Protecting Soil Biodiversity for Soil Health and Sustainable Crop Production

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Soil Microbial Life

- Soil is teeming with life consisting of biota ranging from microscopic bacteria to micro arthropods, macroscopic earthworms and and megafauna which are partime residents representing a large portion of the earth’s biodiversity

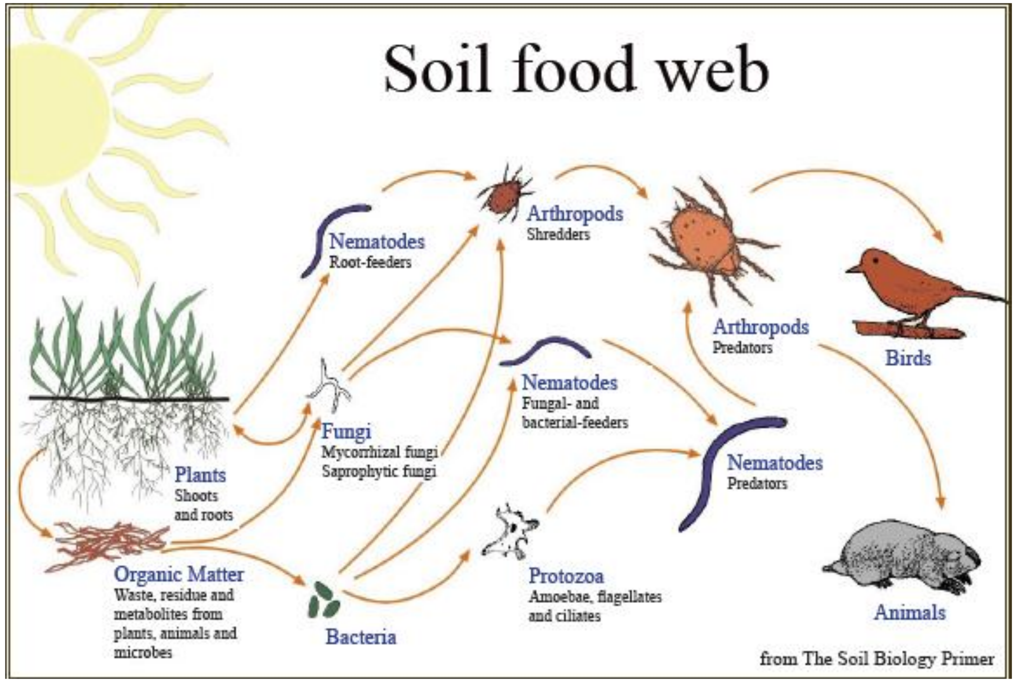
- It is home to over twenty five percent of species observed on the earth.

- Only one percent of them have been identified

- A diverse, balanced and active soil biota provide soil conditions necessary for sustainable crop production with little negative environmental effect.

Microbial complexity

- Refers to different species and their population in the soil at a time
- This biological complexity is responsible for the various processes in soil
- Diversity of organisms and population decide the nature and variety of processes



The food web: Organisms and their interaction

- Soil food web is the community of organisms living all or part of their lives in soil
- Primary producers like plants, lichens, moss, photosynthetic bacteria, and algae fuel the food web

Sources of energy utilization by organisms

- Sun's energy to fix carbon dioxide from the atmosphere.
- Organic compounds found in plants,
- From waste by-products.
- Chemo autotrophs, get energy from nitrogen, sulphur, or iron compounds

Classification of Soil Organisms

- Four major groups identified based on their body size
- Microflora (bacteria, fungi, algae and actinomycetes)
- Mesofauna (collembola, mites)
- Macrofauna (earthworms, beetles, termites)
- Megafauna-part-time soil residents (moles, snakes, lizards, mice, rabbits)

Functions of Soil Microbes

Production systems for human existence

- Role in food production systems very relevant today
- Global population heads towards nine billion by mid-century
- Provides the nutrients that plants need to grow and sustain animals,
- Aids in production of our own food, textile, fibres, wood and pharmaceuticals

Chemical engineers

Microflora (bacteria, fungi, algae and actinomycetes)

- Smallest organisms in soil
- Decompose organic matter, transform residues into nutrients, N,P,K,S
- Act singly or groups in performing functions

Mesofauna (collembola, mites)

- Important role in the carbon cycle
- Easily vulnerable to climate change.
- Feed on a wide range of materials including other soil animals, microorganisms,
- Live on decaying plant material, fungi, algae, lichen, spores, and pollen.
- Feaecal matter in the pores add to the fertility of the soil

Biological regulators

- Regulate the abundance and activity of chemical engineers through feeding
- Enhances or reduces the productivity of the system.

Ecosystem engineers

- Architects and builders of the system

Macro fauna (earthworms, beetles, termites)

- Aid in soil structure development enabling other groups to thrive,
- Build passages, tunnels and pore networks for transport of materials
- Occurs as diverse group controlling activities of lower organisms
- Form a crucial link in the food web.

- Some are plant pests and parasites, while others activate microflora.
- Helps to fragment organic material, creating more surface area
- Speeds up mineralization process and release of nutrients for plants and microbes.
- Presence of all groups of organisms in the soil depends on soil type, water availability and cultivation practices.
- Ability to grow and reproduce fluctuates with season and resources

The architects

- Include earthworms, termites, ants, woodlice, plant roots
- Millipedes, centipedes, beetles, caterpillars and scorpions.
- Earthworm casts and tunnels, termite mounds, ant heaps increase porosity
- Enhance the nutritional and moisture supply
- Mega fauna-Part-time soil residents include moles, snakes, lizards, mice and rabbits
- Perform valuable functions in maintaining soil biodiversity.
- Burrowing activity for food and shelter permits air and water movement

Activities of soil microbes

Building of Soil Structure

- Aid in forming structural aggregates contributing to climate regulation
- Sticky protein produced by fungi help to bind particles
- Termites and root channels produce serve as habitats for other organisms
- Permit air and water movement
- Enables storage and release of carbon
- Largest emissions of CO_2 from crop lands, land use change, intensive tillage

Storing and Purifying Water

- Detoxification of contaminated water better the more the biodiversity
- The root channels, nests and galleries by earthworms, ants and termites all promote water absorption
- Vegetation with its leaf litter and root systems, captures water
- Absence of vibrant soil microbial community leads to soil degradation through erosion and flooding

Cleaning contaminated land

- Remarkable power to reduce impact of pollutants by bioremediation
- Decompose organic pollutants converting them to non-toxic molecules.
- Cheapest method of soil decontamination
- Nutrients as fertilizers added in contaminated site to enhance activity of microbes for efficient clean up
- Wide variety of toxins, pesticides detoxified
- Require specific species and abundant population
- Organisms that control the structure and porosity of soil help to disperse and degrade contaminants
- Natural soil decontamination take years, if not decades
- Heavy metals such as Cd, Pb, Hg cannot be degraded and accumulate in food chain or contaminate ground water.

Control of pest and diseases outbreak

- Diverse microbial population has a greater capacity to impede pest/disease incidence
- Harbours a range of predator species
- Varied nutrient supply modifies the pest population based on nutrient needs

Providing life-saving medicines

- Soil is a great medicine cabinet for the future
- Micro-organisms such as bacteria and fungi constantly produce genetic compounds to fight other microbes. for survival
- Study of previously unknown soil species and their unique survival strategies offer potential to create a new life-saving drugs

Economic value of soil biodiversity

- Various methods have been used to estimate the economic value
- One way to calculate value is to consider the price of food, fibres, raw materials produced
- Another option is to identify the cost of an alternative product that fulfils the same function to replace the services provided by soil organisms Example- the cost of fertilisers and pesticides
- Cost of reversing damage caused in the absence of a healthy ecosystem, such as erosion or flooding;
- Worldwide economic value of soil biodiversity at around $1.5 trillion per year (US study in 1997)

Potential threats to soil biodiversity

- Climate change has direct impact on soil organisms by altering their habitat and food web
- Indirectly, through increased erosion, droughts, wildfires and so on.

Carbon storage and climate control

- Higher temperatures promote faster breakdown of organic material in soil
- Accelerated release of carbon dioxide into the atmosphere
- Lead to further rises in temperature

Nutrient cycling and fertility

- Changes in CO_2 concentration, temperature and rainfall has impact on the availability of nutrients
- Warming can increase the nitrogen availability to plants, and microbes .
- Combination of warming and high rainfall reduce population of certain soil bacteria.

Water control

- Fluctuations in temperature and rainfall affect soil structure and acidity.
- Increase ability to absorb and store water and sustain soil-dwelling organisms.
- Soil organism are extremely sensitive to water availability
- Bacteria, earthworms. live in the water filled pores of soil

Soil borne Pest and disease control

- More diverse the soil community, the better pest and control
- Changes to the climate system will likely impact certain species more than others,
- Pests may be bacteria, fungi, nematodes,

Erosion -hazards

- Results in removal of organic matter and nutrient from fertile top soil
- Caused by wind, water degrading cultivated lands, deforestation

Salinisation

- Accumulation of water-soluble salts in soil, poisons. the microflora
- Pushes bacterial species into a dormant phase, and kill other soil organisms.
- Decrease in plant growth and crop productivity, increased risk of desertification

Soil compaction

- Natural and human activities, particularly use of heavy machinery on wet soils
- Air is squeezed out of the soil, preventing water infiltration
- Complete destruction of soil structure and habitat of many microbes
- Reduces availability of nutrients.

Sealing

- An impermeable layer between the above-ground and below-ground environment
- Completely suffocates the soil and wipes out the entire microbial population
- Aftermath of urbanization and the widespread use of asphalt and concrete,

Land-use change

- Different soils and land use support varying levels of biodiversity,
- Grasslands support more biodiversity than other soils, followed by forests, croplands and urban land.
- The challenge is to manage each type in the most sustainable way to allow soil microbes to thrive.
- Agricultural lands , are less favourable to soil organisms depending on management
- Regular, deep tillage, ploughing, use of chemical fertilizers and pesticides,
- Removal of crop residues, insufficient recycling of organic manures
- deprives the soil ecosystem for food and micro environment for the microbes

Managing microbial activity to maintain soil health

Organic matter management

- Add sufficient quantities of organic matter from cover crops and other crop residues as well as from off-field sources like animal manures and composts.
- Organic materials from various sources have different effects on a soil's biological, physical and chemical properties and modifying influence on pest and disease incidence
- Keep soils covered with living vegetation and/or crop residue.
- Crop residues protect soils from moisture and temperature extremes
- Allow earthworms to adjust gradually to temperatures, reducing their mortality.
- Enhances rainfall infiltration thereby increasing moisture availability to crops

Minimum tillage

- Excessive tillage destroys the food sources and micro niches on which beneficial soil organisms depend.
- Minimum or zero tillage leaves more residues on the soil surface and creates a stable environment, slow turnover of nutrients and encourage more diverse communities of decomposers
- Minimize erosion, damages soil health by removing top soil rich in organic matter.

Managing soil acidity and optimum moisture levels

- Acid soil amelioration through liming is necessary to maintain soil pH
- Optimum levels take care of problems related to nutrient solubility, availability and toxicity
- Indirectly reduces the incidence of soil borne diseases
- Maintain optimum moisture levels

Nutrient management

- Most of the plant nutrients have specific interaction with pathogens in mitigating or modifying disease intensity in various crops.

- Potassium is most effective as it imparts disease resistance to crops from the attack of various pathogens

- Silica though not an essential element provides resistance to diseases through structural defence against invading pathogens

- Use best management practices to supply nutrients to plants based on specific pathogen/nutrient interaction.

- Use of soil and plant tissue tests to provide balanced dose based on soil/crop needs

Minimize use of inorganic supplements

- Modify the soil, water and vegetative resource management by limiting external inputs and emphasizing organic matter supply, nutrient recycling, conservation and diversity

- Replace agrichemical applications with more resource-efficient, environmentally safe methods for managing nutrients and reducing pest and disease populations

Soil Health assessment and soil health cards scenario in India and Kerala

- Soil health cards issued include only physical and chemical parameters
- Biological parameters of soil not included in view of the cumbersome laboratory work involved
- Quick methods not available
- Soil testing labs not equipped and staff not trained to carry out this work

Microbial activity assessment tests

- Earthworm counting
- Cotton Strip Assay
- In situ cellulose decomposition (toilet roll)
- Fungi: bacteria ratio
- Active (labile) carbon Potassium permanganate method
- Microbial activity (CO2) respiration/ using respirometer and titration
- Microbial biomass
- Microbial enzyme activity
- DNA extraction methods

FAO biodiversity framework, on ecosystem restoration,

- Development of standard protocols and procedures for assessing soil biodiversity
- Establishment of soil information and monitoring systems covering soil biodiversity as a key indicator of soil health
- Improving knowledge (including local or traditional) of the soil microbiome
- Strengthen the knowledge on the different soil groups and biodiversity components
  Viz: microbes, micro, meso, macro and mega fauna
- Global capacity building program for the use and management of soil biodiversity
- Establish Global Soil Biodiversity Observatory.

Reference

European Communities, 2010 The factory of life. Why soil biodiversity is so important, Luxembourg: Office for Official Publications, 22 pp


Thank You