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Soil and Humans: A Comparative and A Pictorial Mini-Review

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Abstract

Soil is an essential component in the ecological system that supports human life with needed food for humans, feeds for animals, fibres, fuels, building materials, and other necessities. However, soil suffers from a number of problems caused by humans, presented here in pictorial form. This review will take us on a narrative journey through soils with a focus on the soil-human relationship and its impact on soil ecosystems. Soil has direct and indirect relationships to humans, starting with the crucial roles of soil in human life, including its support of human civilization through ecosystem services, sustainable agriculture, and human health. It is essential and urgent to manage soils for health and sustainability by building the soil-food-environment-health nexus. This work is an attempt to highlight major roles that soil plays in human life in a presentation that is more photos and less words, because one photo is worth one thousand words.

Keywords: Human civilization, Soil functions, Soil ecosystem services, Sustainable agriculture, Soil research

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1. Soil and its connection to humans

The uppermost unconsolidated layer of the Earth's surface includes essential and disintegrated components of mineral particles, water, humus or organic matter, and air, and is called soil. Soil interacts with the atmosphere, biosphere, hydrosphere, and lithosphere (**Figs. 1-4**). Soil is the safe-guard of human history and civilizations, with million stories that narrate the soil-human connection (Balks and Zabowski 2016). Every day an enormous number of articles, in different editorial forms and in different journals, are published referring to connections between soils and humans (Baveye et al. 2016). Such contributions include documentary films, social media networks, and popular books and children's literature (Brevik et al., 2022). Aspects of culture can tell us what people think of soil (Patzel et al., in press). Why is soil considered a source of life? The answer may include that soil supplies us with food, feed, fiber and fuel, keeps our ecosystem in balance, absorbs carbon (C-sequestration) and filters water to halt flooding and improve the quality of drinking water (Brevik et al. 2019).

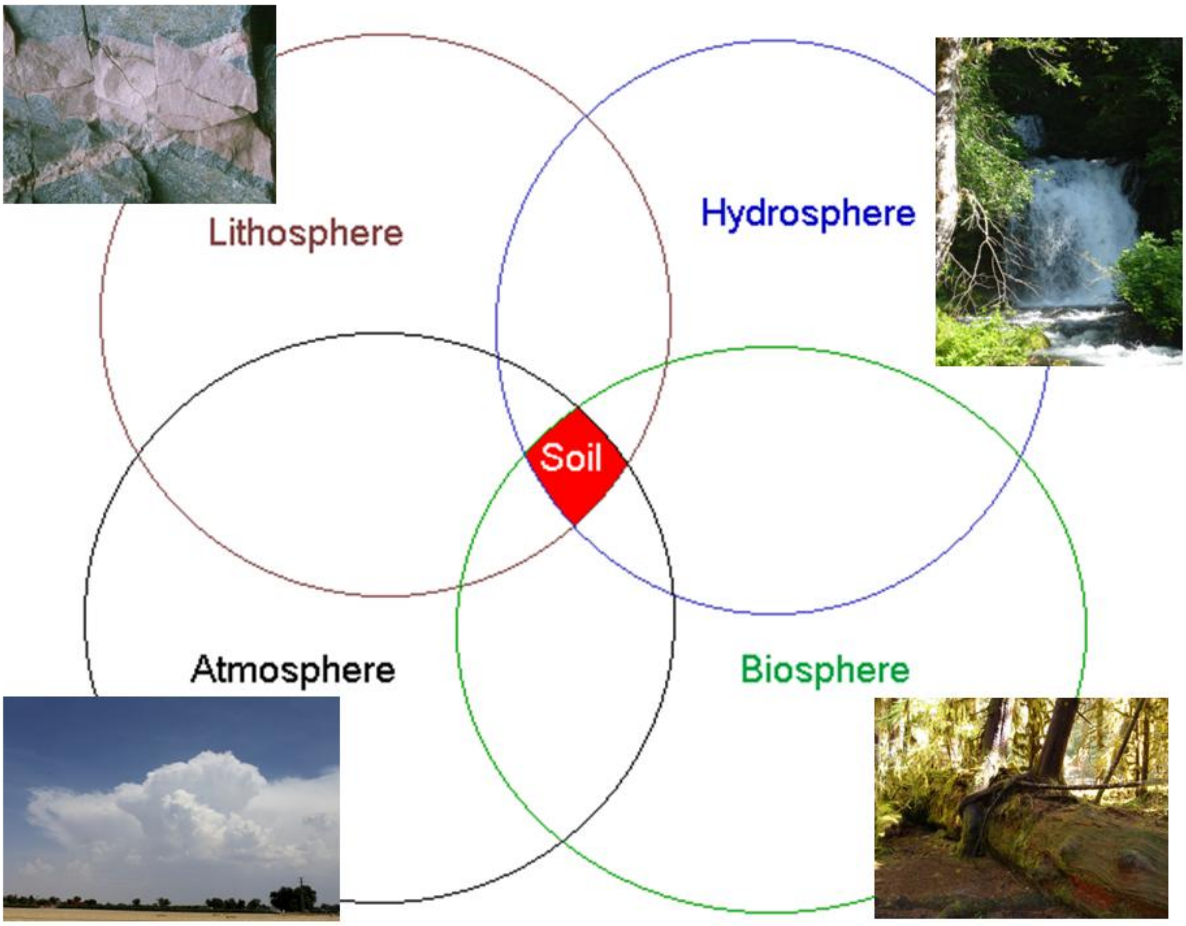


Fig. 1. Soil is found at the intersection of the atmosphere, biosphere, hydrosphere, and lithosphere. Photos by Brevik

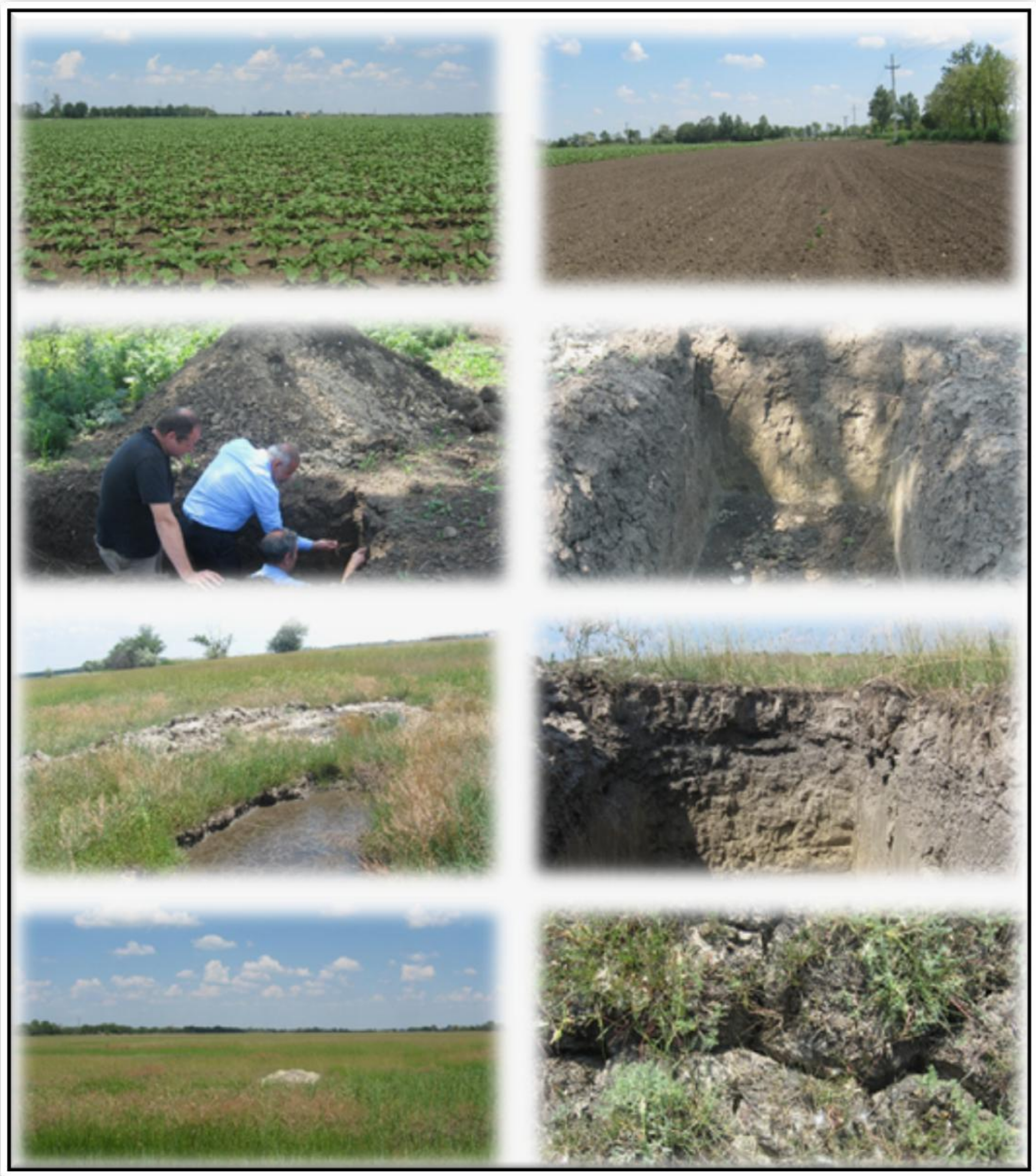


Fig. 2. Salt-affected soils in the Northern Great Plain in Karcag, Hungary, as a characteristic saline soil of waterlogged soils in central Europe. These soils form in dry warm climates with 500 mm or less of annual average preceipation. All photos by El-Ramady

Why is soil so important to us? Over 97% of our food comes from soil. This would be an enough reason, but soil is important in many other ways. Soils provide a range of ecosystem services beyond just food, and support us with feed, energy, shelter, and fibres. The close relationship between soil and humans has been investigated in numerous publications (e.g., Brevik and Pereg 2017; Steffan et al. 2018; Bipin et al. 2019; El-Ramady et al. 2019a, b; Brevik et al. 2020; Brevik et al. 2021; El-Ramady et al. 2021; Oliver and Brevik 2022).

Fig. 3. Some soil profiles visited during the annual meeting of the German Soil Science Society in Göttingen, Germany in 2017. These represented different soils that formed based on their landscape positions. All photos by El-Ramady

Fig. 4. A soil profile, crops being grown in the soils, and the soil landscape at a farm managed by SzentIstván University in Gödöllő (Hungary). All photos by El-Ramady in 2014.

The continuous monitoring and study of soils and their status is very important to building a sustainable future. How can we interact with this natural resource in a way that is mutually beneficial to both soil and humanity? Answering this question will require using modern equipment to characterize the soil, understand changes brought about by human actions, and identify ways that soils and humans can coexist (**Fig.5**).

Fig. 5a: Studying, measuring, and recording the changes in meteorological parameters at an experimental farm in München, Germany. All photos by El-Ramady

Fig. 5b. Soil study using lysimeters in Helmholtz center München, Germany except the last photo (lower right) from the Soil study using lysimeters in Debrecen university, Hungary. All photos by El-Ramady

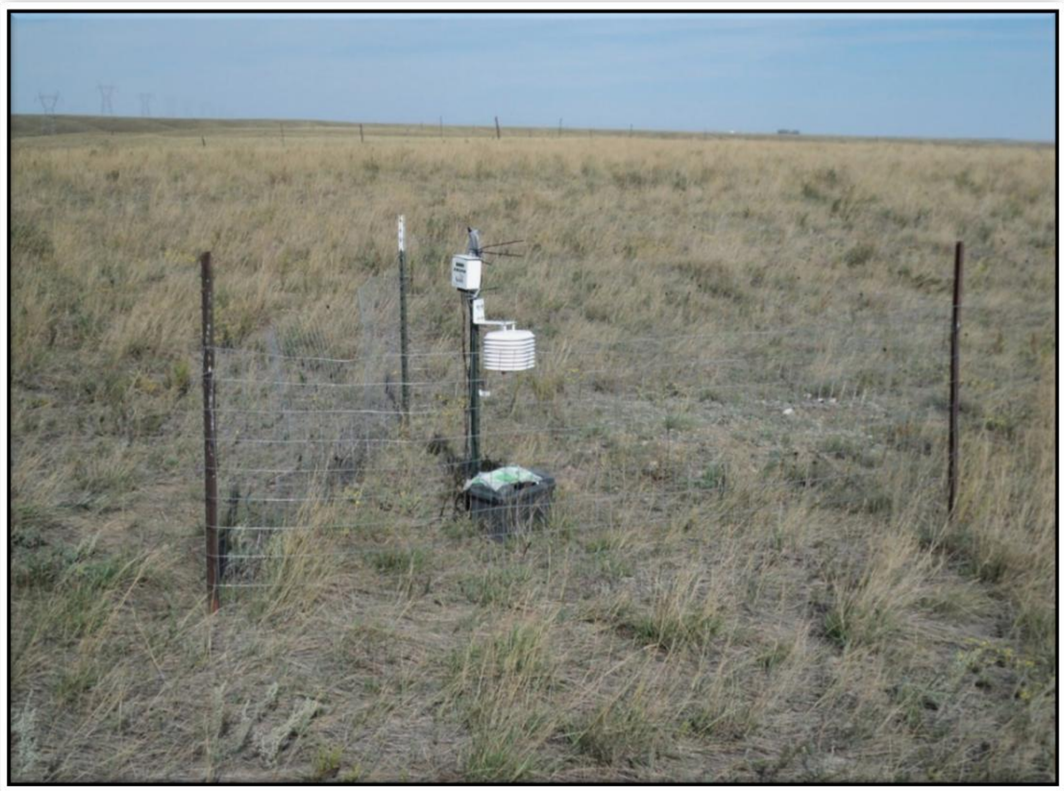


Fig. 5c. Soil moisture and air temperature sensors set up at a study site in Montana, USA. Photo by Brevik

There are many research topics that still need to be considered within the fundamental and applied aspects of soil science, including within the traditional subdisciplines of soil physics, soil biology, soil chemistry, soil mineralogy, and pedology across a range of ecosystems. There are also a number of soil-environment interactions that need investigation such as (1) soil biology and biochemistry, (2) forest, range and wildland soils, (3) newly emerging fields and methods in soil sciences, (4) micromorphology, (5) plant–soil–microbe interactions and their feedbacks, (6) soil biodiversity and microbiology, (7) soil fertility and plant nutrition, (8) soil genesis, GIS and remote sensing, and digital soil mapping, (9) soil geography, (10) soil mapping and evaluation, (11) soil mechanics and hydrology, (12) soil tillage and management, (13) soil-borne pathogens, (14) soil–plant interactions and their feedbacks, (15) soils and food security, (16) soil and human health, (17) soils, global change, and land use change, (18) soil–water relationships, (19) soil-water management and conservation, (20) carbon, nutrient and other elemental cycling, (21) soil degradation, reclamation, remediation and rehabilitation, (22) wetland soils, (23) managing soil and its relationship to recovering from the COVID-19 pandemic, and (24) molecular plant nutrition.

2. What is the difference between soil and human?

The origin of the word human is humus, which means soil (Rozzi et al., 2020). Therefore, in this sense there is no difference between soil and human, because our bodies are formed from the same components as soil, and one day will return to the soil (**Table 1**). What happens to soil often happens to humans as well, because our body and its mental/physical health depends in many ways on the richness of the soil (Brevik et al., 2020). Thus, this is a major reason for the global call for sustainable soil management.

TABLe 1. A comparison between soil and humans

Item (s)	The soil	The humans
The main components	Soil minerals and organic matter contain large amounts of O, H, N, C, Ca, and P, with many other elements also present	99% of the solid portion of the human body is comprised of 6 elements (O, H, N, C, Ca, P), but many others are included
Origin of the name	Soil comes from Latin word “solum" or the ground	Human comes from the word “humus” meaning earth/ground
Respiration	Soil emits CO_2, CH_4 and N_2O; soil air averages N (79%), O_2 (20.6%), and CO_2 (0.2%)	Humans inhale O_2 and exhale carbon dioxide (CO_2)
Digestion	Soil organisms decompose organic materials to release nutrients for plants	Humans digest food in association with the gut microbiome and convert it to nutrients
Is it/he a live?	Soil is living, when contains living organisms (worms, fungi, insect, and microorganism)	Human is considered a live, when can breathe, move, reproduce, eat, etc.
Nutritional supply	Soil nutrition comes from mineral weathering, organic matter decomposition (natural), and fertilization (anthropogenic)	Human nutrition is derived from food produced almost entirely in or through soil, such as edible plants or animal products
Dependence on each other	Soil can exist without human activities	Humans cannot survive without soil, it is the main source for the sustenance of humans

3. What are the crucial roles of soil for human life?

As mentioned before, soil not only plays a great role in all our lives, but it is also life itself, because without soil there is no life. The crucial roles of soil in human life have existed since the earliest civilizations (**Fig. 6**). For example, the ancient Egyptian civilization flourished due to alluvial soils and the water of the Nile River. Soil is also the biggest reservoir for biodiversity. Human culture, health, and social behavior are highly influenced by the soil (Bipin et al. 2019). This section will highlight the roles of soil in human life including human civilization, soil ecosystem services, and sustainable agriculture.

3.1 Soil and human civilization

There is a strong link between soil and human civilization, which is likely to become stronger in the future due to the increased anthropogenic demands on world soils. This is particularly due to the increase in the world population (**Table 2**). The first civilizations depended on soil and water (i.e., hydraulic civilizations), and thrived in the valleys of the Tigris, Euphrates, Nile, Indus, and Huang rivers, among others (Lal 2007). Many reports confirmed the role of soil in thriving many civilizations like the Egyptian civilization (**Figs. 6 and 7**) from more than 3000 BC, such as Lal (2007), Minami (2009), Brevik et al. (2018), Bipin et al. (2019), and Dazzi and Lo Papa (2022). The Egyptian civilization derived its strength from fertile soil around the Nile River during the periods and dynasties of ancient Egypt.

TABLE 2. World population over time and its expected levels up to 2100 (in billions)

Year	Christian era (CE)	1600 CE	1850	1950	1987	1999	2011	2020	2023	2030	2050	2100
Population of world	0.300	0.600	1.25	2.6	5.0	6.0	7.0	7.8	8.0	8.5	9.7	11.0

Source: After Lal (2007) and https://www.un.org/en/global-issues/population accessed on 3.6.2022

Fig. 6. Some photos of the most visited tourist locations in Egypt (Khan Khalili in Cairo and the pyramids area in Giza), which have several statues, papyrus, and more as symbols of the Egyptian civilization. This civilization was maintained and sustained by alluvial soils and the water of the Nile River. All photos by El-Ramady.

Fig. 7. Some of the main Egyptian civilization sites in Luxor, Aswan, Cairo, Giza and Alexandria, which represent different periods and dynasties of ancient Egypt beside the Nile River, which was the supporting source of this civilization. All photos by El-Ramady

3.2 Main soil functions and ecosystem services

Soil has many functions, which represent its capability to provide various environmental, agricultural, landscape architecture and urban applications. These soil functions are mainly linked to agricultural productivity, environmental quality, natural ecosystems, soil as a source of raw materials, and as base for buildings (**Fig. 8;** Lal 2007, 2008).

Fig. 8. Possible soil functions pictures: photos from upper left: Soils are essential to grow crops for food, feed, fiber, and fuel. North Dakota, USA, upper right: Wetlands are important for the natural filtration of water. Iowa, USA. Lower left: In some instances, clearing land for agricultural production has led to massive gully erosion. Sustainable land management is very important. Georgia, USA. Lower right: Soils are important foundation materials for engineered structures. France. All photos by Brevik

Specifically, the key soil functions have been identified as (1) production of food and other biomass; energy needs and biofuels, (2) regulating water supplies, its purification, water loss, and utilization, (3) biological habitat and gene pool, provision of nutrients, water, and heat, (4), as a source of raw materials, (5) physical and cultural heritage, protecting and preserving the physical artifacts of ancient nations for better understanding of cultural heritage, (6) platform for man-made structures and source of raw materials, (7) management for biodiversity and ecosystem functions, (8) regulating and mitigating climate changes, (9) a medium for waste disposal, (10) mapping soil functions, (11) soil as a carbon recycler, and (12) fiber production (van Leeuwen et al. 2019; Vogel et al. 20119; Baveye et al. 2020). There are many soil ecosystem services that benefit humans, including (i) cultural aspects (aesthetics, knowledge, recreational, sense of place and spirituality), (ii) provision aspects (fiber, food, physical support, water and wood), and (iii) regulation (biological control of pests and diseases, carbon stock/sequestration and regulation of N_2O and CH_4, water purification, mitigation of floods, drought and landslides, nutrient filtration, waste recycling and detoxification), as reported by Rodrigues et al. (2021). Additional studies have proposed and developed conceptual frameworks and classifications of soil ecosystem services such as Robinson et al. (2013), Pereira et al. (2018), Baveye (2021), and Farfan& Wall (2022).

Recently, many studies have been published with a focus on soil ecosystem services including themes such as soil biodiversity (Farfan and Wall 2022), fresh water and its filtration by soil (**Fig. 9**; Han et al. 2022), water resources and supply-demand (Li et al. 2022), climatic warming and biodiversity losses (Kattel 2022), climate change and land use (Gao et al.

2022), etc. Soil biodiversity can contribute to many ecosystem services including water filtration, nutrient cycling, carbon storage, pest control, and soil stabilization, all important global issues for human well-being. Recently, several molecular techniques have been employed to understand global distributions and changes in soil biodiversity. There are many factors affecting soil biodiversity like organic materials and climate changes. Understanding the threats to soil biodiversity is an important issue for conservation of this vital resource for human life (Farfan and Wall 2022).

Fig. 9. Soil has a vital role in regulating fresh water and its filtration. These photos show irrigation canals and rivers, which are important for agriculture (Shoubra, Cairo, Egypt the 2 upper photos), Halle Saale in the two middle photos (Germany), Gyöngyös in lower photo right (Hungary), Braunschweig in lower photo left (Germany). All photos by El-Ramady.

3.3 Soil for sustainable agriculture

Soil is the most important component in our agro-ecosystems, which can sustain human life as the ultimate source of mineral nutrients for humans and other organisms. Soils have direct and/or indirect links to the 17 global sustainable development goals through their relationship to issues such as crop productivity, environmental sustainability, and human health. Sustainable soil management is a great challenge facing the future of global food security. This should include appropriate practices for soil conservation and proper nutrient management, eliminate any further soil degradation by pollution or erosion, and produce sufficient, safe, healthy and nutritious food. These approaches may require integrated agro-systems like using the wastes from animal husbandry farming to produce organic fertilizers and biogas (**Fig. 10a, b**). Many studies have investigated topics such as improving the N-use efficiency of crops (Elrys et al. 2022), healthy soils for sustainable urban agriculture (Salomon and Cavagnaro 2022), soil conditioners for sustainable agriculture (Babla et al. 2022), nanoremediation (Boregowda et al. 2022), zero tillage for sustainable agroecosystems and food security (Hassan et al. 2022), and biochar for sustainable management of soil (Song et al. 2022; Wang et al. 2022).

Fig. 10a. A completed and integrated agricultural system, which can produce important products for human life. These photos represent the production of dairy milk through animal husbandry. Organic manures and animal wastes could be collected for manufacture of biogas or use as a crop nutrient souce. All photos from a farm in Göttingen, Germany by El-Ramady

The use of greenhouses in agricultural production to control the crop production environment is considered a promising approach to create more food production with an increasing population that strains available arable land resources (**Fig. 11**). The traditional greenhouses in arid zones around the world have several obstacles or problems including soil salinization and decline of soil fertility. Soil acts as a source and sink for greenhouse gases (GHGs) including CO_2 (35%), CH_4 (47%), N_2O (53%), and NO (2%1) of GHG emissions quantified as global budgets (Oertel et al. 2016). Many agricultural practices can reduce the GHGs from soil such as soil mulching (Wei et al. 2022), soil amendments like biochar (Farid et al. 2020; Yang et al. 2022), and zero tillage (Virk et al. 2022). However, poor soil management can also release greenhouse gases into the atmosphere (Brevik, 2012).

Fig. 10b. An integrated agricultural system that produce products necessary for human life. These photos represent the production of organic manure from animal husbandry. These manures could be used in manufacturing biogas and increasing soil fertility. All photos from a farm in Göttingen, Germany by El-Ramady

Fig. 11. The agricultural production under protected conditions or greenhouses in different forms is an important but challenging issue for sustainable agriculture. These photos show field covers (upper left), high tunnels (upper right), and different types of greenhouses in Gödöllő (Hungary) and in Bari (Italy). The importance of natural soil varies in these systems. All photos by El-Ramady

Agricultural machinery are important devices that can be used in farming or other agricultural practices. There are several types of equipment, which include hand or power tools, tractors and the countless kinds of tools that tractors tow (**Fig. 12**). Agricultural mechanization has greatly improved the efficiency of several operations in the field (Parvin et al. 2022), but heavier agricultural vehicles have increased soil compaction and stress risks (Keller et al. 2019; Mileusnić et al. 2022). The increased ability to till the soil has also led to the release of greenhouse gases through soil organic matter decomposition (Brevik, 2012).

Fig. 12a. Agricultural machinery is very important for modern agriculture. It can be used in several practices such as multipurpose machines at SzentIstván University, Hungary. Photo by El-Ramady

Fig. 12b. Large modern agricultural equipment can create severe compaction and related problems in soil, such as during installation of drain tile near Fargo, North Dakota, USA. Photo by Brevik

4. The soil - human health nexus

There are several links between soil and human health including food security, essential nutrients, beneficial organisms, exposure to pollutants and pathogens, medications, and clean water. Soil biological, chemical, and physical properties and processes are very important for human health (Oliver and Brevik 2022). A common example of how soils influence human health is the transfer of nutrients from soil to people *via* plant and animal sources as well as through direct ingestion (**Fig. 13**).

There are many soil-derived products that are used for human health. These can be grouped into soil minerals as a source of essential elements to the human body, healthcare products, fangotherapy which uses peat and clay for healing purposes, and a variety of benefits from soil micro-organisms, such as medicine production (Nieder et al. 2018). Soil is also a potential source of clean energy, where the ability of the soil to perform as a battery is being considered as an emerging research field (Bipin et al. 2019).

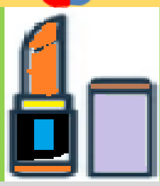
Soil minerals as therapeutic agents		**Oral administration**	Mineral Supplements Anti-acids Gastrointestinal Protectors Anti-diarrheic Osmotic Oral Laxatives Direct Emetics Anti-anemics Homoeostasis
		Topical administration	Decongestive Eye Drops Anti-inflammatories Antiseptics and Disinfectants Dermatological Protectors Keratolytic Reducers
		Parenteral administration	Parenteral therapy as anti-anemics and homoeostatics
Soil minerals as excipients		Common excipients are phyllosilicates (clays)	
Soil minerals as cosmetic products		Toothpaste Sun protection products Creams, Powders and Emulsions Bathroom Salts and Deodorants	
Soil materials for fangotherapy (using peat and clay for healing purposes)		Peat Clay Therapies	Mud Packs Mud Bath
Soil microbes		Drug producers Probiotics Enzyme producers	
Geophagia		Nutritional Aspects Microbiological Benefits Immunological effects	

Fig. 13. Examples of medicinal uses of soil components (adapted from Nieder et al. 2018)

There has been considerable recent interest in the nexus of soil and human health. Topics covered have included soil biodiversity and human health (Wall et al. 2015), climate change and biodiversity (Kattel 2022; Shivanna 2022), soil and water pollution in relation to human health (Abdelhafez et al. 2021a; Bech 2022; Gonçalves et al. 2022), and complex systems such as soil-human health and the land-water-energy nexus (Onabola et al. 2022), water–energy–food nexus (Bian and Liu 2021; Correa-Porcel et al. 2021; Fernández-Ríos et al. 2022; Moreira et al. 2022; Sorek et al. 2022; Yin et al. 2022), soil-food-environment-health nexus (Gu et al. 2021), climate change-food security-human health nexus (Schnitter and Berry 2019; Samberger 2022), and water-energy-nutrients-food nexus (Haitsma et al. 2022). Soil and human health include both positive and negative influences of soil. Soil pollution in locations like urban areas, mining and industrial sites, battlefields, and agricultural fields has caused problems for human health (Brevik et al. 2020). Soil microorganisms have major impacts on human health, which may include or control soil-borne pathogens (Mohamed et al., 2018; Eid et al. 2019; Abdelhafez et al. 2021b). More information on this nexus can be found in the review by Brevik et al. (2020) and the numerous references they cite.

5. Conclusions

This is a photographic mini-review about the soil and its relationship to humans. This work is an attempt to let the photographs talk more than the words by presenting many photos that show aspects of the soil-human relationship. The main topic of the work is discussing the soil and how it is similar and/different from humans, the crucial role of soil for human health, the main soil functions and ecosystem services, and the role of soil in sustainable agriculture.

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