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EDITED BY
Sören Thiele-Bruhn,
University of Trier, Germany

REVIEWED BY
Jiangbing Xu,
Nanjing University of Information Science and Technology, China

*CORRESPONDENCE
Pranay Arora,
pranay.arora@student.manchester.ac.uk

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Life below land: the need for a new sustainable development goal

Pranay Arora*

Department of Earth and Environmental Sciences, The University of Manchester, Manchester, United Kingdom

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Introduction

Sustainable development goals (SDGs) are a set of seventeen goals adopted as United Nations (UN) agenda for 2030, which provide a blueprint for a sustainable future not only for humans but a diversity of life forms on earth (United Nations, 2023a). The seventeen goals, aim to work towards building a stable and safe environment for coming generations. The goals are interrelated in multitudinous ways and working towards one goal can affect the progression of other goals as well. SDGs were adopted by the UN in 2015 and were hailed as a landmark decision that can have a concrete effect on how we work towards sustainability.

There is no denying that after the adoption of SDGs the work related to sustainability has improved but as we move on, there is a constant need to re-look and assess the situation. While assessing the SDGs and the present scenario, it seems that we have missed on a very important aspect of sustainability of life on earth. It is vital to adopt or introduce a new sustainable development goal, "Life Below Land." This includes the whole lot of biodiversity found in soil around the globe and consists of microfauna (e.g., Rotifers), mesofauna (e.g., Collembola and mites), macrofauna (e.g., earthworms), protists (protozoans, algae, and slime moulds), photosynthetic organisms (such as algae), fungi and microorganisms (including eubacteria, archaebacteria). All these species interact in numerous ways impacting the formation of soil, its health and quality, making research in this area one of the most important issues in order to achieve the targets of SDGs. This article aims to showcase the importance of soil biota, analyse the impacts of anthropogenic activities on this hidden world beneath us, and consequently elucidate the importance of a new SDG.

Proposed SDG and its linkages with other goals

Soil ecosystems are the richest component of Earth's reserve of biodiversity. Soil harbours more than 25% of global biodiversity. Additionally, more than 40% of organisms that live on terrestrial ecosystems rely on soils during their course of life (United Nations, 2020).

Soil health is defined as its ability to support plant and animal growth. Soil harbours organisms from all the five kingdoms of the living world, which are intricately associated with each other to ensure its health and that of other ecosystems on Earth. The human population is expected to reach 9.7 billion by 2050 (United Nations, 2023b). This will increase the pressure on soil ecosystems for achieving targets of food security (SDG 2, Zero Hunger), making soil health an important issue. Studies have shown that the relationship between soil biodiversity and health are directly linked to goal 2, as soil influences around

95% of total food consumed. Veerman and Pinto Correia (2020) defined soil health as "the capacity of soils to contribute to ecosystem services in line with the UN-SDGs and the EU Green Deal." Land degradation is inherently linked to soil quality and the land-poverty nexus is ambiguous with unidentified dynamics. Heger et al. (2020) determined a positive relationship between income and land quality. Degraded soils impose negative impact on agricultural and environmental income as well as economic status of rural and tribal population. The goals: SDG 1 "No Poverty" and SDG 8 "Decent Work and Economic Growth" can only be achieved if quality of soil is maintained and "hidden harvest" associated with livestock rearing and forest management are regulated to alleviate poverty.

Soil microbial diversity has been shown to have a positive link with soil functions across all biomes. Organisms from all the five kingdoms combine to cycle important macro and micronutrients in the soil. These macronutrients are vital for crop growth and soil sustainability (Jacoby et al., 2017). Land degradation is characterized with soils deficient in nutrients and essential minerals, impacting soil living component. Various extreme weather events such as droughts, floods and heat/cold waves further lower the soil quality impacting the goal 3 "Good Health and Well being." An overwhelming part of our food calories come from soil, however, the role of soil health and management of soil diversity are not explicitly mentioned in SDGs and require special attention.

Soil macrofauna (like earthworms, ants, termites, etc.) are ecosystem engineers influencing soil structure, composition, and hydrology, impacting the flow of nutrients and energy in the system (Sofo et al., 2020). Soil microflora perform some exclusive activities. For example, symbiotic and asymbiotic Nitrogen (N) fixation is one of the most important biochemical processes of soil and microbes are the key players who accomplish it. Various species of nitrifying, denitrifying and anammox microbes participate in the N-cycle. These organisms interchange N in gaseous, organic, and inorganic forms, making them readily available to plants (Hayatsu et al., 2010). Major micro and macro-fauna groups including protozoans and nematodes play important role in N-cycle by increasing N-mineralisation by 8%–19% (Nadarajah, 2019). Similarly, phosphate solubilizing microbes (PSMs) present in soil solubilize inorganic Phosphorous (P), making it available to plants. PSMs also store P in biomass, which can be used by plants (Tian et al., 2021). In the Carbon (C)- cycle, microbes can fix as well as release C (mostly CO_2) from/into the atmosphere. Photoautotrophic and chemoautotrophic microbes in soil are effective CO_2 removers from the atmosphere and have a crucial role in natural C-sequestration. Respiring microbes, on the other hand, release CO_2 into the atmosphere. Overall, there is a net C removal by soil microbes making their conservation important (Gougoulias et al., 2014). The beneficial role of soil biota in recharging the nutrients cycling and status of soil can help in achieving targets of several SDGs (Goal 1 "No Poverty"; Goal 2 "Zero hunger"; Goal 3 "Good Health and Wellbeing"; Goal 4 "Life on Land", Goal 5 "Climate Action").

Soil organisms are involved in symbiotic relationships with above-ground plants and animals, while there are intricate associations within the soil communities also. Endophytic microbes like members of family *Rhizobiaceae* (among bacteria) and arbuscular mycorrhizal (AM) fungi form intimate relationships with diverse plant species helping in their survival and improving soil health. These relationships have evolved over the years and are governed at molecular level. Legume-rhizobia association fixes approximately 40 million tonnes of N each year, therefore it is an important part of N-cycle and also results in lesser dependence on N fertilizers (Udvardi and Poole, 2013). These associations of "Life Below Land" with "Life on Land" (Goal 4) show their close inter-relationship, which is ignored in the SDGs. The goal "Life on Land" targets the implementation of sustainable techniques to manage terrestrial and inland freshwater ecosystems covering forests, grasslands, wetlands and marginal lands. However, there is no mention of soil biodiversity in the sub-targets of the goal. The data on Inter Cycle Organism Interaction (ICOI) for various nutrients is almost negligible. Therefore, monitoring soil health and quality in the proposed goal will also help in monitoring the status of different soils.

Goal 13 "Climate Action" focuses on designing of policies or strategies and creating awareness about climate change mitigation, however, soil diversity and its importance is neglected. Soil biodiversity controls plant growth, increase soil multi-functionality, and makes soil as well as above-ground communities more resilient to climate change (Chamorro-Martinez et al., 2022). Introduction of this goal would provide better understanding of agricultural sustainability and ensure holistic approach to mitigate climate change and sustain the life on land. Life below land is one of the biggest sink of carbon on land and ensuring its sustainability will play crucial role in managing climate change.

Even though there has been an increase in the understanding of soil communities in recent times, there is still a gap in the knowledge of community interactions, functions and fluctuations due to anthropogenic activities. According to WHO (2021) one-quarter of human deaths are directly or indirectly associated with climate change and pollution. Soil pollution is correlated with atmospheric and hydrospheric pollution due to natural circulation of matter. Soil is the major depositor and accumulator of various pollutants, including powders in the air and toxic gases, transformed and transported by precipitation. Water and soil are also essential for the establishment of life on land and their continuous interactions govern agro-stability. Several blind spots remain in spatial, environmental, taxonomic and functional relations of soil biota due to limited technology, research and documentation. Huge gaps in data between soil biodiversity and functions were found by Guerra et al. (2020) in samples between different regions. Ever since last green revolution use of agro-chemicals has polluted the soils and pollutants were carried from soil to water bodies causing eutrophication and water pollution. Heavy metals and plastics are other pollutants finding their way through soil ecosystems. Therefore, Goal 6 "Clean Water and Sanitation," Goal 11 "Sustainable Cities and Communities," Goal 12 "Responsible Consumption and Production," and Goal 14 "Life Below Water" can only be achieved if soil ecosystem is stable and its health is monitored. Figure 1 highlights the linkages and role of proposed goal with the existing SDGs.

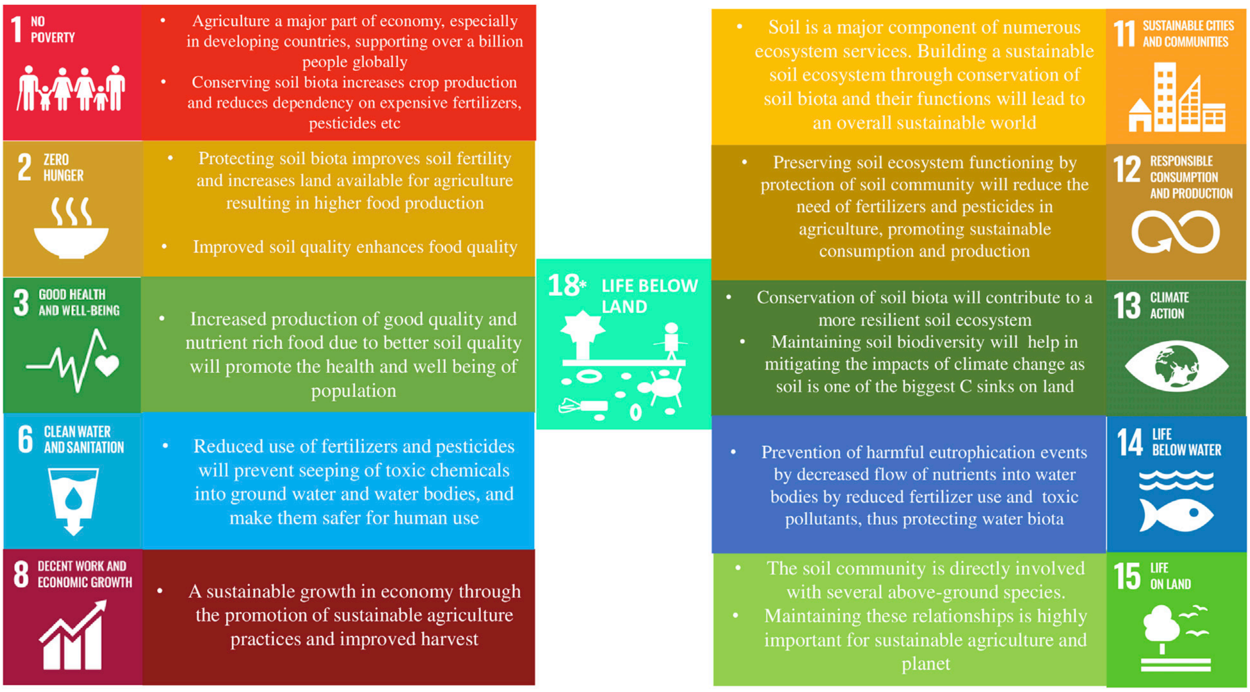

FIGURE 1
The proposed goal "Life Below Land" intercately links and impacts other SDGs in positive ways.

Anthropogenic impacts on soil biota

Human activities have impacted almost all the spheres on Earth including soil ecosystems. Although the gap in knowledge about anthropogenic impacts on soil biota and its functioning is still high, enough studies have been done to show that the current situation is threatening for the future of the planet. Soil functionality is directly related with organism abundance and diversity, however, anthropogenic factors are resulting in a loss of soil species, which can be very harmful for sustainability (Yang et al., 2022). A constant decline in the ability of soils to promote plant productivity has been observed in regions of central and southeast Europe for the past few decades due to increase in human activities (Günal et al., 2015). Same can be said about the soils in other parts of the globe, however, lack of studies limit the knowledge on the extent of damage done.

Impacts of land-use change have been studied across different regions of globe. While some studies show that the impact of land-use change is only on the soil microbial structure rather than the soil function (Bissett et al., 2011), others show a shift in microbial community across different land management systems (Suleiman et al., 2013). Data has revealed that soils can sequester about 20 Pg C in 25 years, which is more than 10% of anthropogenic emissions (FAO, 2023). Intensive land-use conversion and agricultural practices have led to a decline in soil C, N, and P content, altering the soil pH, microbial community structure and depletion of substantive soil C stocks (Sui et al., 2019). This has resulted in a higher amount of C-loss from these soils, further intensifying the rise in GHG emissions (Malik et al., 2018). Similarly, increasing intensification has also resulted in a decline of microbiome network complexity in global soils due to loss of bacterial, fungal, and protist species (Romdhane et al., 2022). Agricultural land-management techniques like conventional tillage negatively affect soil biodiversity by impacting availability of organic matter and affecting decomposition rates, leading to GHG emissions (Hassan et al., 2022).

Human activities have affected the soil biota through impacts on the global biogeochemical cycles. Increase in N-input through fertilizers has resulted in an exponential rise in N_2O emissions from soil due to increased microbial activity (Shcherbak et al., 2014). N_2O is a significant GHG, and its warming potential is 100 times more than that of CO_2, making its release from soils catastrophic for the future. Increased artificial N-concentrations also enhance P-mobilization by improving PSM activity; the extra P produced gets washed away and reduces P-availability in the soil (Marklein and Houlton, 2011). Global warming has also resulted in a rise in soil-borne phytopathogens, specifically fungi. Their distribution is expected to rise even further at global level as the warming continues (Baquerizo et al., 2020). Enhanced mobility of pathogens can result in increased frequency of crop failure, further stressing the soil ecosystems. In addition, injudicious use of fertilizers contributes to soil pollution and soil salinization. As per data, there are over 5 million sites globally with soils contaminated with toxic elements (Khan et al., 2021). Soil salinization renders 1.5 million ha of farmland per year out of production and decreases the potential of land by up to 46 million ha per year (FAO, 2022). Soil degradation rates due to anthropogenic influence are 100–1,000 times faster than natural erosion rates. (United Nations Convention to Combat Desertification, 2022). A report by United Nations Convention to Combat Desertification

(UNCCD) (2022) revealed that about 40% of global land has been degraded, affecting half of humanity as well as half of global GDP. This is not only linked to loss of soil biota but will also speed-up the loss of soil nutrients in future, thus proving detrimental for food production. Climate change related events like droughts, floods, high and low temperatures, cyclones, etc., are also expected to rise in the future. These events have direct and negative influence on soil biota in various ways and result in changes in soil community structure (Preece et al., 2019).

Strategies and targets for the proposed SDG

Identifying the impacts of anthropogenic activities is important for achieving soil sustainability and requires a significant increase in research in this area. The impact of climate change on below-soil surface biodiversity is greater than the above ground systems. However, its richness is rather poorly studied and is often neglected while designing the models of climate action plans or adaption studies. This is high time to introduce red list of soils and their associated biodiversity across the globe through Geographic Information System (GIS) or creating database sharing spectra of soils. Apart from mapping the soil in terms of biodiversity, the quality of soils can be related with anthropogenic activities, pollutants concentration, and deforestation rate, to elaborate the role of secondary activities in degrading the land and examine the progress made over time. The investigation of various soil parameters, through the proposed SDG, can help in preparing a database with record of soil biodiversity, nutrient content and carbon sequestration for achievement of carbon neutral ecosystems. Establishment of national and international repositories, safeguarding the data of soils from fragile and extreme ecosystems can help in conserving them, as in these ecosystems life below land is the main reason for the existence of life on land. Furthermore, soil maps can also be a potential tool to determine the links between soil and human health and these perspectives can be a holistic approach to sustainability.

The main targets of the proposed goal can include the following:

- to ensure conservation and restoration of soil micro/macroflaura
- ensure the mapping of soil health in both arable and non-arable lands and ensure a soil health card that includes biodiversity to monitor the sustainability efforts over time
- take urgent action if the quality of soil is highly degraded or getting degraded; hotspots of degraded soil systems can be listed in the red list to prevent irreversible damage to soil ecosystem
- identify the hotspots of the unique and fragile biodiversity regions of earth and ensure their conservation
- soil biodiversity indexing to monitor its fertility and life content

Conclusion

Soil health and quality directly depends on the soil communities, and therefore, the importance of spreading awareness about them has to be increased among the masses. The services offered by soil biota are priceless and cannot be replicated through any technology. Therefore, making effective policies regarding preservation of non-polluted and restoration of contaminated or degraded soils is very important. The success of the 17 SDGs in terms of increasing awareness and policy making is visible globally. However, soil biodiversity has often been overlooked and is not well represented in any of the existing SDGs. Even at the recently held COP15 Biodiversity summit, the focus was on the above-ground biota. Hence, improving soil sustainability can be achieved by recognising a new SDG focussing on "Life Below Land." This goal has linkages with other SDGs and working on it will have positive impacts on all the goals. In addition to these, the proposed goal will also introduce some new aspects and strategies for sustainability. Therefore, UN needs to include new targets to cope up with the developing scenario to achieve sustainability. After all survival and health of humans is directly dependent on the soil and its quality.

Author contributions

PA came up with the idea, worked on the manuscript and figures, did the literature analysis, and completed all the requirements of the manuscript.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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