degraded lands. *Science*, *375*(6584). https://doi.org/10.1126/science.abe0725

Costantini, E. A. C., & Mocali, S. (2022). Soil health, soil genetic horizons and biodiversity #. *Journal of Plant Nutrition and Soil Science*, *185*(1), 24–34. https://doi.org/10.1002/jpln.202100437

Dai, Z., Xiong, X., Zhu, H., Xu, H., Leng, P., Li, J., Tang, C., & Xu, J. (2021). Association of biochar properties with changes in soil bacterial, fungal and fauna communities and nutrient cycling processes. *Biochar*, *3*(3), 239–254. https://doi.org/10.1007/s42773-021-00099-x

De Garine-Wichatitsky, M., Binot, A., Ward, J., Caron, A., Perrotton, A., Ross, H., Tran Quoc, H., Valls-Fox, H., Gordon, I. J., Promburom, P., Ancog, R., Anthony Kock, R., Morand, S., Chevalier, V., Allen, W., Phimpraphai, W., Duboz, R., & Echaubard, P. (2021). "Health in" and "Health of" Social-Ecological Systems: A Practical Framework for the Management of Healthy and Resilient Agricultural and Natural Ecosystems. *Frontiers in Public Health*, *8*. https://doi.org/10.3389/fpubh.2020.616328

de Graaff, M.-A., Hornslein, N., Throop, H. L., Kardol, P., & van Diepen, L. T. A. (2019). *Effects of agricultural intensification on soil biodiversity and implications for ecosystem functioning: A meta-analysis* (pp. 1–44). https://doi.org/10.1016/bs.agron.2019.01.001

Debeljak, M., Trajanov, A., Kuzmanovski, V., Schröder, J., Sandén, T., Spiegel, H., Wall, D. P., Van de Broek, M., Rutgers, M., Bampa, F., Creamer, R. E., & Henriksen, C. B. (2019). A Field-Scale Decision Support System for Assessment and Management of Soil Functions. *Frontiers in Environmental Science*, *7*. https://doi.org/10.3389/fenvs.2019.00115

Dharmawan, I. W. S., Pratiwi, Siregar, C. A., Narendra, B. H., Undaharta, N. K. E., Sitepu, B. S., Sukmana, A., Wiratmoko, M. D. E., Abywijaya, I. K., & Sari, N. (2023). Implementation of Soil and Water Conservation in Indonesia and Its Impacts on Biodiversity, Hydrology, Soil Erosion and Microclimate. *Applied Sciences*, *13*(13), 7648. https://doi.org/10.3390/app13137648

Gbenga-Fabusiwa, F. J., Jeff-Agboola, Y. A., Ololade, Z. S., Akinrinmade, R., & Agbaje, D. O. (2022). Waste-to-wealth; nutritional potential of five selected fruit peels and their health benefits: A review. *African Journal of Food Science*, *16*(7), 172–183. https://doi.org/10.5897/AJFS2021.2138

Ghobakhloo, M., Iranmanesh, M., Grybauskas, A., Vilkas, M., & Petraitė, M. (2021). Industry 4.0, innovation, and sustainable development: A systematic review and a roadmap to sustainable innovation. *Business Strategy and the Environment*, *30*(8), 4237–4257. https://doi.org/10.1002/bse.2867

Gomaa, E. Z. (2020). Human gut microbiota/microbiome in health and diseases: a review. *Antonie van Leeuwenhoek*, *113*(12), 2019–2040. https://doi.org/10.1007/s10482-020-01474-7

Gonzalez-Sanchez, E. J., Veroz-Gonzalez, O., Moreno-Garcia, M., Gomez-Ariza, M. R., Ordoñez-Fernandez, R., Trivino-Tarradas, P., Kassam, A., Gil-Ribes, J. A., Basch, G., & Carbonell-Bojollo, R. (2021). Climate change adaptability and mitigation with Conservation Agriculture. In *Rethinking Food and Agriculture* (pp. 231–246). Elsevier. https://doi.org/10.1016/B978-0-12-816410-5.00012-8

Guo, M. (2021). Soil Health Assessment and Management: Recent Development in Science and Practices. *Soil Systems*, *5*(4), 61. https://doi.org/10.3390/soilsystems5040061

Hariram, N. P., Mekha, K. B., Suganthan, V., & Sudhakar, K. (2023). Sustainalism: An Integrated Socio-Economic-Environmental Model to Address Sustainable Development and Sustainability. *Sustainability*, *15*(13), 10682. https://doi.org/10.3390/su151310682

Höss, S., Reiff, N., Traunspurger, W., & Helder, J. (2021). On the balance between practical relevance and standardization - Testing the effects of zinc and pyrene on native nematode communities in soil microcosms. *Science of The Total Environment*, *788*, 147742. https://doi.org/10.1016/j.scitotenv.2021.147742

Hossain, A., Krupnik, T. J., Timsina, J., Mahboob, M. G., Chaki, A. K., Farooq, M., Bhatt, R., Fahad, S., & Hasanuzzaman, M. (2020). Agricultural Land Degradation: Processes and Problems Undermining Future Food Security. In *Environment, Climate, Plant and Vegetation Growth* (pp. 17–61). Springer International Publishing. https://doi.org/10.1007/978-3-030-49732-3_2

Hou, D., Bolan, N. S., Tsang, D. C. W., Kirkham, M. B., & O'Connor, D. (2020). Sustainable soil use and management: An interdisciplinary and systematic approach. *Science of The Total Environment*, *729*, 138961. https://doi.org/10.1016/j.scitotenv.2020.138961

Ikkonen, E., Chazhengina, S., & Jurkevich, M. (2021). Photosynthetic Nutrient and Water Use Efficiency of Cucumis sativus under Contrasting Soil Nutrient and Lignosulfonate Levels. *Plants*, *10*(2), 340. https://doi.org/10.3390/plants10020340

Ikram, M., Ferasso, M., Sroufe, R., & Zhang, Q. (2021). Assessing green technology indicators for cleaner production and sustainable investments in a developing country context. *Journal of Cleaner Production*, *322*, 129090. https://doi.org/10.1016/j.jclepro.2021.129090

Irawan, N. C. (2023a). Manajemen Sistem Agribisnis Hortikultura Berkelanjutan. In *Agribisnis Hortikultura* (pp. 33–52). CV. Tohar Media. https://www.researchgate.net/publication/372108262_Manajemen_Sistem_Agribisnis_Hortikultura_Berkelanjutan

Irawan, N. C. (2023b). Pengembangan Budidaya Kopi Berkelanjutan. In F. L. Baguna (Ed.), *Budidaya Tanaman Kopi dan Olahannya Untuk Kesehatan* (1st ed., pp. 123–128). CV. Tohar Media. https://doi.org/978-623-8148-42-4

Irawan, N. C., Esthi, R. B., Wijayanti, I. K. E., Widodo, Z. D., & Darmaningrum, K. (2023). Unlocking Organic Agroindustry Employee Eco-Innovation: Role of Green Product Knowledge and Green Transformational Leadership. *Indonesian Journal of Economics, Social, and Humanities*, *5*(3), 204–222. https://doi.org/10.31258/ijesh.5.3.204-222

Irawan, N. C., Haryuni, Dewi, T. S. K., Priyadi, S., & Suswadi. (2023). Promoting Sustainable Urban Farming Through Plant Clinic Consultations on Car Free Days. *Journal of Community Capacity Empowerment*, *1*(2), 16–23. https://doi.org/10.36728/jcce.v1i2.2813

Javed, A., Ali, E., Binte Afzal, K., Osman, A., & Riaz, D. S. (2022). Soil Fertility: Factors Affecting Soil Fertility, and Biodiversity Responsible for Soil Fertility. *International Journal of Plant, Animal and Environmental Sciences*, *12*(01). https://doi.org/10.26502/ijpaes.202129

Jayaraman, S., & Dalal, R. C. (2022). No-till farming: prospects, challenges – productivity, soil health, and ecosystem services. *Soil Research*, *60*(6), 435–441. https://doi.org/10.1071/SR22119

Johnson, K. L., Gray, N. D., Stone, W., Kelly, B. F. J., Fitzsimons, M. F., Clarke, C., Blake, L., Chivasa, S., Mtambanengwe, F., Mapfumo, P., Baker, A., Beckmann, S., Dominelli, L., Neal, A. L., & Gwandu, T. (2022). A nation that rebuilds its soils rebuilds itself- an engineer's perspective. *Soil Security*, *7*, 100060. https://doi.org/10.1016/j.soisec.2022.100060

Kalaivanan, D., Selvakumar, G., & Carolin Rathinakumari, A. (2023). Soilless Cultivation to Secure the Vegetable Demand of Urban and Peri-Urban Population. In *Recent Research and Advances in Soilless Culture*. IntechOpen. https://doi.org/10.5772/intechopen.102695

Keesstra, S., Mol, G., de Leeuw, J., Okx, J., Molenaar, C., de Cleen, M., & Visser, S. (2018). Soil-Related Sustainable Development Goals: Four Concepts to Make Land Degradation Neutrality and Restoration Work. *Land*, *7*(4), 133. https://doi.org/10.3390/land7040133

Khmelevtsova, L. E., Sazykin, I. S., Azhogina, T. N., & Sazykina, M. A. (2022). Influence of Agricultural Practices on Bacterial Community of Cultivated Soils. *Agriculture*, *12*(3), 371. https://doi.org/10.3390/agriculture12030371

Kopittke, P. M., Menzies, N. W., Wang, P., McKenna, B. A., & Lombi, E. (2019). Soil and the intensification of agriculture for global food security. *Environment International*, *132*, 105078. https://doi.org/10.1016/j.envint.2019.105078

Kour, D., Kaur, T., Devi, R., Yadav, A., Singh, M., Joshi, D., Singh, J., Suyal, D. C., Kumar, A., Rajput, V. D., Yadav, A. N., Singh, K., Singh, J., Sayyed, R. Z., Arora, N. K., & Saxena, A. K. (2021). Beneficial microbiomes for bioremediation of diverse contaminated environments for environmental sustainability: present status and future challenges. *Environmental Science and Pollution Research*, *28*(20), 24917–24939. https://doi.org/10.1007/s11356-021-13252-7

Krauss, J. E., & Krishnan, A. (2022). Global decisions versus local realities: Sustainability standards, priorities and upgrading dynamics in agricultural global production networks. *Global Networks*, *22*(1), 65–88. https://doi.org/10.1111/glob.12325

Krnic Martinic, M., Pieper, D., Glatt, A., & Puljak, L. (2019). Definition of a systematic review used in overviews of systematic reviews, meta-epidemiological studies and textbooks. *BMC Medical Research Methodology*, *19*(1), 203. https://doi.org/10.1186/s12874-019-0855-0

Lazarova, S., Coyne, D., G. Rodríguez, M. G., Peteira, B., & Ciancio, A. (2021). Functional Diversity of Soil Nematodes in Relation to the Impact of Agriculture—A Review. *Diversity*, *13*(2), 64. https://doi.org/10.3390/d13020064

Lehmann, J., Bossio, D. A., Kögel-Knabner, I., & Rillig, M. C. (2020). The concept and future prospects of soil health. *Nature Reviews Earth & Environment*, *1*(10), 544–553. https://doi.org/10.1038/s43017-020-0080-8

Lehmann, J., Hansel, C. M., Kaiser, C., Kleber, M., Maher, K., Manzoni, S., Nunan, N., Reichstein, M., Schimel, J. P., Torn, M. S., Wieder, W. R., & Kögel-Knabner, I. (2020). Persistence of soil organic carbon caused by functional complexity. *Nature Geoscience*, *13*(8), 529–534. https://doi.org/10.1038/s41561-020-0612-3

Li, Y., He, J., Yue, Q., Kong, X., & Zhang, M. (2022). Linking rural settlements optimization with village development stages: A life cycle perspective. *Habitat International*, *130*, 102696. https://doi.org/10.1016/j.habitatint.2022.102696

Linnerud, K., Holden, E., & Simonsen, M. (2021). Closing the sustainable development gap: A global study of goal interactions. *Sustainable Development*, *29*(4), 738–753. https://doi.org/10.1002/sd.2171

Lybrand, R. A. (2023). Connecting soils to life in conservation planning, nutrient cycling, and planetary science. *Earth-Science Reviews*, *237*, 104247. https://doi.org/10.1016/j.earscirev.2022.104247

Maji, U. J., Mohanty, S., Mahapatra, A. S., Mondal, H. K., Samanta, M., & Maiti, N. K. (2022). Exploring the gut microbiota composition of Indian major carp, rohu (Labeo rohita), under diverse culture conditions. *Genomics*, *114*(3), 110354. https://doi.org/10.1016/j.ygeno.2022.110354

Martin, L., White, M. P., Hunt, A., Richardson, M., Pahl, S., & Burt, J. (2020). Nature contact, nature connectedness and associations with health, well-being and pro-environmental behaviours. *Journal of Environmental Psychology*, *68*, 101389. https://doi.org/10.1016/j.jenvp.2020.101389

McLennon, E., Dari, B., Jha, G., Sihi, D., & Kankarla, V. (2021). Regenerative agriculture and integrative permaculture for sustainable and technology driven global food production and security. *Agronomy Journal*, *113*(6), 4541–4559. https://doi.org/10.1002/agj2.20814

Mehmet Tuğrul, K. (2020). Soil Management in Sustainable Agriculture. In *Sustainable Crop Production*. IntechOpen. https://doi.org/10.5772/intechopen.88319

Mesías, F. J., Martín, A., & Hernández, A. (2021). Consumers' growing appetite for natural foods: Perceptions towards the use of natural preservatives in fresh fruit. *Food Research International*, *150*, 110749. https://doi.org/10.1016/j.foodres.2021.110749

Mohanty, B., Pradhan, D., Das, R., & Das, M. T. (2021). *Biogeochemical Cycles in Soil Microbiomes in Response to Climate Change* (pp. 491–519). https://doi.org/10.1007/978-3-030-76863-8_26

Mondejar, M. E., Avtar, R., Diaz, H. L. B., Dubey, R. K., Esteban, J., Gómez-Morales, A., Hallam, B., Mbungu, N. T., Okolo, C. C., Prasad, K. A., She, Q., & Garcia-Segura, S. (2021). Digitalization to achieve sustainable development goals: Steps towards a Smart Green Planet. *Science of The Total Environment*, *794*(June), 148539. https://doi.org/10.1016/j.scitotenv.2021.148539

Montgomery, D. R., & Biklé, A. (2021). Soil Health and Nutrient Density: Beyond Organic vs. Conventional Farming. *Frontiers in Sustainable Food Systems*, *5*. https://doi.org/10.3389/fsufs.2021.699147

Morecroft, M. D., Duffield, S., Harley, M., Pearce-Higgins, J. W., Stevens, N., Watts, O., & Whitaker, J. (2019). Measuring the success of climate change adaptation and mitigation in terrestrial ecosystems. *Science*, *366*(6471). https://doi.org/10.1126/science.aaw9256

Movilla-Pateiro, L., Mahou-Lago, X. M., Doval, M. I., & Simal-Gandara, J. (2021). Toward a sustainable metric and indicators for the goal of sustainability in agricultural and food production. *Critical Reviews in Food Science and Nutrition*, *61*(7), 1108–1129. https://doi.org/10.1080/10408398.2020.1754161

Mwamburi, L. A. (2022). Removal of Microbial Contaminants From Polluted Water Using Combined Biosand Filters Techniques. In *Sustainable Solutions for Environmental Pollution* (pp. 265–291). Wiley. https://doi.org/10.1002/9781119827665.ch5

Naamala, J., & Smith, D. L. (2020). Relevance of Plant Growth Promoting Microorganisms and Their Derived Compounds, in the Face of Climate Change. *Agronomy*, *10*(8), 1179. https://doi.org/10.3390/agronomy10081179

Naz, M., Dai, Z., Hussain, S., Tariq, M., Danish, S., Khan, I. U., Qi, S., & Du, D. (2022). The soil pH and heavy metals revealed their impact on soil microbial community. *Journal of Environmental Management*, *321*, 115770. https://doi.org/10.1016/j.jenvman.2022.115770

Nunes, F. C., de Jesus Alves, L., de Carvalho, C. C. N., Gross, E., de Marchi Soares, T., & Prasad, M. N. V. (2020). Soil as a complex ecological system for meeting food and nutritional security. In *Climate Change and Soil Interactions* (pp. 229–269). Elsevier. https://doi.org/10.1016/B978-0-12-818032-7.00009-6

Octavia, D., Suharti, S., Murniati, Dharmawan, I. W. S., Nugroho, H. Y. S. H., Supriyanto, B., Rohadi, D., Njurumana, G. N., Yeny, I., Hani, A., Mindawati, N., Suratman, Adalina, Y., Prameswari, D., Hadi, E. E. W., & Ekawati, S. (2022). Mainstreaming Smart Agroforestry for Social Forestry Implementation to Support Sustainable Development Goals in Indonesia: A Review. *Sustainability*, *14*(15), 9313. https://doi.org/10.3390/su14159313

Polistina, K. (2022). Bullying to sustainability: human behaviour barriers to local ecological sustainability. *SN Social Sciences*, *2*(10), 206. https://doi.org/10.1007/s43545-022-00507-4

Prihadyanti, D., & Aziz, S. A. (2022). Indonesia toward sustainable agriculture – Do technology-based start-ups play a crucial role? *Business Strategy & Development*, *6*(2), 140–157. https://doi.org/10.1002/bsd2.229

Rai, P. K. (2022). Environmental Degradation by Invasive Alien Plants in the Anthropocene: Challenges and Prospects for Sustainable Restoration. *Anthropocene Science*, *1*(1), 5–28. https://doi.org/10.1007/s44177-021-00004-y

Rajput, S., Sengupta, P., Kohli, I., Varma, A., Singh, P. K., & Joshi, N. C. (2022). Role of Piriformospora indica in inducing soil microbial communities and drought stress tolerance in plants. In *New and Future Developments in Microbial Biotechnology and Bioengineering* (pp. 93–110). Elsevier. https://doi.org/10.1016/B978-0-323-85163-3.00003-X

Reichstein, M., & Carvalhais, N. (2019). Aspects of Forest Biomass in the Earth System: Its Role and Major Unknowns. *Surveys in Geophysics*, *40*(4), 693–707. https://doi.org/10.1007/s10712-019-09551-x

Rejekiningrum, P., Apriyana, Y., Estiningtyas, W., Sosiawan, H., Susilawati, H. L., Hervani, A., & Alifia, A. D. (2022). Optimising Water Management in Drylands to Increase Crop Productivity and Anticipate Climate Change in Indonesia. *Sustainability*, *14*(18), 11672. https://doi.org/10.3390/su141811672

Richard, B., Qi, A., & Fitt, B. D. L. (2022). Control of crop diseases through Integrated Crop Management to deliver climate-smart farming systems for low- and high-input crop production. *Plant Pathology*, *71*(1), 187–206. https://doi.org/10.1111/ppa.13493

Ruppel, O. C. (2022). *Soil Protection, Food Security and the Nexus Between Climate Governance and Trade in Agriculture* (pp. 481–520). https://doi.org/10.1007/978-3-030-96347-7_19

Saleem, M., Hu, J., & Jousset, A. (2019). More Than the Sum of Its Parts: Microbiome Biodiversity as a Driver of Plant Growth and Soil Health. *Annual Review of Ecology, Evolution, and Systematics*, *50*(1), 145–168. https://doi.org/10.1146/annurev-ecolsys-110617-062605

Saraiva, A., Fernandes, E., & von Schwedler, M. (2021). The pro-environmental consumer discourse: A political perspective on organic food consumption. *International Journal of Consumer Studies*, *45*(2), 188–204. https://doi.org/10.1111/ijcs.12611

Sarkar, S., Skalicky, M., Hossain, A., Brestic, M., Saha, S., Garai, S., Ray, K., & Brahmachari, K. (2020). Management of Crop Residues for Improving Input Use Efficiency and Agricultural Sustainability. *Sustainability*, *12*(23), 9808. https://doi.org/10.3390/su12239808

Sasmito, S. D., Basyuni, M., Kridalaksana, A., Saragi-Sasmito, M. F., Lovelock, C. E., & Murdiyarso, D. (2023). Challenges and opportunities for achieving Sustainable Development Goals through restoration of Indonesia's mangroves. *Nature Ecology & Evolution*, *7*(1), 62–70. https://doi.org/10.1038/s41559-022-01926-5

Sbihi, H., Boutin, R. C., Cutler, C., Suen, M., Finlay, B. B., & Turvey, S. E. (2019). Thinking bigger: How early-life environmental exposures shape the gut microbiome and influence the development of asthma and allergic disease. *Allergy*, *74*(11), 2103–2115. https://doi.org/10.1111/all.13812

Sekaran, U., Lai, L., Ussiri, D. A. N., Kumar, S., & Clay, S. (2021). Role of integrated crop-livestock systems in improving agriculture production and addressing food security – A review. *Journal of Agriculture and Food Research*, *5*, 100190. https://doi.org/10.1016/j.jafr.2021.100190

Serra-Majem, L., Tomaino, L., Dernini, S., Berry, E. M., Lairon, D., Ngo de la Cruz, J., Bach-Faig, A., Donini, L. M., Medina, F.-X., Belahsen, R., Piscopo, S., Capone, R., Aranceta-Bartrina, J., La Vecchia, C., & Trichopoulou, A. (2020). Updating the Mediterranean Diet Pyramid towards Sustainability: Focus on Environmental Concerns. *International Journal of Environmental Research and Public Health*, *17*(23), 8758. https://doi.org/10.3390/ijerph17238758

Shostak, S. (2022). 'When you heal the soil…': Environmental racism and socioecological repair in contemporary urban agriculture. *Environmental Sociology*, *8*(4), 400–412. https://doi.org/10.1080/23251042.2022.2073626

Singh, P. A., Bajwa, N., Chinnam, S., Chandan, A., & Baldi, A. (2022). An overview of some important deliberations to promote medicinal plants cultivation. *Journal of Applied Research on Medicinal and Aromatic Plants*, *31*, 100400. https://doi.org/10.1016/j.jarmap.2022.100400

Singha, K., & Navarre-Sitchler, A. (2022). The Importance of Groundwater in Critical Zone Science. *Groundwater*, *60*(1), 27–34. https://doi.org/10.1111/gwat.13143

Sofo, A., Zanella, A., & Ponge, J. (2022). Soil quality and fertility in sustainable agriculture, with a contribution to the biological classification of agricultural soils. *Soil Use and Management*, *38*(2), 1085–1112. https://doi.org/10.1111/sum.12702

Sowińska-Świerkosz, B., García, J., & Wendling, L. (2023). Linkages between the concept of nature-based solutions and the notion of landscape. *Ambio*. https://doi.org/10.1007/s13280-023-01935-z

Sun, Y., & van der Ven, H. (2020). Swimming in their own direction: Explaining domestic variation in homegrown sustainability governance for aquaculture in Asia. *Ecological Economics*, *167*, 106445. https://doi.org/10.1016/j.ecolecon.2019.106445

Szklarek, S., Górecka, A., & Wojtal-Frankiewicz, A. (2022). The effects of road salt on freshwater ecosystems and solutions for mitigating chloride pollution - A review. *Science of The Total Environment*, *805*, 150289. https://doi.org/10.1016/j.scitotenv.2021.150289

Tauqeer, H. M., Turan, V., Farhad, M., & Iqbal, M. (2022). Sustainable Agriculture and Plant Production by Virtue of Biochar in the Era of Climate Change. In *Managing Plant Production Under Changing Environment* (pp. 21–42). Springer Nature Singapore. https://doi.org/10.1007/978-981-16-5059-8_2

Tavares, M. C., Azevedo, G., & Marques, R. P. (2022). The Challenges and Opportunities of Era 5.0 for a More Humanistic and Sustainable Society—A Literature Review. *Societies*, *12*(6), 149. https://doi.org/10.3390/soc12060149

Teague, R., & Kreuter, U. (2020). Managing Grazing to Restore Soil Health, Ecosystem Function, and Ecosystem Services. *Frontiers in Sustainable Food Systems*, *4*. https://doi.org/10.3389/fsufs.2020.534187

Tegene, B. G., & Tenkegna, T. A. (2020). Mode of Action, Mechanism and Role of Microbes in Bioremediation Service for Environmental Pollution Management. *Journal of Biotechnology & Bioinformatics Research*, 1–18. https://doi.org/10.47363/JBBR/2020(2)116

Tirado, M. C., Vivero-Pol, J. L., Bezner Kerr, R., & Krishnamurthy, K. (2022). Feasibility and Effectiveness Assessment of Multi-Sectoral Climate Change Adaptation for Food Security and Nutrition. *Current Climate Change Reports*, *8*(2), 35–52. https://doi.org/10.1007/s40641-022-00181-x

Toor, G. S., Yang, Y.-Y., Das, S., Dorsey, S., & Felton, G. (2021). *Soil health in agricultural ecosystems: Current status and future perspectives* (pp. 157–201). https://doi.org/10.1016/bs.agron.2021.02.004

Trivedi, P., Mattupalli, C., Eversole, K., & Leach, J. E. (2021). Enabling sustainable agriculture through understanding and enhancement of microbiomes. *New Phytologist*, *230*(6), 2129–2147. https://doi.org/10.1111/nph.17319

Urra, Alkorta, & Garbisu. (2019). Potential Benefits and Risks for Soil Health Derived From the Use of Organic Amendments in Agriculture. *Agronomy*, *9*(9), 542. https://doi.org/10.3390/agronomy9090542

van Leeuwen, J. P., Creamer, R. E., Cluzeau, D., Debeljak, M., Gatti, F., Henriksen, C. B., Kuzmanovski, V., Menta, C., Pérès, G., Picaud, C., Saby, N. P. A., Trajanov, A., Trinsoutrot-Gattin, I., Visioli, G., & Rutgers, M. (2019). Modeling of Soil Functions for

Assessing Soil Quality: Soil Biodiversity and Habitat Provisioning. *Frontiers in Environmental Science*, *7*. https://doi.org/10.3389/fenvs.2019.00113

Visser, Keesstra, Maas, de Cleen, & Molenaar. (2019). Soil as a Basis to Create Enabling Conditions for Transitions Towards Sustainable Land Management as a Key to Achieve the SDGs by 2030. *Sustainability*, *11*(23), 6792. https://doi.org/10.3390/su11236792

Wang, A., Fu, W., Feng, Y., Liu, Z., & Song, D. (2022). Synergetic effects of microbial-phytoremediation reshape microbial communities and improve degradation of petroleum contaminants. *Journal of Hazardous Materials*, *429*, 128396. https://doi.org/10.1016/j.jhazmat.2022.128396

Wang, R., Bush-Evans, R., Arden-Close, E., Bolat, E., McAlaney, J., Hodge, S., Thomas, S., & Phalp, K. (2023). Transparency in persuasive technology, immersive technology, and online marketing: Facilitating users' informed decision making and practical implications. *Computers in Human Behavior*, *139*, 107545. https://doi.org/10.1016/j.chb.2022.107545

Wang, X., Whalley, W. R., Miller, A. J., White, P. J., Zhang, F., & Shen, J. (2020). Sustainable Cropping Requires Adaptation to a Heterogeneous Rhizosphere. *Trends in Plant Science*, *25*(12), 1194–1202. https://doi.org/10.1016/j.tplants.2020.07.006

Were, K., Singh, B., Milne, E., & Ayaga, G. (2022). Restoration, Sequestration and Modeling of Carbon in Degraded Soils. In *Biodegradable Waste Management in the Circular Economy* (pp. 401–418). Wiley. https://doi.org/10.1002/9781119679523.ch14

Yadav, A. N., Kour, D., Kaur, T., Devi, R., Yadav, A., Dikilitas, M., Abdel-Azeem, A. M., Ahluwalia, A. S., & Saxena, A. K. (2021). Biodiversity, and biotechnological contribution of beneficial soil microbiomes for nutrient cycling, plant growth improvement and nutrient uptake. *Biocatalysis and Agricultural Biotechnology*, *33*, 102009. https://doi.org/10.1016/j.bcab.2021.102009

Yatoo, A. M., Ali, S., Hamid, S., Hassan, B., Zaheen, Z., Ali, M. N., Akhter, R., Amin, I., Mir, M. ur R., Rashid, S. M., & Rehman, M. U. (2020). Role of Soil Biota and Associated Threats. In *Bioremediation and Biotechnology, Vol 4* (pp. 143–165). Springer International Publishing. https://doi.org/10.1007/978-3-030-48690-7_7

Yin, C., Zhao, W., & Pereira, P. (2022). Soil conservation service underpins sustainable development goals. *Global Ecology and Conservation*, *33*, e01974. https://doi.org/10.1016/j.gecco.2021.e01974

Yoro, K. O., & Daramola, M. O. (2020). CO2 emission sources, greenhouse gases, and the global warming effect. In *Advances in Carbon Capture* (pp. 3–28). Elsevier. https://doi.org/10.1016/B978-0-12-819657-1.00001-3

Young, R. E., Gann, G. D., Walder, B., Liu, J., Cui, W., Newton, V., Nelson, C. R., Tashe, N., Jasper, D., Silveira, F. A. O., Carrick, P. J., Hägglund, T., Carlsén, S., & Dixon, K. (2022). International principles and standards for the ecological restoration and recovery of mine sites. *Restoration Ecology*, *30*(S2). https://doi.org/10.1111/rec.13771

Yu, J., & Pedroso, I. R. (2023). Mycotoxins in Cereal-Based Products and Their Impacts on the Health of Humans, Livestock Animals and Pets. *Toxins*, *15*(8), 480. https://doi.org/10.3390/toxins15080480