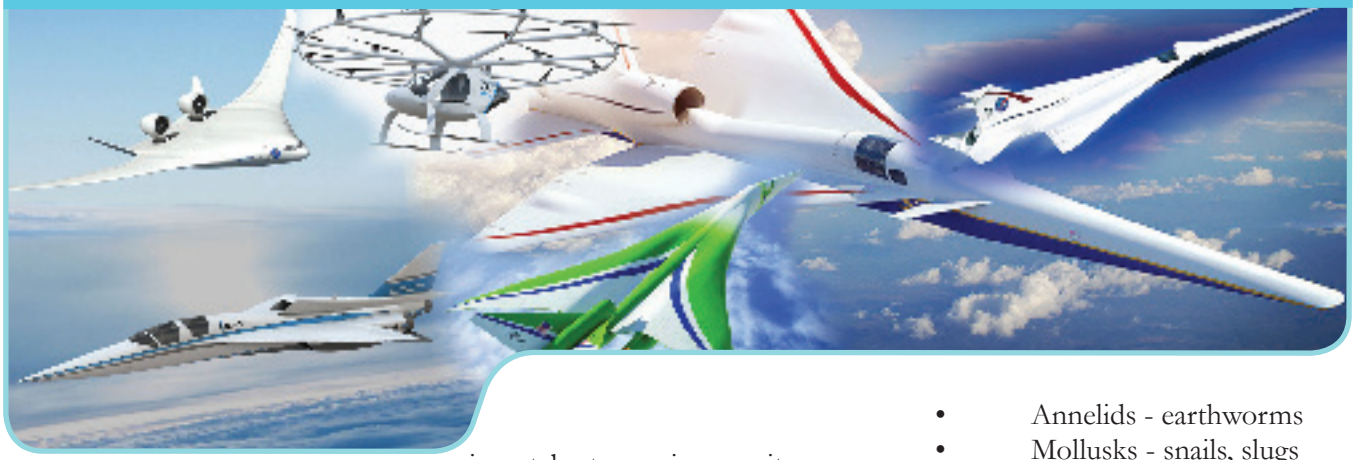
Human Impacts on Biogeochemical Cycles

Dr D.M.Suratissa



Biogeochemical cycle

Biogeochemical cycle, any of the natural pathways by which essential elements of living matter are circulated. The term biogeochemical is a contraction that refers to the consideration of the biological, geological, and chemical aspects of each cycle. There are biogeochemical cycles for the chemical elements carbon, hydrogen, mercury, nitrogen, oxygen, phosphorus, and sulfur. Biogeochemical cycles depend on the soil organisms, mostly microorganisms.

What is soil fauna?

Soil represents one of the most important reservoirs of biodiversity. Soil fauna is an key of the biodiversity and plays an essential role in several soil ecosystem functions; furthermore, it is often used to provide soil quality indicators. Soil biodiversity indicate several thousand invertebrate species per site, as well as the relatively unknown levels of microbial and protozoan diversity. Soil microorganisms are classified as eukaryotes and prokaryotes. Prokaryotes are single cell organisms while Eukaryotes are either single-celled or multicellular. According to their size they can be classified as,

1. Macro fauna (>2mm, width)

Major specific groups of macro fauna are:

- Vertebrates – gophers (Central American Rodent), moles, mice
- Arthropods - ants, beetles, termites, centipedes
- Annelids - earthworms
- Mollusks - snails, slugs

2. Mesofauna (0.1-2mm, width)

Major specific groups of mesofauna are:

- Arthropods – mites, collembola (springtails), protura (Wingless Insect)
- Annelids – enchytraeid (pot) worms

3. Microfauna (<0.1mm, width)

Major specific groups of microfauna are:

- Nematodes
- Rotiferans
- Protozoans

Soil fauna found at different ecosystems

Tundra soils are formed at high latitudes. It is usually very cold in the tundra. Tundra soils are generally frozen.These regions are too cold for the decomposition of organic matter.In both Tundra and Boreal ecosystems the soil is acidic, waterlogging and has less nutrients. Soil fauna in these ecosystems have short life cycles. Few soil organisms can be found. In temperate

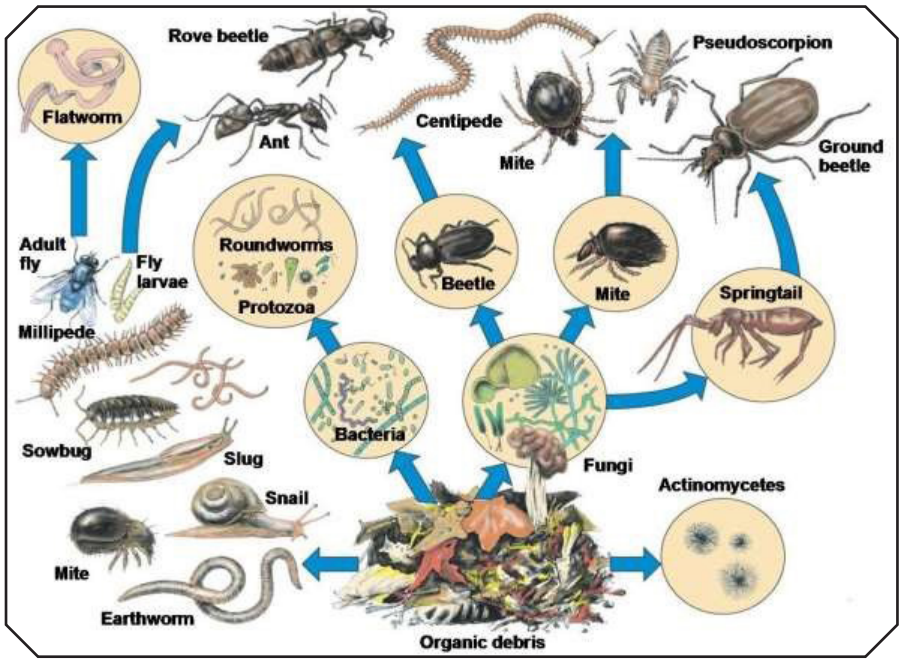


Fig 1 : diversity of soil fauna

ecosystems, the soil pH is variable. Nutrient availability is varying with the changing seasons. More soil organisms can be seen.Tropical soils are found in areas with high annual temperature and rainfall. Soil is rich with nutrients. Soil fauna have long life cycles and consists of high density of soil fauna. Arid ecosystems have a long dry season usually fires occur on arid forests. Temperature of the soil is high and low nutrient available in the soil.

The role of soil fauna.

Soil fauna is abundant with in the soil and it is greatly influenced by the nutrient status and with physical factors including moisture, aeration, pH, temperature, presence of other organisms with in the soil. Soil biota play an essential role in soil functions as they are involved in processes such as the decomposition of organic matter such as dead leaves, stems, dead animals, the formation of humus and the nutrient cycling of many elements.Generally, all the products synthesized by living organisms can be broken down by microorganisms, which is known as biodegradation.They play a major role in the infiltration and distribution of organic matter within soil horizons. Soil fauna also maintain the soil quality by affecting porosity and aeration. The function of soil organisms as organic matter decomposers is very important to maintain the sustainable role for the growth of plants and primary productivity.

The most essential role-taking place with in the soil is the detritus food chains, which are maintained by soil fauna. In detritus food chains, the animal and plant detritus, which are deposited on the soil, are used to consume by organisms such as isopods, certain earthworms, and springtails, many species of mites and the larva and adults of many insects.

The mechanical action performed by soil fauna is very considerable. It is mostly bacteria and fungi, who performed the chemical degradation within the soil system. When consider the whole world, earthworm has identified as the most valuable organism with in soil. They feed on humus compost, dead roots, capable burrowers and they make tunnels that extend horizontally, and vertically that

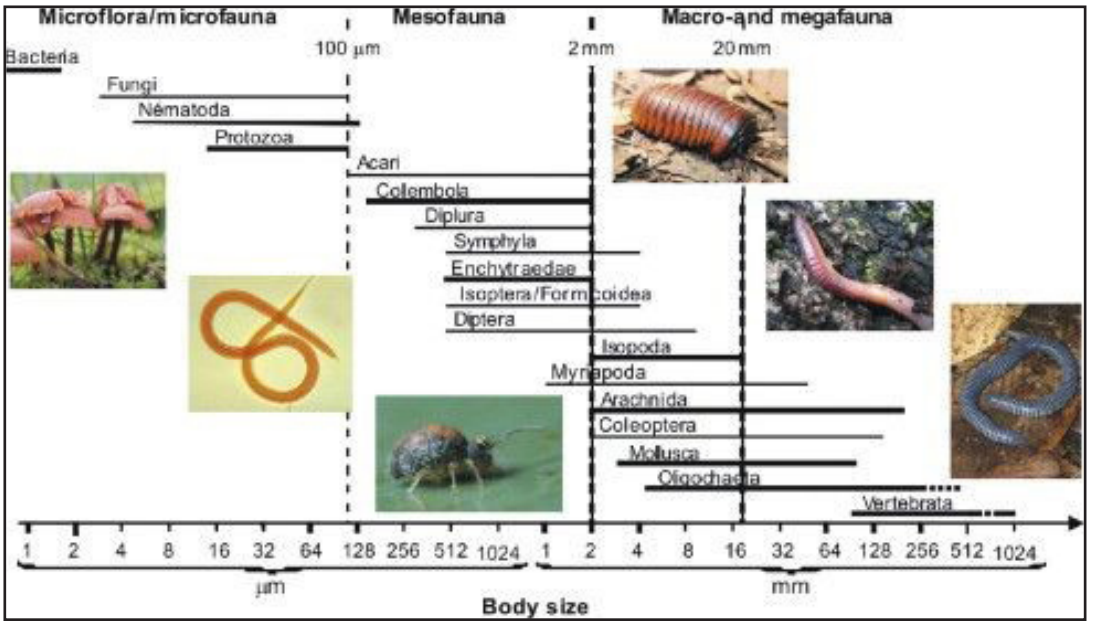


Fig 2 : soil fauna according to their body size

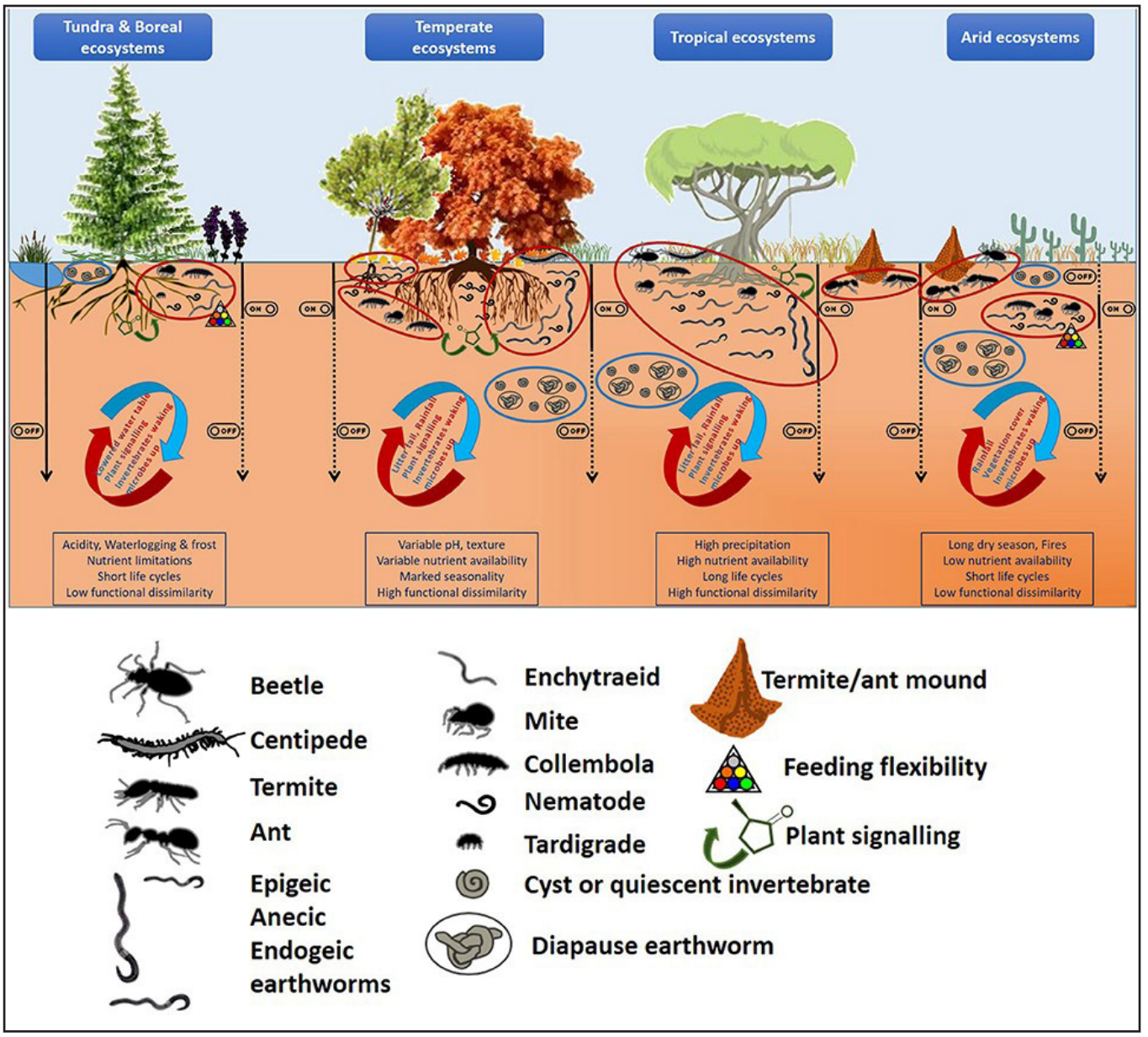


Fig 3 : Soil Fauna found in different ecosystems

can reach several meters in depth. Earthworms perform a significant effect on both structure and chemical composition of soil while living with in it. Earthworms convert most of the organic matter they consumed into a form, which can easily use by plants. Earthworms produce worm cast, from the mineral substances together with organic substances that they ingest after cemented with a little mucus protein. Warm cast contribute to the humifaction and mineralization of organic matter and helps to increase microbial population, enzyme activities and nutrient mineralization that support plant growth and yield. As earthworms released worm

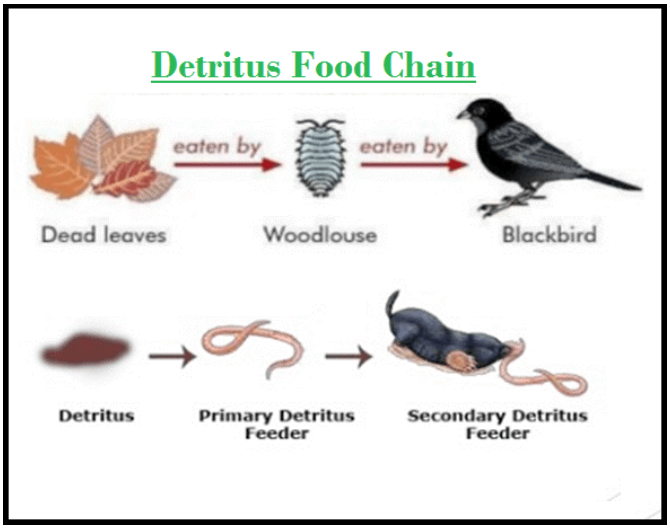


Fig 4 : detritus food chain

Fig 5 : Earthworms in the soil

cast in the entire texture of the soil, fertility with in the whole soil system is increased.Earthworm are able to increase the amount of Nitrogen present in the ground through excretion of ammonia and urea.

The aeration of the soil is also increased by their burrowing action and improved the circulation of water within the soil layer by the tunnels they made on their paths while increasing the porosity of the ground. Due to the continual burrowing activity spaces with in the soil or the porosity increases. As a result, aerobic bacterial activity and the consequent speed of demolition of organic substances

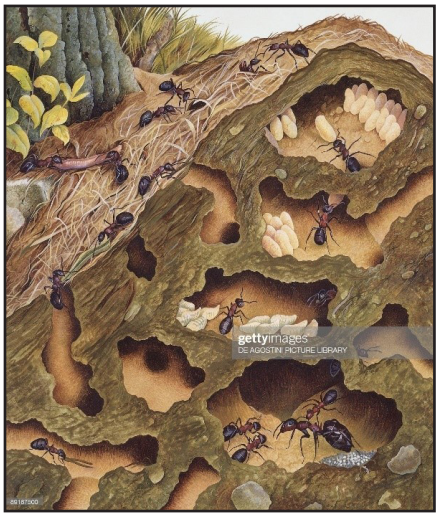


Fig 6 : cross section of an anthill

also increases. Burrowing activity of earthworms are enable the soil to be mixed with organic matter from the surface layers to be incorporated into the lower layers, while mineral substances are bringing towards the surface.

The anthill, which is considered a wonderful modification of the soil by burrowing organisms with a complex of chambers generally constructed on several levels and linked together by tunnels and corridors. The tunnels that connect the chambers contribute to the circulation of air and water within the anthill.

As in the case of earthworms, mollusks also help to increase the stability and structure of the soil and making it less vulnerable to process of

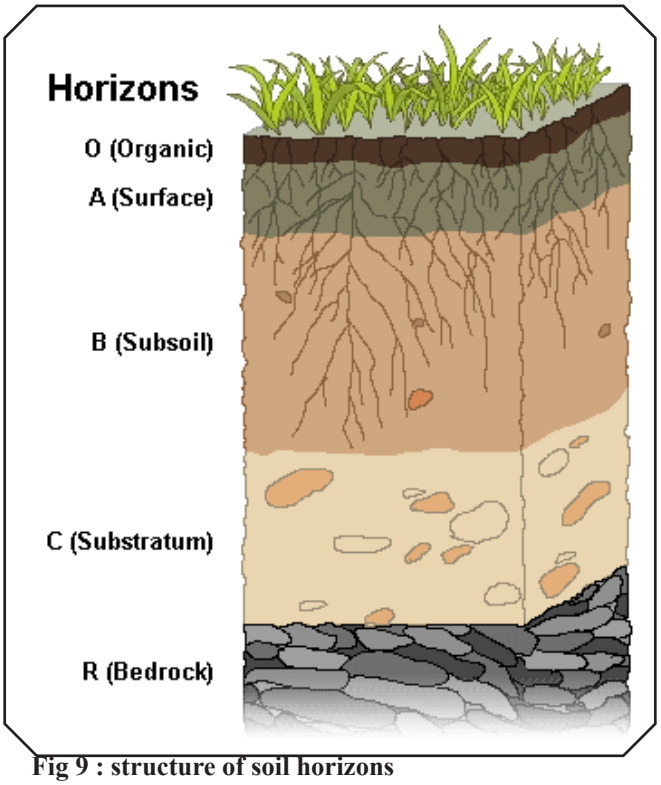


Fig 9 : structure of soil horizons

Fig 7 : Snail on the earth

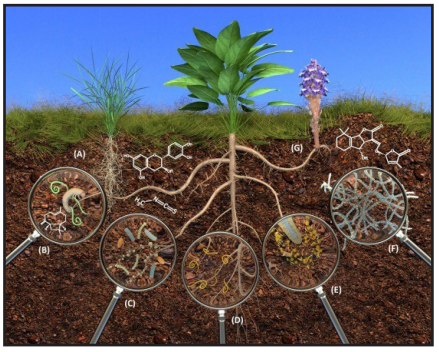


Fig 8 : Microorganisms relationship with plant roots

erosion through the secretion of cutaneous mucous, that have a cementing effect on the particles in the ground. The nutrient content in the soil is increased by the mucus secreted by them and by their dead bodies and help in reducing the carbon to nitrogen ratio of the litter and facilitating decomposition.

The presences of roots are providing a shelter for greater density of microorganisms. Rhizosphere refers to the area of soil that is directly affected by a plant's root system, associated root secretions, and microorganisms. Roots penetrate in to the ground, act on clay minerals and the particles of soil surrounding them, this led to the formation of an area around them in which the water pathway, and the movement of nutrients and microflora is more heavily channeled than in the rest of the soil. There is a significant difference of chemical nature within the rhizosphere than the rest of the soil. The close

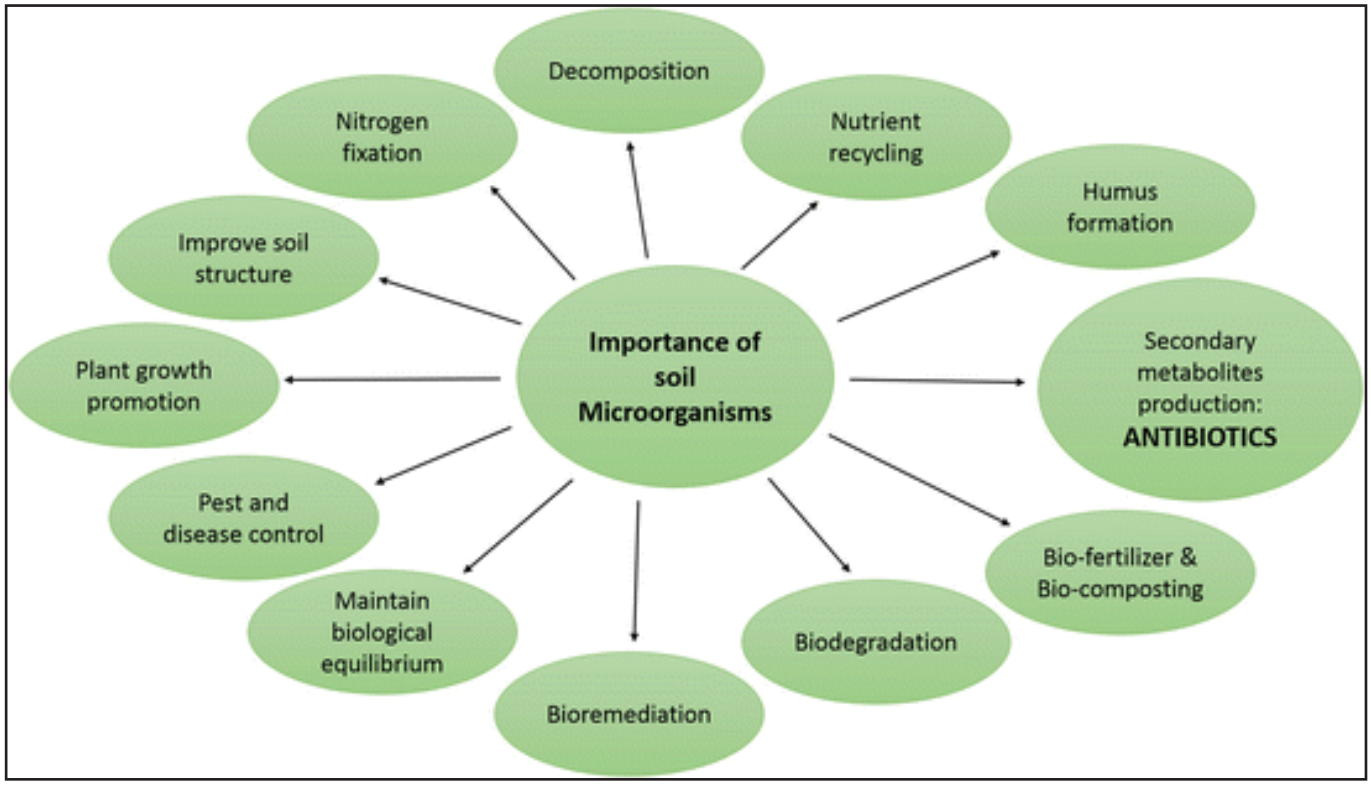


Fig 10 : Summary of the functions of Soil Micro organisms

relationship between the roots and micro-flora is lead to bacteria or fungi becoming an integral part of the roots as in mycorrhizas symbiosis. There are various kinds of interactions between the soil and the plant root system; some are beneficial while others restrict the growth of plants. Numerous soil animals feed directly on the roots of plants.

The distribution of soil fauna. As most soil developed, distinctive layers can be identified within them. These are the products of natural soil forming processes. These layers are called soil horizons. Soil horizons form a basis for classifying soil.

The A and B-horizons together form the proper soil where great diversity of organisms is observed. Two groups of soil organisms can be identified as those who live in the mineral layer and those who live in the organic layer. The most important factors that determine the life on soil layers are the moisture content and the pH. The other important characters are litter, porosity, etc. other than these factors plant species, plant diversity, composition and animal grazing determine the abundance, diversity,

Fig 11 : Satellite view of Beijing, China in 1978 and 2013. This before and after image shows urban expansion over the years

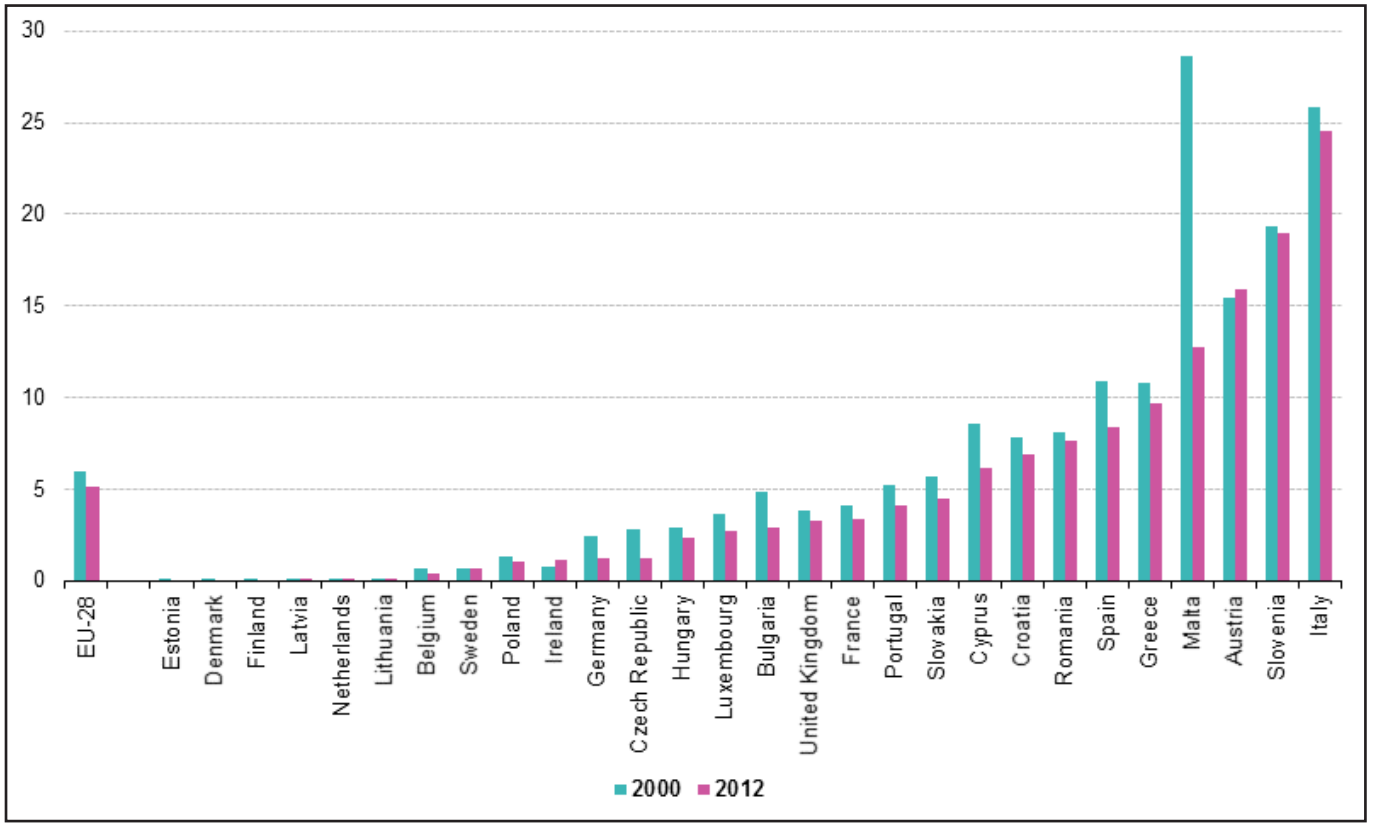


Fig 12 : Estimated soil erosion by water, by country, 2000 and 2012

composition and activity of species on the soil. The soil community is depending on the availability of nutrient resources and the diversity of the microhabitats.

Human impact on soil fauna
Due to the impact of man, the above-mentioned soil faunal diversity had affected severally. Soil had lost its fertility as well as its capacity to carry out their function due to human activities on the nature. The involvement of the man to the disturbance to the natural soil ecosystem runs back to the prehistoric man's age. Up to date the natural soil ecosystem had effected by many ways such as erosion, the loss of fertility and decline in organic matter, compaction, salinization, phenomena of flooding and landslides, contamination and the reduction of biodiversity. Any disturbance to the nature due to anthropogenic activities led to alter physical, chemical and biological properties of soil. It may affect long-term productivity. Urbanization can be considered as a major effect by man, which causes severe effects on nature. The urbanization process leads to the conversion of indigenous habitat to various forms of anthropogenic land use, the fragmentation and isolation of areas of indigenous habitat, and an increase in local human population density.

Human's participation on agricultural practices is also a major problem, which effect on soil fauna seriously. Hunter-gatherers were adapted to agriculture in the very past of the world from prehistoric period. From that date, human have extensively altered the global environment and caused a reduction in biodiversity. These changes in biodiversity alter ecosystem processes and change the resilience of ecosystems to environmental change. Consequently, any land use change resulting in the removal of perennial tree vegetation will produce a reduction of soil biodiversity. As of the year 2000, about 37 percent of Earth's land area was agricultural land. Due to the increment of agricultural land percentage day by day, the rate of extinction also increased. Agricultural management practices, which effect on the abundance of biomass and diversity of soil litter and animal are influenced by management practices such as variation in tillage, treatment of pasture and crop residue, crop rotation, application of pesticides, fertilizers, manure, sewage and irrigation practices. Tillage operations while practicing is highly effect on soil fauna. Tillage systems

can be identified as conventional tillage, minimum tillage and no-tillage. In conventional tillage due to the ploughing soil is inverted and break up the soil, use to burry crop residues and generally destroy the soil structure. In minimum tillage, the number of plowing is reduced and much of plant debris

desiccation, destruction of habitat and disruption of access to food sources.

Aim of the agricultural technology is to obtain a maximum yield. As a result of that, farmers are engaged in monoculture, where a single crop is planted in the field. When this

suitable for the crop production are also use for growing. Soil erosion may increase when hillsides are used in agricultural practices. The weathered rock particles, humus, sand other light materials on the soil are moved by the means of active transporting agents such as running water, blowing wind.More

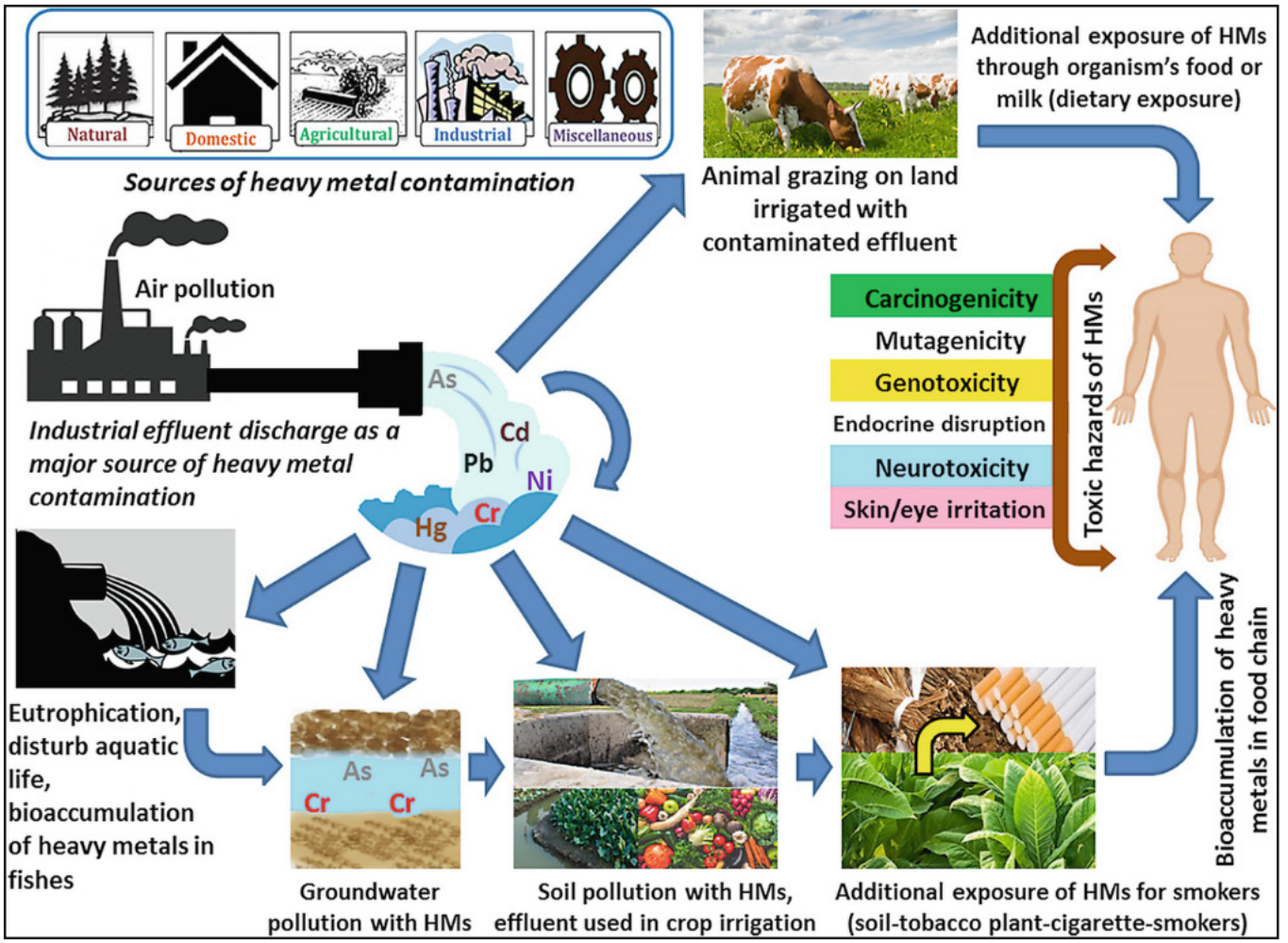


Fig 13 : Bioaccumulation of heavy metals in food chain

is not affected. There is no any disturbance to the soil by the no tillage practices. According to the above mentioned tillage practices the most suitable method is no-tillage method. The conventional tillage caused a reduction of microbial and other organism richness due to exposure to

is practiced on large area of land, high yield as expected can be obtain only if the prevailing environmental conditions are optimum for the maximum growth of plants. They may heavily destroy by the environmental changes and from pest attacks. To meet the growing demand the lands that are not

than 55 percent of this damage is caused by water erosion and nearly 33 percent by wind erosion. These particles are moved as sediments. They are transported from one place and relocated in another place. When the top soil layer is eroded the remaining barren soil is subjected to the direct solar radiation, then the temperature on the earth increased the action

Fig 14 : Land of herding and overgrazing exacerbates desertification

of converting litter in to humus is increased. This produced humus is in turn moved away as earlier mentioned sediments through rain or through the wind. As a result of that the soil organisms are highly affected, they lose their primary habitat. The remaining barren soil is not suitable for their living mainly due to the evaporation of the soil water and due to the loss of its fertility. When the top soil coat eroded, gravel marble and large rocks are directly exposing to the sun light, changing the wind patterns prevailing at the environment also.Every year soil erosion and other forms of land degradation rob the world of 5-7 million hectares of farming land. Every year 25 000 million tons of top soil washed away: China's Huang River alone dumps 1 600 million tons a year into the sea. The United States has lost about one-third of its topsoil since settled agriculture began.

To face the increasing demand farmers use fertilizers to improve the fertility of the soil and use pesticides, weedicides to get rid from the pests who damage the cultivation and to avoid the unnecessary plants in the field. Because of these chemicals surface water layer get contaminated. Some of the chemicals are also leached in to the ground water polluting them. Soil fauna can also be harmed by contaminated groundwater. Sometimes the heavy metals present in the fertilizers such as Arsenic, Lead, and Cadmium led inbiological magnification. Biologicalmagnification is the increasing concentration of a substance, such as a toxic chemical, in the tissues of tolerant organisms at successively higher levels in a food chain. Finally, this effect appears on human as they consumed at higher levels in the food chain.

Herding practices for meat, milk and milk products, and hides for tents and clothing is also cause a major problem on soil fauna. When the herding is practicing beyond the sustainable limit, desertification may occur. The hungry animals try to eat the whole plant with the stem and the roots and due to the hoof of grazing animals such as cattle, sheep, deer the soil pulverized. The pulverized soil get eroded easily and as there's no any barriers to the flow of water, the water that fall on the ground may easily run off with the sediments. It may too cause on the habitat of soil fauna.

Due to the anthropogenic activities the nutrient cycles, prevailed in the ecosystems also get altered. As an example can take the Nitrogen cycle.The nitrogen cycle is the biogeochemical cycle by which nitrogen is converted into multiple chemical forms as it circulates among atmosphere, terrestrial, and ecosystems.

There are four key steps in the nitrogen cycle; they are ammonification, nitrification, denitrification and nitrogen fixation.
1.Ammonification. More than 90% of organic nitrogen in the soil exists as proteins. Proteins from dead plants and animals are decomposed by extracellular proteolytic enzymes secreted by microorganisms into amino acids. Resulting amino acids are taken into microbial cells and are then subjected to ammonification in which, amino groups of amino acids are converted into ammonia. In most soil, ammonia is solubilized in water to form ammonium ions. Ammonium ions are utilized by plants and soil microorganisms.

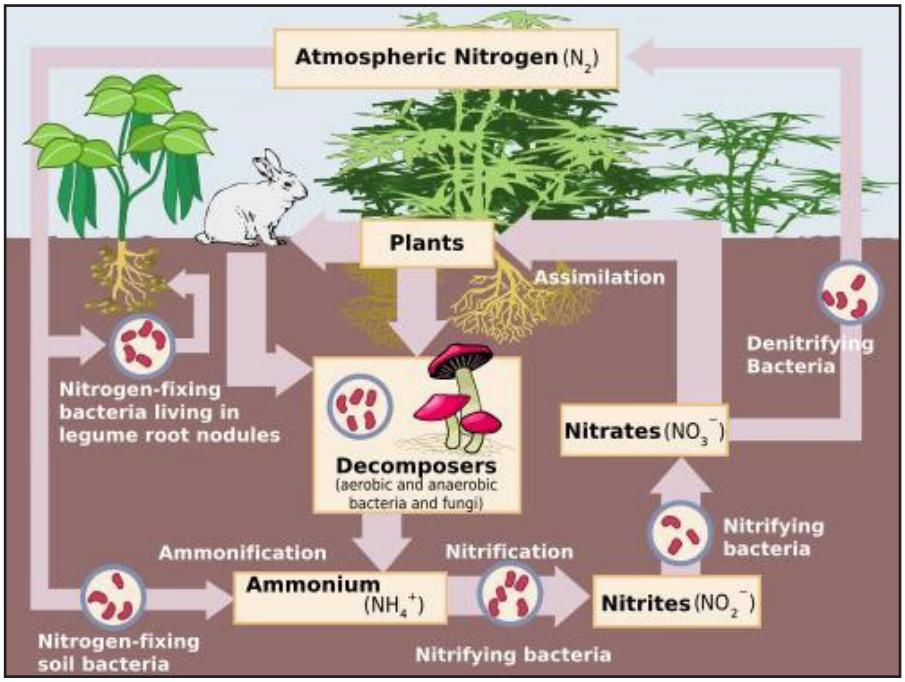


Fig 15 : Nitrogen cycle

2.Nitrification is the biological oxidation of ammonia or ammonium to nitrite followed by the oxidation of the nitrite to nitrate. The transformation of ammonia to nitrite is usually the rate-limiting step of nitrification. This process is done by nitrifying bacteria living in soil in two stages. In the first stage, microorganisms such as Nitrosomonas, oxidizes ammonium ions in to nitrates.

NH4+ NO2-
In the second stage, microorganisms such as Nitrobacter, oxidizes nitrites into nitrates.

NO2- NO3-
Plants utilize nitrate as their source of Nitrogen. Therefore, microorganisms play essential roles in providing nitrogen in bioavailable forms for plants and animals.

3.Denitrification is the use of nitrate by some microorganisms in the absence of atmospheric oxygen and reduces it into N2. This causes loss of nitrogen in to the atmosphere. Pseudomonas species converts nitrate ions into molecular nitrogen through following steps,
NO3- NO2- N2O N2

4.Nitrogen fixation is the process of conversion of nitrogen gas to ammonia is termed as nitrogen fixation. There are two types of nitrogen fixing microorganisms as free-living and symbiotic.
•Free-living nitrogen fixing bacteria- these bacteris are abundant in the rhizosphere. These organisms, exhibit mechanisms to prevent the exposure of nitrogenase enzyme to the atmospheric oxygen. Eg:- Azotobacter

•Symbiotic nitrogen- fixing microorganisms-They play an important role in agricultural crops such as leguminous crops; soybean, beans, peas and peanuts. Plants form root nodules where, anaerobic conditions and nutrients for bacteria are given.

Ammonia is also made through a synthetic process called the Haber process. Nitrogen and Hydrogen are reacting under great pressure and temperature in the presence of a catalyst to make ammonia.
There is only one way of producing nitrogen, Denitrification. Denitrification is a microbial facilitated process where nitrate is

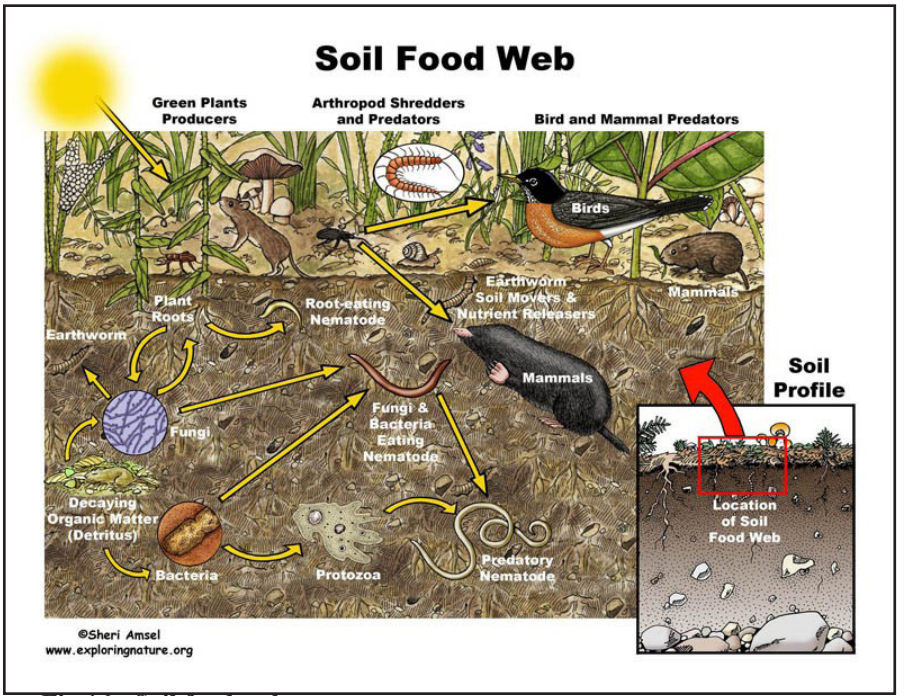


Fig 16 : Soil food web

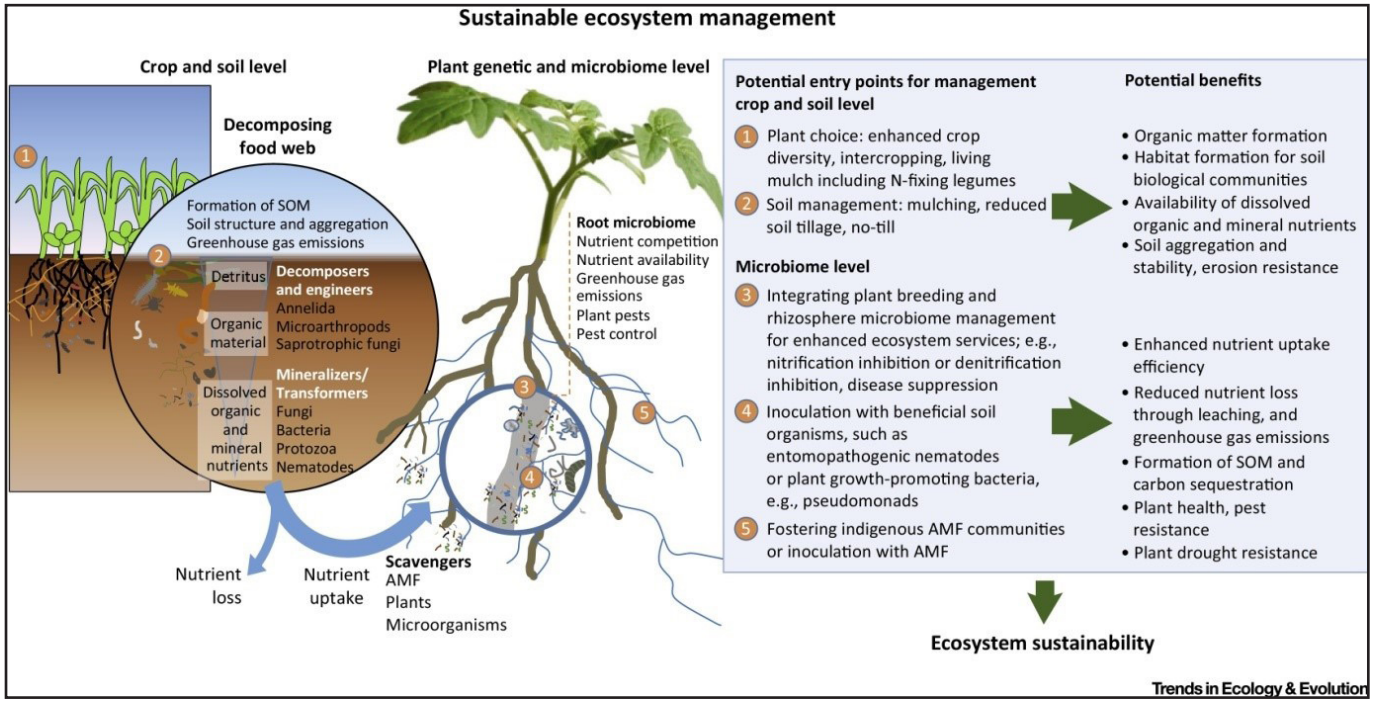


Fig 17 : Sustainable eco-system management

reduced and ultimately produces molecular nitrogen through a series of intermediate gaseous nitrogen oxide products.

Through the human activities such as improper agricultural practices, clear cutting, land clearance, improper irrigational practices the soil fauna get altered. It may affected on the major process of producing Nitrogen in the atmosphere, denitrification. When the soil bacteria who carry out the denitrification get disrupted, the process of emitting Nitrogen in to the atmosphere get disturbed. Because of that an imbalance of atmospheric nitrogen may occur. Plants and animals could not live without nitrogen. It is an important part of many cells and processes such as amino acids, proteins, and even our DNA. Nitrogenis also needed to make chlorophyll in plants, which plants use in photosynthesis to make their food and energy. When the nitrogen content in the atmosphere reduced, the amount of nitrogen that can be consumed by plants in the form of nitrate also reduced. The leaves become yellow in color because they are unable to make sufficient chlorophyll. Leaves in this state are said to be chlorotic.Nitrogen deficiencies also cause leaves to remain small, and drop prematurely, resulting in less photosynthesis occurring in the plant.This makes it crucial that the fields have enough nitrogen in the soil to grow a prosperous crop. Because of that, it may restrict the growth of plants, reproduction of plants and the yield of plants. Plants are the primary producers and they represent the first trophic level in a food chain. When the productivity of primary consumers reduced, the herbivores that are at the second trophic level and the secondary consumers, tertiary consumers in higher trophic levels also get affected. At last as described earlier human, who consumed at higher trophic levels get affected.

Human Impacts on Carbon Cycle

Microorganisms perform a great role in the Carbon cycle too. All organisms contain a large amount of carbon in organic compounds such as cellulose, starch, proteins and fat. Important first step in the carbon cycle is the Photosynthesis. In here the atmospheric inorganic carbon dioxide is reduced to form organic compounds by photosynthetic organisms. Photoautotrophs such as plants, cyanobacteria, algae and photosynthetic bacteria fix carbon using energy from sunlight. Chemoheteretrophs such as animals and protozoa depend on organic compounds produced by autotrophs to utilize them as their carbon source. through food chain, carbon fixed from carbon dioxide by autotrophs, transferred from organisms at lower trophic levels to the organisms at higher trophic levels. Both autorotrophs and chemoheterotrophs, release a part of their fixed carbon as carbon dioxide to the atmosphere through respiration. This carbon dioxide is again made available for autotrophs. In chemohetotrophs, release

a part of their fixed carbon as carbon dioxide to the atmosphere through respiration. This carbon dioxide is again made available for autotrophs. In chemoheterotrophs, undigested food is released to the environment as feces which are later decomposed by soil microorganisms. Rest of the carbon fixed in organisms, remain within them until they die. Once the organisms are dead, these organic compounds are decomposed and carbon dioxide is returned back to the atmosphere. Micro-organisms mainly bacteria and fungi play a major role in organic matter decomposition. Micro-organisms play another major role in carbon cycle in relation to methane gas. Ocean sediments contain a large amount of methane. However, about 80% of methane generated within ocean is consumed by microorganisms called methanotrophs before it reaches to the atmosphere.

Human activities such as the burning of fossil fuels and deforestation have begun to have an effect on the carbon cycle and the rise of carbon dioxide in the atmosphere. Human activities affect the carbon cycle through emissions of carbon dioxide (sources) and removal of carbon dioxide (sinks). The carbon cycle can be affected when carbon dioxide is either released into the atmosphere or removed from the atmosphere. The greenhouse effect occurs naturally. However, human activity intensifies the process, in which Earth absorbs some energy from the sun in its atmosphere and reflects the rest back toward space. This trapped energy warms Earth's surface. The production and consumption of fossil fuels have increased greenhouse gases in the atmosphere and contributed to global warming.

Human activities have a major effect on the global sulfur cycle too. After the industrial revolution in 19th century, releasing of Sulphur oxides and Nitrogen oxides in to the atmosphere increased. Acid rains are formed when these gases are oxidized in the atmosphere and return to the ground dissolved in raindrops. Sulphur dioxide falls as H2SO3 and H2SO4 while NOx falls as HNO3. Sulphur dioxide and Nitrogen dioxide are very strong phytotoxic; toxic to plants. The combination effects of both the gasses are more toxic to plants than they are alone. As mentioned earlier this cause on the primary producers and its effect appear along with the food chain.The nutritive value of soil is reduced to a greater extent. Acid rain effects can also be seen on the useful microorganisms, which convert the decayed organic matter into essential nutrients for the soil.Excessive acidity on the soil also harmful. pH is a most important factor which determines the survival of organisms with in the soil. Most bacteria and protozoa survive at a neutral pH most fungus are survive at acidic pH while blue green bacteria survive at an alkaline pH. The soil chemistry will be altered at a pH below 3.5. The high acidity cannot be tolerate by most of soil fauna and much of soil organisms are destroyed due to this effect.Bacteria density is reducedand the fungus density increases creating an imbalance of density of microorganisms with in the soil. Finally, this may led to delayed decomposition of organic matter, reduction in the process of humus formation and increases in fungal diseases. Most of plant also cannot bare this acidity. The effects are inhibition of germination and growth of seedlings and causes yellowing of leaves and subsequent death of trees.

As discussed, soil fauna perform a major contribution on the earth. Soil is an eco-system in which the different mentioned creatures interact and contribute to the global cycles that make all life possible. Every handful of soil is likely to contain billions of organisms with representatives from every phylum of living things. Unsustainable anthropogenic activities create disruptive effects on soil fauna affecting their abundance with in the soil ecosystem. When the soil density altered, the function performed by soil organisms on the soil get disturbed.Any disturbance to the soil fauna due to human activities ultimately comeback to the human who did the change on the environment. To maintain the life on the earth we should protect the soil fauna being destroying. Through a sustainable eco-system management, soil fauna can be protected to some extent. Figure 16 shows the way of practicing a sustainable eco-system management.

Dr D.M.Suratissa
Depaetment of Zoology and Environmental Sciences
University of Colombo
Colombo 03
suratissa@yahoo.com