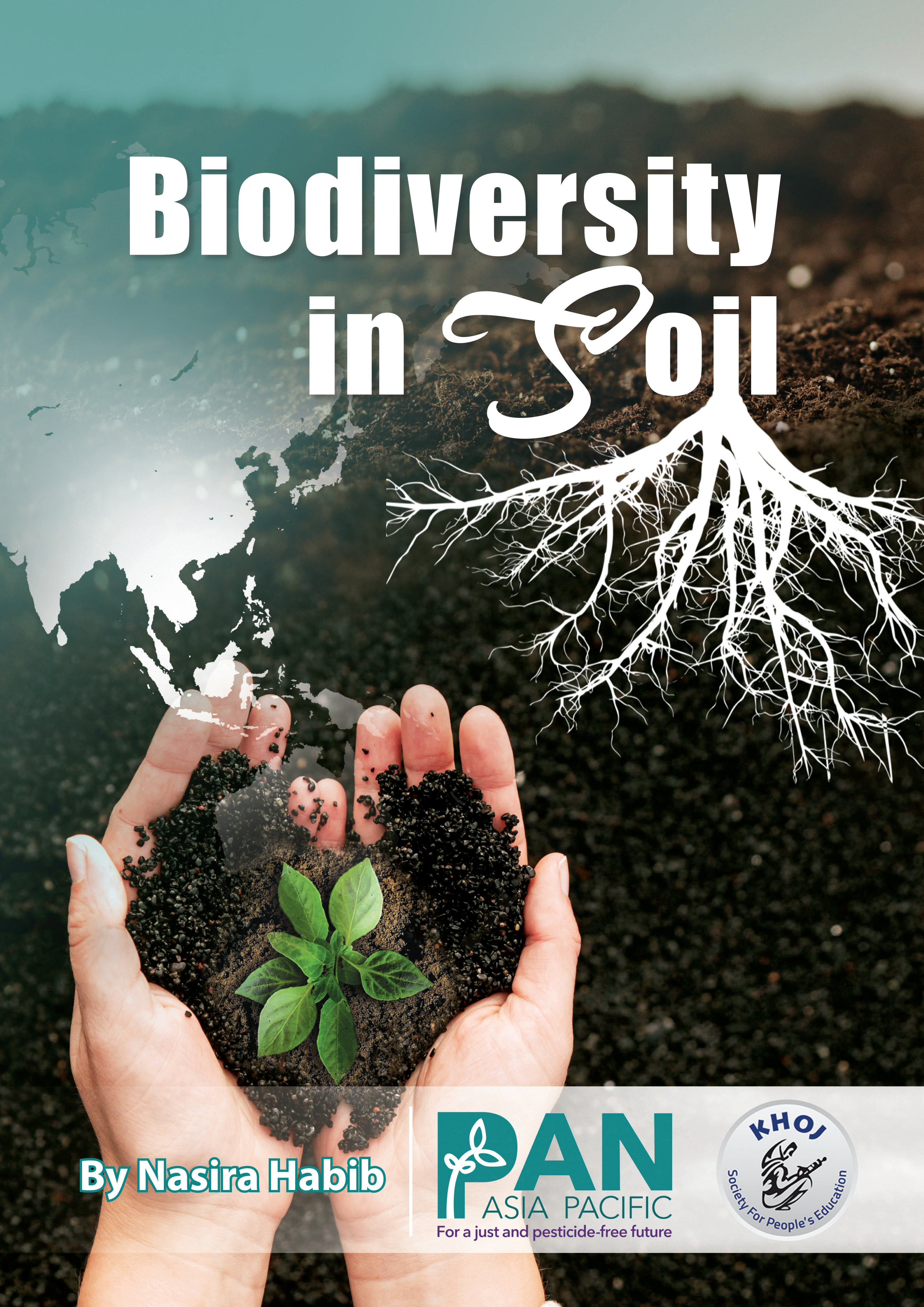
Biodiversity in Soil



By Nasira Habib

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Biodiversity in Soil

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Contents

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Biodiversity in Soil

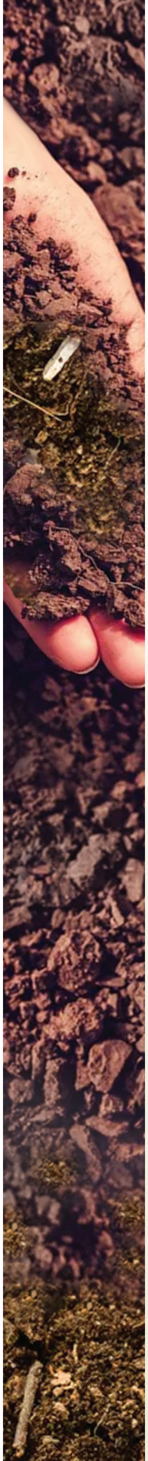
Soil is our lifeline. It sustains life with a variety of foods, holds and filters water to provide us with clean and safe potable water and maintains ecological balance by storing carbon. But there is so much to understand about soil and how it works.

Soil is much more than just a combination of minerals in rock material in the form of sand, silt and clay. Soil is set apart from dirt due to the rich microscopic organisms and organic matter contained in it. A single teaspoon of soil contains more microorganisms than there are people on earth and one gram of soil can have more than fifty thousand species of microbes (The Royal Society, 2020). This diversity is precious and should be preserved. These tiny creatures, which the human naked eye is unable to even see, play a vital role and have an important purpose in soil health.

These microorganisms make an invaluable contribution to our lives. Bacteria and fungi decompose and thrive in dead plant material, dead insects and dead animals and faeces. Without these decomposers, the dead materials would pile up, cause unimaginable pollution and heavily impede life processes. They not only break down the organic waste but also recycle it to process food for plants. There is another group of microbes that has taken on the role of mining minerals. They produce the organic acids that break down the crystalline structures of the rocks into sand, silt and clay. There is yet another category of microbes that partner with certain plants, colonise their roots and fix nitrogen. They thrive in favourable conditions and grow rapidly. Their huge populations attract their predators – protozoa, nematodes and microarthropods. They feast on the bacteria and fungi and keep their population under control. These predators have a surplus of nutrients in their bodies, which they excrete. This excrement contains nutrients that plants need and are in a form that plants can uptake.

The process of plants accessing these nutrients is fascinating. Plants require the beneficial microorganisms closer to their roots. As we know plants make food through photosynthesis and store 20–85% of that energy (depending on the category of plants) in their roots. However, the sugars produced through photosynthesis are not enough and do not fulfil their nutritional requirements. They also need a wide range of minerals to grow, maintain their health and produce healthy, delicious and nutrient-dense food. They offer 30–40% of the photosynthetic food stored in their roots to bacteria and fungi to attract them. They fulfil different food requirements of all species of beneficial bacteria and fungi. The microbes respond positively, are attracted to the plant roots and colonise them. The predator excrement contains soluble inorganic nutrients in plant available form. Plants uptake the nutrients they require and grow happily and healthily.

Some of these microbes in the soil travel to the above-ground parts of the plant and cover stems, leaves, flowers and fruits. The exchange between plants and microbes also takes place here. This is nature's way of nutrient cycling and providing nutrients to the plants. There are no nutrients that are lacking in the soil. In fact, there is a surplus of nutrients, massively more to grow healthy plants. Plants don't require us to add inorganic chemicals to the soil.



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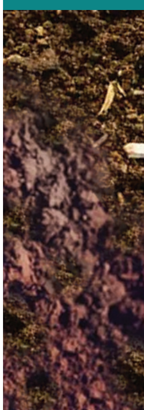
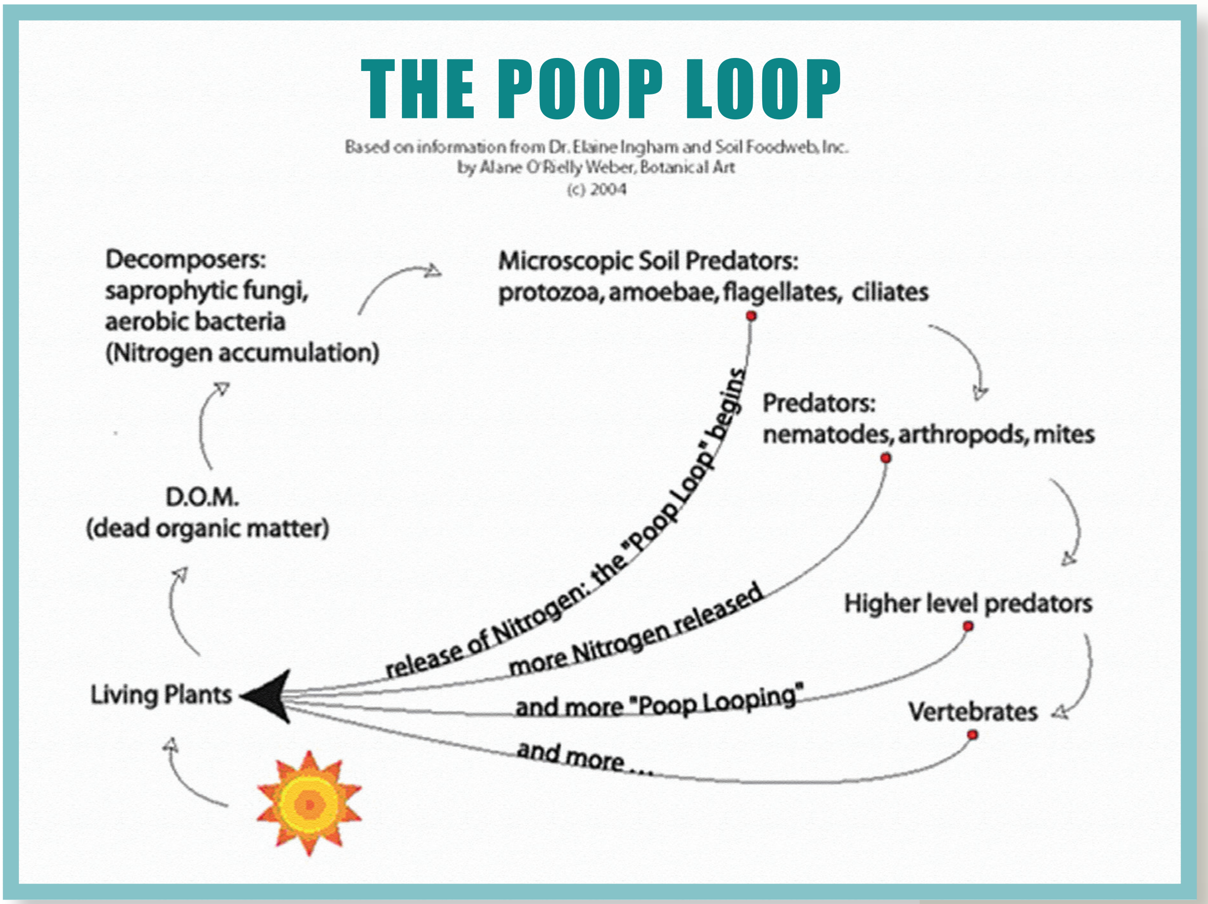




Source: Life Cycle of Compost 2016.pdf,
https://cesantaclara.ucanr.edu/files/233873.pdf

Beneficial bacteria and fungi build soil structure that is oxygenated and porous

Beneficial bacteria produce glues which make it easier for them to adhere to the surfaces of organic matter and mineral particles. These particles stick to each other, creating tiny clumps called microaggregates. When particles are pulled together, small empty spaces are created around them. Beneficial fungi also produce some glues and their tube-like structures act as ropes to clump together the microaggregates built by beneficial bacteria. This act creates larger spaces around the clumps called macroaggregates. When microarthropods, earthworms and insects burrow through the soil, they create even larger spaces in the soil structure like tunnels. This activity makes passageways for air circulation and water retention.

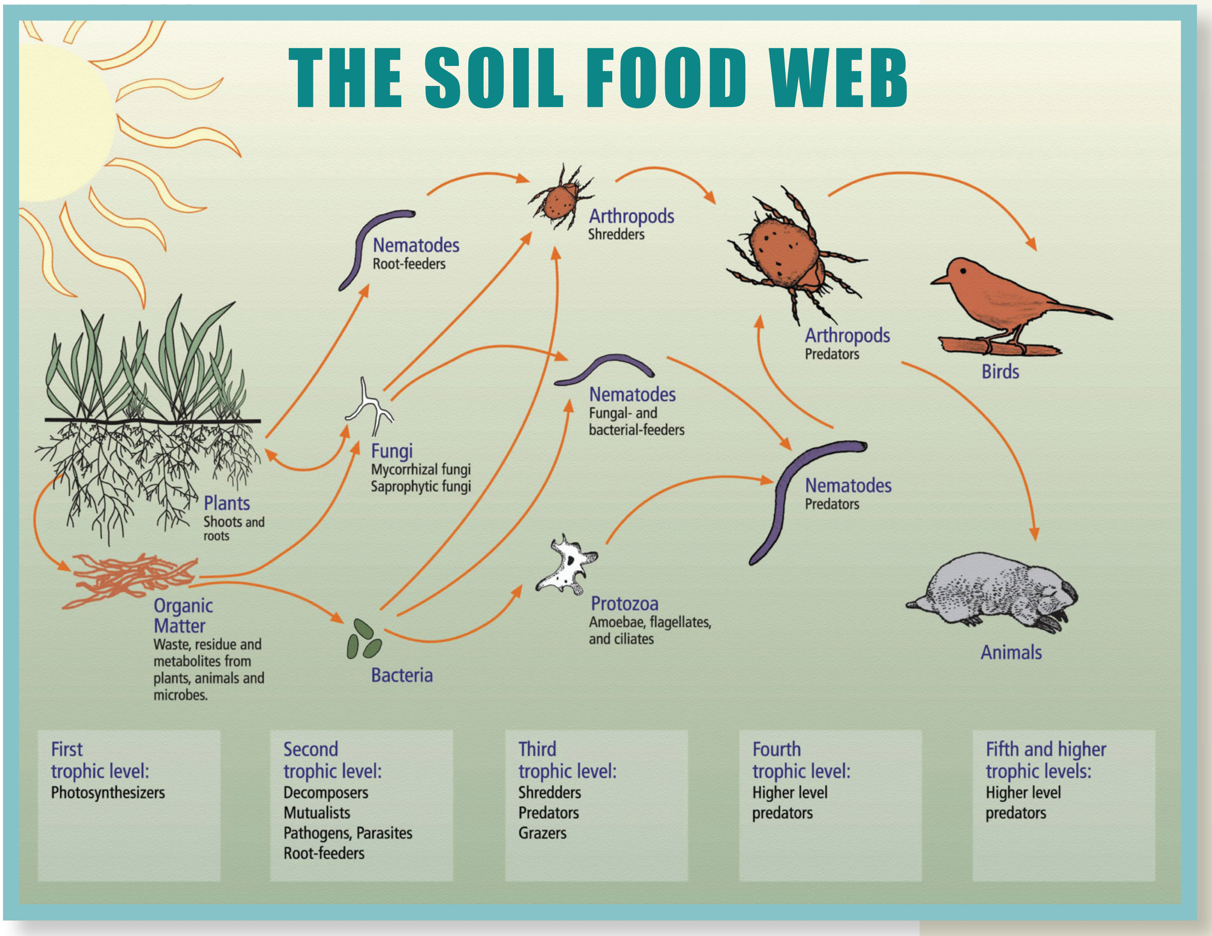
Microbes decompose the litter on the soil surface, get energy for their growth and increase soil organic matter. They also have a congenial habitat in the soil. They need a regular supply of organic matter for their survival. Organic matter causes soil particles to bind and form stable soil aggregates. As a result, a soil structure is created that can absorb and retain water for months. Plant roots are able to penetrate deeper within the soil to take water and nutrients from the soil. Water filters through soil macroaggregates and is purified of contaminants and pollutants.

Well-structured soil creates unfavourable conditions for most disease-causing microorganisms. In oxygen-rich environment they can't perform well (Dr. Elaine's Soil Food Web School, 2019). In aerobic conditions, beneficial biology outcompete the disease-causing bacteria, fungi, protozoa and nematodes. They cover the root system of the plants which severely restricts the disease-causing organisms' access to the food plants release through their roots.

> **"Microbes decompose the litter on the soil surface, get energy for their growth and increase soil organic matter."**

Additionally, this wall created by the beneficial microbes does not allow them to infect the roots with diseases (Dr. Elaine's Soil Food Web School, 2019). Beneficial predators eat the disease-causing organisms. To sum up, soil microbes protect plants through competition, consumption, inhibition and induction. Healthy food webs can replace pesticides (Dr. Elaine's Soil Food Web School, 2020).

Pests are attracted only to the sick plants – plants whose roots are not covered with beneficial microbes. Healthy plants release chemicals that deter pests from attacking them. They do not release exudates to attract bacteria and fungi (Dr. Elaine's Soil Food Web School, 2019). In nature's design, there is no role for pesticides to grow plants and food. Beneficial fungi store carbon received in the form of plant exudates. Most of their long tube-like structures called hyphae are made of carbon. They keep growing and branching out in different directions, storing more and more carbon. If we regenerate world's soils by restoring soil food web, we can sequester enough carbon to reduce CO_2 emissions to the safe level of 350 parts per million in six years (Dr. Elaine's Soil Food Web School, 2019). This can put a stop to climate change.



Source: Soil Food web Institute (Australia).

Here the question arises: if we had such a low-cost, productive and environmentally-friendly system available in nature, what went wrong? Why are we facing such serious challenges of the degradation of soil, soil erosion, pollution of the environment, emission of greenhouse gases, and rise in global temperatures and uncertainty about the future of life on the planet? What happened is the story of human greed. We abandoned living in harmony with nature.

What went wrong?

Around seventy years ago, the green revolution was launched which waged a war against nature. Soil was treated as lifeless, inert matter. Deep tillage was introduced. Mono-cropping was preferred over biodiverse fields. Inorganic chemical fertilisers and pesticides were imposed on the farmers along with water-intensive high-yielding seed varieties. This package has proved to be a recipe for disaster.

Deep tillage kills fungi, protozoa, nematodes, microarthropods, earthworms and other soil life and disrupts their habitats. The only microorganisms left are bacteria. They release a huge amount of carbon dioxide into the atmosphere. The loss of microbial diversity breaks the web of nutrient cycling and plant growth is adversely affected. Secondly, deep tillage fluffs up the soil surface but compaction occurs where the plough is pressing down the soil. Water and oxygen are unable to penetrate into the soil and anaerobic conditions are created. Disease-causing organisms thrive and plant health is compromised. Thirdly, the hard pan created does not let the plant roots go deeper and actualise their genetic potential. In other words, the productivity of the plants is seriously compromised. Fourthly, by slicing and dicing the soil microorganisms and the soil aggregates they build, deep tillage reduces soil porosity. The loss of soil structure diminishes the water infiltration capacity of the soil and increases the risk of soil erosion.

Conventional agriculture replaces soil microbial life with soluble inorganic fertilisers. These toxic chemicals are salts and have massively killed the soil life. Additionally, in the natural system, microbes provide nutrients only on the demand of the plant. They keep replenishing the nutrients every second of the day. They are not present in high concentration in the soil. Water, therefore, cannot wash them away. Chemical fertilisers, on the other hand, do not respond to the specific nutrient demands of the plants in the way that natural nutrient cycling processes do in ecosystems. Instead, chemical fertilisers provide nutrients to the soil in a more static and non-selective manner. Large quantities are dumped in the fields. They do not differentiate between plant species or varieties with varying nutrient requirements. Only around 40% of the nitrogen-based fertilisers get absorbed by crops. The rest is volatised or runs off, polluting the environment, the soils and the water bodies.

This approach to grow food went against nature's design of biodiversity and promoted mono-cropping, where a single crop is cultivated on large tracts of land. The lack of plant biodiversity creates a habitat for pests of that particular crop. Pests thrive on the host plants without any competition or threat from natural predators like ladybugs, lacewings, and dragonflies. They have a consistent and uninterrupted supply of their preferred food source throughout the growing season. This constant availability allows pests to thrive and reproduce rapidly.

Conventional agriculture responds to this problem by using chemical pesticides on plants. Pesticides kill indiscriminately and have negative effects on soil biodiversity. They disrupt the balance of predator-prey interactions among soil-dwelling organisms, reducing overall soil biodiversity. Pesticides, while designed to target specific pests, can also harm non-target organisms in the soil, such as earthworms, beneficial insects, and soil-dwelling microorganisms. These organisms play essential roles in soil health and ecosystem functioning. Pesticides, including herbicides, insecticides and fungicides can leave residues in the soil. These residues can persist in the

> **"Deep tillage kills fungi, protozoa, nematodes, microarthropods, earthworms and other soil life and disrupts their habitats."**

environment and have long-term effects on soil health. Pesticide residues may persist in the soil for extended periods after application. These residues can continue to affect soil organisms and biodiversity long after the initial application. Soil bacteria and fungi are crucial for nutrient cycling, organic matter decomposition, and soil structure maintenance. Pesticides can disrupt these microbial communities by directly killing or inhibiting certain species, altering microbial diversity, and affecting their metabolic activities. Many soil organisms, such as predatory mites and nematodes, play a role in regulating pest populations by feeding on pest species. Pesticides can harm these beneficial predators, disrupting natural pest control mechanisms. The repeated use of pesticides can lead to the development of pesticide-resistant pest populations. This, in turn, may require higher pesticide doses for effective control, which can further harm non-target soil organisms. Disruptions in soil biodiversity can have secondary effects on above-ground ecosystems. For instance, changes in soil-dwelling predator populations can affect the dynamics of herbivorous pests and impact plant health. According to a study, pesticides are largely responsible for the decimation of the insect population by 25% per decade for the last thirty years (Caruso, 2020). The world is losing species at a rate of 1,000 times greater than at any other time in recorded human history, and one million species are threatened with extinction (UNEP, 2020).

According to a systematic review of the scientific literature published between 2006 and 2018, supplemented by mortality data from WHO, the occurrence of about 385 million cases of unintentional accidental human poisoning annually is estimated world-wide including around 11,000 fatalities. That means that about 44% of the eighty-six million farming population is poisoned by pesticides every year (Wolfgang et. al., 2020).

There are tremendous social costs of this approach. In a public statement, the United Nations Special Rapporteur on the Right to Food, Michael Fakhri sums up the problem in the following words, "food systems emit approximately one third of the world's greenhouse gases and contribute to the alarming decline in the number animal and plant species. Intensive industrial agriculture and export-oriented food policies have driven much of this damage. Ever since governments started adopting the Green Revolution in the 1950s, the world's food systems have been increasingly designed along industrial models, the idea being that, if people are able to purchase industrial inputs, then they can produce a large amount of food. Productivity was not measured in terms of human and environmental health, but exclusively in terms of commodity output and economic growth. This same system disrupted carbon, nitrogen and phosphorous cycles because it requires farmers to depend on fossil fuel- based machines and chemical inputs, displacing long-standing regenerative and integrated farming practices" (Fakhri, 2022).

While the Green Revolution claimed to lead to increased food production, it often focused on a limited number of staple crops, promoting monoculture farming. This reduced dietary diversity and food security, as communities were made reliant on only a few crops. According to the UN World Soil Day statement in 2022, "Over the last 70 years, the level of vitamins and nutrients in food has drastically decreased, and it is estimated that 2 billion people worldwide suffer from lack of micronutrients, known as hidden hunger because it is difficult to detect" (United Nations, 2023).

> **"Soil degradation induces some soils to be nutrient-depleted, losing their capacity to support crops, while others have such a high nutrient concentration that represent a toxic environment to plants and animals ..."**

Soil degradation induces some soils to be nutrient-depleted, losing their capacity to support crops, while others have such a high nutrient concentration that represent a toxic environment to plants and animals, pollutes the environment and causes climate change. The Green Revolution promoted the cultivation of a few high-yielding crop varieties, often at the expense of traditional and locally-adapted varieties. This led to a significant loss of agrobiodiversity as indigenous crop varieties were displaced.

The homogenisation of agricultural practices and the spread of uniform crop varieties contributed to a loss of cultural and culinary diversity as traditional foods and practices were marginalised. The use of chemical pesticides in Green Revolution agriculture raised health concerns for farmers and their families, as exposure to these chemicals have adverse health effects. Use of heavy machinery, deep tillage, decimation and killing of biology and use of toxic chemicals have brought the world to a point where nature is backfiring and the world is facing the colossal crisis of global warming and other disasters. In the words of Inger Andersen, "As always, the poor and vulnerable were hit hardest by the droughts, floods, wildfires, dwindling biodiversity and surging pollution levels" (UNEP, 2022). Eventually, the very existence of all of humankind will be threatened.

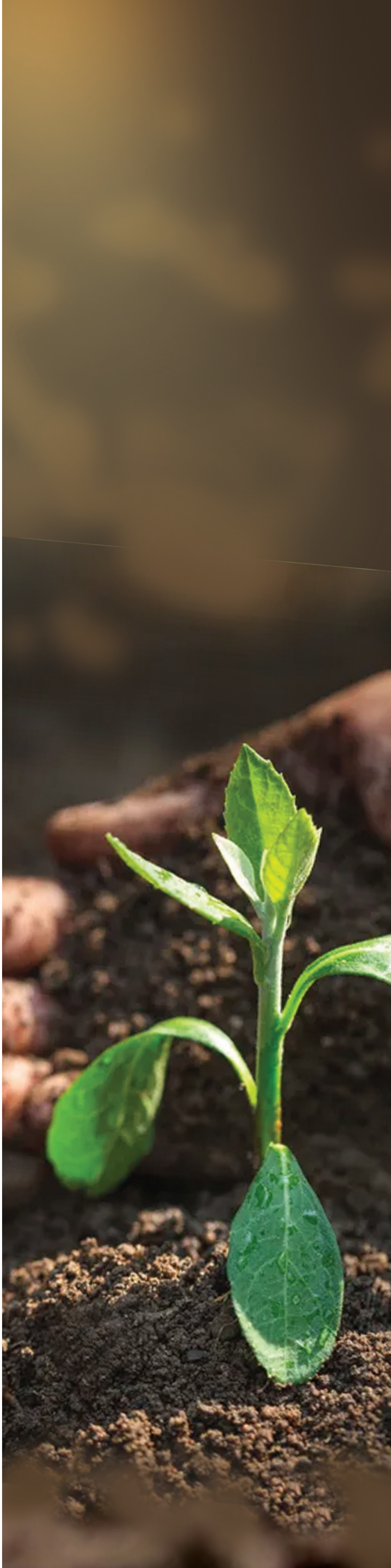
Is There A Way out? Agroecology – Making Peace with Nature

Like us, soils need a balanced and varied supply of nutrients in appropriate amounts to be healthy. Agricultural systems lose nutrients with each harvest, and if soils are not managed sustainably, fertility is progressively lost, and soils will produce nutrient-deficient plants.

Agroecology is an approach to agriculture that seeks to integrate ecological principles into farming systems, emphasising sustainability, biodiversity conservation, and the well-being of both farmers and ecosystems. Agroecological practices can play a significant role in building and improving soils worldwide. Here are some ways in which agroecology can contribute to soil health:

- Soil Biodiversity: Agroecology emphasises biodiversity not only among crops but also at all trophic levels, including beneficial insects, birds, and other wildlife. These organisms contribute to soil health through their interactions and activities. Minimising soil disturbance through reduced tillage and conservation practices helps maintain soil structure and prevents the disruption of soil organisms' habitats. Agroecological systems promote crop diversity, including polyculture (the cultivation of multiple crop species in the same field) and intercropping (growing different crops together). This diversity provides a variety of root structures, organic matter inputs, and niches for soil organisms, enhancing soil biodiversity. Rotating crops in agroecological systems can help break pest and disease cycles and diversify the types of organic matter returned to the soil. Different crops provide different root exudates and residues that support a variety of soil microorganisms.

- Enhanced Soil Organic Matter: The use of cover crops and crop residues in conservation tillage systems can increase soil organic matter content.



Cover crops like legumes and grasses add organic material to the soil when they decompose, improving soil structure and fertility.

- Organic Matter Management: Agroecology encourages the use of organic matter sources like compost, manure, and crop residues to improve soil structure and nutrient cycling. These organic inputs support a diverse community of soil microbes.

- Reduced Soil Erosion: Conservation tillage and organic farming reduce soil erosion through soil surface cover and organic matter (Seitz, et. al., 2018).

- Water Management: Agroecology encourages efficient water management practices, such as rainwater harvesting, mulching, and soil conservation techniques. These practices help maintain soil moisture and prevent waterlogging or drought stress.

- Natural Pest Control: Agroecological systems often rely on natural pest control mechanisms, such as predator-prey interactions and beneficial insect habitat. These practices eliminate the need for synthetic pesticides that can harm soil biodiversity.

- Local Knowledge and Adaptation: Agroecological systems often rely on local knowledge and farmer-led adaptation. Farmers adapt agroecological practices to their specific environmental and cultural contexts, ensuring their effectiveness and long-term sustainability. This can lead to the preservation of traditional knowledge and the development of locally appropriate soil management practices.

- Resilience to Climate Change: Agroecological systems are often more resilient to the impacts of climate change due to their biodiversity and improved soil structure. Diverse agroecological systems can better withstand extreme weather events.

In summary, agroecology is a holistic approach to agriculture that emphasises the importance of building healthy soils as a foundation for sustainable food production. By integrating ecological principles and practices into farming systems, agroecology can help improve soil health, conserve biodiversity, and promote resilient and sustainable agriculture worldwide.

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Call for Action

The solution lies in living in harmony with nature. Nature doesn't need us. We need her. This is our responsibility to make sure that the system works properly so that our soil is healthy and fertile, our plants are protected from pests and diseases, and we enjoy an abundance of delicious and nutrient-dense food.

The UN and the international community began to recognise that soils are a finite and non-renewable resource that underpins food production and sustains ecosystems. Soil health was linked to broader global challenges, including achieving the Sustainable Development Goals (SDGs). International Union of Soil Sciences (IUSS) recommended announcing an international day to celebrate soil in 2002. FAO supported the formal establishment of World Soil Day (WSD) as a global awareness raising platform. The FAO Conference unanimously endorsed World Soil Day in June 2013 and requested its official adoption at the 68th UN General Assembly. In December 2013, the UN General Assembly responded by designating 5 December 2014 as the first official World Soil Day (United Nations, 2023). The United Nations declared the International Decade of Soils to be observed from January 1, 2015, to December 31, 2024. It was officially launched on December 5, 2014. This Decade was established to raise awareness on soil-related issues, promote sustainable soil management practices, and address the challenges of soil degradation, all with the aim of achieving global food security and environmental sustainability.

International Decade of Soils 2015-2024

The International Decade of Soils (2015-2024) has made significant achievements in raising awareness, promoting sustainable soil management practices, and advancing soil-related research and policies. While it may be too early to measure all the long-term impacts, here are some notable achievements during the Decade:

Increased Global Awareness

World Soil Day: The designation of December 5th as World Soil Day, a key initiative during the Decade, has helped raise global awareness on soil-related issues. Each year, events and campaigns are organised worldwide to highlight the importance of soils.

Policy Development and Implementation

National Soil Strategies: Many countries developed national soil strategies and policies during the Decade. For example, the United States launched the "Soil Health Roadmap," which outlines goals and practices for improving soil health.

The European Union adopted the Soil Framework Directive, which aims to establish a common framework for the protection and sustainable use of soil resources within the EU.

Research and Knowledge Sharing

Numerous scientific research projects were initiated during the Decade, leading to a better understanding of soil health, carbon sequestration, and sustainable land management practices.

The establishment of the Global Soil Information Service (ISRIC) and the Soil Data Mart improved access to soil data and information for researchers, policymakers, and land managers.

Capacity Building and Education

Capacity-building programs and workshops were conducted globally to train farmers, land managers and policymakers in sustainable soil management practices.

The Decade produced educational materials, including books, videos, and online resources, to inform the public and students about soil-related issues.

Soil Conservation and Sustainable Agriculture

The Decade encouraged the adoption of conservation agriculture practices such as no-till farming and cover cropping in various regions to reduce soil erosion and improve soil health.

Initiatives supporting organic farming practices and agroecology gained momentum during the Decade, emphasising soil health and biodiversity.

International Collaboration

The Global Soil Partnership (GSP), established by the Food and Agriculture Organization (FAO) during the Decade, facilitated international collaboration on soil-related issues and sustainable land management.

Various regional initiatives and projects were launched to address specific soil challenges, such as soil salinity in South Asia and soil erosion in sub-Saharan Africa.

Soil Education in Schools

Many countries integrated soil education into school curricula to ensure that future generations have a better understanding of soil and its importance.

Policy Dialogues and Forums

The Global Soil Week, organised during the Decade, brought together policymakers, scientists, and stakeholders to discuss soil-related challenges and strategies for sustainable soil management.

While the International Decade of Soils made important contributions to raising awareness, promoting knowledge sharing, and initiating policy changes related to soil conservation and sustainable soil management, the full achievement of its objectives is an ongoing process that will likely require continued efforts beyond the Decade's timeline. The Decade served as a valuable starting point for addressing soil-related challenges, but sustained commitment and action are necessary to ensure the long-term health and sustainability of soil globally. Some of the key challenges are:

- Persistence of Soil Degradation: Despite awareness-raising efforts, soil degradation continues to be a significant global challenge. Many regions still suffer from soil erosion, nutrient depletion, salinisation, and pollution.

- Complexity of Soil Issues: Soil degradation is a complex issue influenced by various factors, including land-use practices, climate change, and socio-economic factors. Addressing these multifaceted challenges requires coordinated efforts and long-term commitment.

- Global Disparities: The success of the Decade's initiatives varied across regions, with some countries making more significant strides in sustainable soil management than others. Disparities in resources and capacity to address soil issues remained a challenge.

- Need for Continued Efforts: Soil conservation and sustainable soil management are ongoing processes that require sustained commitment and effort. The decade-long initiative may not be sufficient to fully address the long-term challenges of soil degradation.

> "... sustained commitment and action are necessary to ensure the long-term health and sustainability of soil globally."

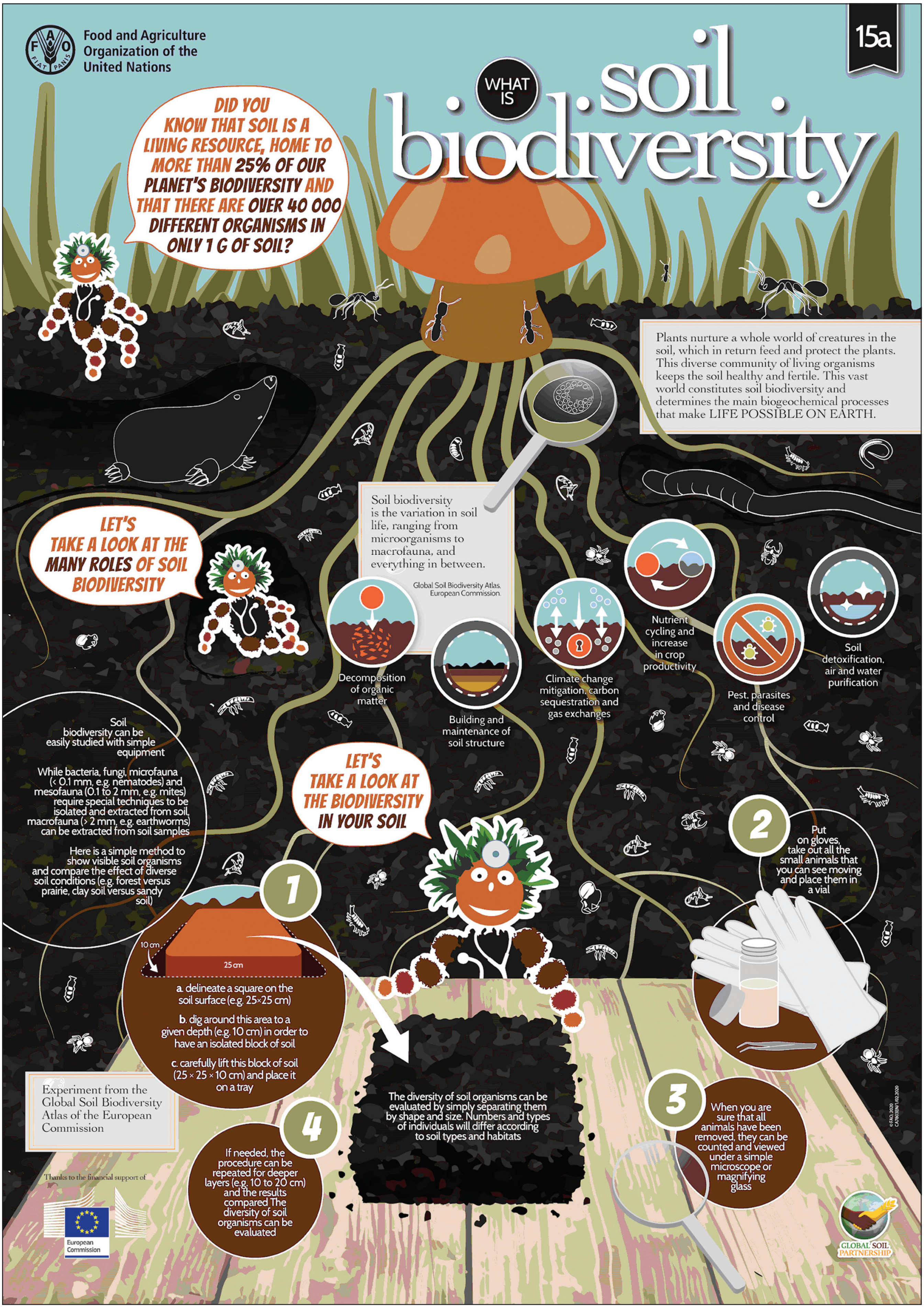
Let's Act Now!

Promoting agroecology involves advocating for and implementing sustainable farming practices that prioritise ecological health, social equity, and economic viability. Here are several actions that individuals, communities, policymakers, and organisations can take to promote agroecology:

- Educate yourself and others about the principles and benefits of agroecology through workshops, seminars, webinars, and educational materials.
- Use social media and community events to share information and success stories about agroecological practices.
- Buy locally-produced, agroecological food products from farmers' markets, community-supported agriculture (CSA) programs, and organic farms.
- Support farmer networks and organisations that promote agroecological practices and provide resources to farmers.
- Lobby for policies that support agroecology, including subsidies, incentives and regulations that encourage sustainable farming practices.
- Encourage governments to allocate funding for research, training, and extension services related to agroecology.
- Provide training and technical assistance to farmers on agroecological practices, including crop diversification, organic farming and soil health management.
- Support farmer-to-farmer knowledge sharing and peer mentoring.
- Establish community gardens and urban farming projects that use agroecological principles to grow food sustainably in urban areas.
- Promote community involvement and education around urban agroecology.
- Integrate agroecological principles into school curricula and educational programs to raise awareness among the younger generation.
- Support university programs and research focused on agroecology.
- Encourage the preservation of traditional and heirloom crop varieties by supporting seed-saving initiatives and community seed banks.
- Promote crop diversity in agriculture to enhance resilience and reduce dependency on a few dominant crop varieties.
- Foster collaboration among farmers, NGOs, scientists, policymakers, and consumers to share knowledge and resources related to agroecology.
- Participate in or support agroecological networks and organisations.
- Educate consumers about the environmental and health benefits of choosing agroecological products and supporting sustainable farming practices.
- Encourage conscious consumption and responsible food choices.
- Invest in agroecological initiatives, such as community-supported agriculture (CSA), farmer cooperatives, and sustainable agriculture projects.
- Support microcredit and financing options for farmers transitioning to agroecological practices.
- Fund and conduct research on agroecological practices, including their impacts on soil health, biodiversity, and resilience to climate change.
- Promote innovation in agroecology, such as the development of agroecological technologies and practices.
- Advocate for policies that promote land tenure security for small-scale farmers, ensuring their access to and control over land and resources.
- Support policies that address land inequality and promote equitable access to land.

Promoting agroecology is a multi-faceted effort that involves individuals, communities, organisations, and policymakers working together to transform agriculture into a more sustainable, resilient, and environmentally-friendly system. By implementing these actions, we can contribute to a food system that is healthier for people, the planet, and future generations.

Get biology functioning!



Source: FAO Campaign Material for World Soil Day (www.fao.org/world-soil-day/en/)

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