

SOIL BIODIVERSITY AND SUSTAINABLE FUTURE

Parikshit Tyagi

The backbone that supports life on land and water, production of food, emending pollution, regulation of climate, maintaining and cycling of nutrient – Soil is the home to 25% of the total earth's biodiversity. There are many scenarios where soil biota can clearly support global sustainability targets, global changes and pressures that threaten soil biodiversity. With the rise in world's human population and as it continues to rise, it is first and foremost to respect and protect natural resources that including soil, water, air, minerals, and biodiversity supporting life throughout on Earth. The remarkable pressure on global systems has been observed due to current rates of consumption and inadequate management of resources and it is also a fact that the land has been degraded globally. Land degradation for the obvious reasons has negatively affected people, threatened sustained human well-being and is a major contributor to climate change and biodiversity loss. Broadly, these agendas address areas to improve human life and environmental sustainability, rely on the participation of all countries and stakeholders, and will require innovative, timely, and interdisciplinary approaches. Soils are central to supporting natural systems and human well-being, yet to date soil biodiversity—the diversity of life in soil which drives ecosystems, sustains life aboveground, and maintains healthy landscapes—has remained largely overlooked in global agendas. For example, the term 'soil biodiversity' does not appear in any UN documentation while forests, wetlands, rivers, and drylands have received specific attention to their benefit. Soil-dwelling organisms, including bacteria, fungi, nematodes, earthworms, moles, and even plant roots, contribute the majority of

living biomass on Earth and represent more than 25% of all described species, not to mention the genetic diversity represented within these species. The activity and complex interactions of soil organisms provides the backbone for many ecosystem functions, including nutrient cycling, pathogen control, water infiltration, foundations to food webs, and supporting agroecosystems. Our understanding of the critical connections between soil biodiversity and sustainability are rapidly progressing. The time has come to incorporate this knowledge to bolster global actions and create a more holistic sustainability agenda that can simultaneously address biodiversity loss, climate change, and land degradation. Like most of the resources humans rely on, soils and soil biodiversity are under threat by land degradation, climate change, pollution, urbanization, and over-use and misuse. Soils are a finite, non-renewable resource because they cannot be replenished within a human lifespan. The formation of soils relies on a complicated balance between time, climate, topography, the underlying parent material, and of course organisms. Therefore, timing—the swiftness in which we act to protect soils—is crucial. Several global efforts have recognized the urgency with which we must act. For example, the Global Soil Biodiversity Initiative launched in 2011 to bring together researchers and policy makers to integrate the knowledge we are gaining with actions for a sustainable future. Integration of soil for nature and global sustainability largely focused on soil's physical and chemical properties with little consideration for biodiversity. Despite this energy, more must be done to recognize and integrate the role of soil biodiversity in building a sustainable future. For example, the

majority of soil biodiversity research examines diversity at a community level, across species and trophic levels; however, diversity within species is a critical component of biodiversity which has been all but ignored in soil habitats. Despite the important role soil biodiversity plays across ecosystems, soil organisms face many of the same threats as aboveground organisms and receive far less research, media attention, and legal protection. Habitat loss from land-use change, climate change, and invasive species, both above and belowground, are as challenging for soil organisms as they are for terrestrial and aquatic organisms. Habitat loss is the primary threat to soil biota. Agriculture is the largest driver of habitat loss and biodiversity declines globally, including land conversion to agricultural use and management practices within agroecosystems. Conversion of Amazonian forest to agricultural land-use results in the homogenizations of soil

bacterial communities and loss of soil fungal diversity as well as reductions in macrofauna. Agricultural fields support smaller and less diverse soil communities than forests and grasslands and agricultural intensification further reduces soil biodiversity, particularly larger bodied organisms (e.g., invertebrates). Even reduced tillage systems typically host less soil biodiversity than natural ecosystems. In addition to agricultural land use changes, urbanization and suburbanization leads to the destruction of soil habitats through building construction and pavement which results in soil sealing. Habitat quality can be degraded through pollution, including excessive nutrient inputs, and invasive species. Increased N inputs, from atmospheric deposition or from direct fertilizer application, is also a form of pollution and can shift soil bacterial communities and decrease overall microbial activity. Habitat quality can also be impacted by invasive species. Invasive



plants can alter belowground communities through release of exudates toxic to some soil organisms. In other situations, soil organisms can be invasive species, reducing plant fitness and animal diversity and abundance. However, habitat loss and degradation are not the only threats to soil biodiversity. Climate change is the paramount challenge of our generation, and soil biota are impacted like all other life on Earth. Climate change includes a suite of environmental changes including atmospheric concentration of greenhouse gases, namely CO₂, precipitation quantity and frequency, and temperature. Globally, these variables are predicted to shift in different directions and magnitudes. A meta-analysis of soil microbial community studies found soil fungal abundance responses to elevated CO₂ varied by taxon and ecosystem [90]. Altered precipitation regimes impact insects, both above- and belowground. In an Australian grassland, summer drought periods corresponded with increased aboveground insect plant predator populations the following spring, but no changes in belowground invertebrates. Temperature impacts soil communities in unique ways as well. Increased temperatures impact soil biota

physiologically. An exotic species was more tolerant of higher temperatures than native springtail species, potentially increasing the risk that exotic invasive species could usurp native soil communities as climates change. Given the numerous interacting consequences of global climate change and the hyper-diversity of soil communities, there are many uncertainties in understanding climate change impacts on soil biodiversity. Opportunities exist to protect and support soil biodiversity, which in turn sustains the diversity of life on Earth, including humanity. Many actions that support biodiversity aboveground also support biodiversity belowground. Because soil biodiversity is woven into many facets of ecosystems, explicit consideration of soil biodiversity can provide a holistic approach to advance many components of global sustainability agendas. Protecting existing natural areas, restoring degraded habitats, employing sustainable agricultural practices, and embracing urban biodiversity are all practices that reinforce and sustain diverse soil communities and the functions and services they provide across all ecosystems (Figure 3).

Natural area protection and management is critical to sustaining biological diversity, both above and belowground. Many land management decisions are driven by above-ground plants and animals, but soil organisms can provide an important focus for natural area management. Restoring belowground communities can stabilize soils and reduce erosion, and provide additional benefits in restored ecosystems, including faster recovery of soil C pools in restoration with high plant diversity compared with low plant diversity. Sustainable food production is essential to the future of humanity and nature on Earth, and as outlined above, soil and the biodiversity within it is the foundation of sustainable future. Sustainable agricultural actions focused on soil biology are needed across cultures and farming contexts. Soil biodiversity is at the heart of sustainable agriculture, supporting crop and livestock production across all types of systems with fewer inputs that are costly to farmers and impact non-target species and habitats. Recognizing soil as complex, biological ecosystems that support sustainable agroecosystems, rather than input/output systems to be optimized is a critical perspective necessary to advancing a sustainable future.

There are many ways to support and encourage soil biodiversity in urban areas. Green spaces support the most soil biological diversity in cities. Prioritizing green space in urban planning is an important way to maintain soil biodiversity and retain the ecosystem benefits it provides. In planning urban space use, including parks, using mulch for ground cover instead of rock increases earthworm abundance and reduces surface temperature [139],

increasing water infiltration and alleviating “heat island”. In addition, thoughtful urban development choices that ‘build up not out’ can be an important tool for protecting soil biodiversity and ecosystem services not only in urban areas, but also preventing conversion of natural areas and productive agricultural land. A co-benefit of many of these approaches is creating spaces for people to gather, share, learn, play, and relax. With most of humanity living in cities, and that percentage growing, urban areas are an important part of our present and future, and actions that support biological diversity belowground can make cities more livable and sustainable. Soil biodiversity knowledge and research is moving beyond academic circles and being used to support solutions to biodiversity loss, local (water quality, food security), regional (land degradation), and global (climate change) challenges. Managing soils, as the vibrant living systems they are, provides a new perspective for integrated actions and solutions. Soil organisms, microscopic and macroscopic, support all ecosystems: Cycling energy and nutrients to support plant and animal growth in terrestrial systems and maintaining nutrient balances in water, thereby aquatic organisms and ecosystem health. The ways in which soil biodiversity interfaces with multiple ecosystem functions makes it a natural focus for advancing a holistic global sustainability agenda. Soil biodiversity is at the heart of natural solutions for climate, biodiversity, and humanity, including protecting natural areas, restoring degraded ecosystems, employing sustainable agricultural practices, and adapting urban areas for nature and people. As we work toward a sustainable future, let us not overlook the critical and diverse asset, right beneath our feet.

