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Soil macro fauna: A retrospection with reference to soil formation and soil health

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Abstract
Earthworms, termites and ants are the major group of soil macrofauna. They can alter the soil environment by changing soil properties. They have great potentiality to change soil physical properties like bulk density, infiltrability, hydraulic conductivity, porosity, aggregate stability. Due to this ability they are only species which plays a significant role in pedoturbation. Similarly, their role in nutrient cycling and organic matter breakdown is of unique interest. Earthworm cast, termite mounds and ant nest are fortified with the microbial population. Increasing microbial activity in soil increases the nutrient mineralization and release. Their activity enhances root distribution so that immobile macro nutrients like phosphorous and other micronutrients, which are absorbed by plant through root interception, are easily available to the plants. Hence, these groups of soil macrofauna play an important role in soil formation and maintenance of soil health and they are considered as 'soil engineers'.

Keywords: Soil macro fauna, earthworms, termites, ants, soil formation, soil health

Introduction
Soil fauna (Macrofauna, Mesofauna and Microfauna) are active members of the ecosystem. They perform many functions that go unnoticed. They modify soils and change their properties. Studies have shown that soil fauna can function in different ways to improve soil quality for agricultural use. Soil macrofauna especially earthworms, termites, ants and others have been recognized as important factors in regulating soil processes and thereby the soil profile development. The influence of earthworms is well documented and it is the dominant member of the soil macrofauna influencing the soil formation processes in the temperate zone. In the tropics, termites and ants play the major role in nutrient recycling, movement and transportation of soil material. These organisms fulfill various functions, like allowing the soil to absorb processed organic matter such as leaves, wood, trunks and branches they also maintain an ecological balance capable of preventing the invasion of pests and provide greater fertility without using chemicals.

Soil macrofauna consists of a large number of different organisms that live on the soil surface, in the soil pores and in the soil area near roots. Their way of living, their feedings habits, their movements into the soil, their excretions and their death have direct and indirect impacts on their habitat. The biological activities of soil macrofauna regulate soil processes and soil fertility to a significant extent.

The effects of soil macrofauna on soil can be divided into three classes: physical, chemical and biological effects. These effects are determined by the functional group involved in the process.

Physical role of soil macrofauna
Main physical effects of soil macrofauna can be highlighted:
1. Macromixing
2. Micromixing
3. Gallery construction
4. Fragmentation of litter
5. Aggregate formation

Macromixing
Ants, termites, earthworms and ground beetles can move an important quantity of soil, bringing back to the surface mineral matters from deeper horizons and burying the organic matter from the surface horizons, from litter and from excrements. For example, a large nest of ants comprises several million individuals. It forms a cavity in soil with numerous chambers. The excavated earth is deposited on the soil surface surrounding the nest.

The removal of fine material in depth sometimes creates porous zones under the nest where water can be accumulated temporarily.

Petr *et al*., (2005) [10] studied ant-induced soil modification and its effect on plant below- ground biomass and concluded that Lasius flavus is a dominant mound-building ant species of temperate grasslands that significantly modifies the soil parameters and involved in soil formation. These modifications are usually the result of workers activities such as food accumulation and nest construction.

Macromixing

Other groups of soil macrofauna influence soil structure in a less spectacular way, but the micromixing that they realize is as important as macromixing. These organisms, mainly represented by Diptera larvae, have a more limited capacity to dig the soil. They stay on the soil surface where they realize a fundamental task for the incorporation of organic matter to soil. However, they can be carried into soil by leaching to a depth of up to 60 cm.

Gallery construction

Gallery (burrow) formation is very important for soil aeration and water flux. For example, earthworms and termites develop networks of galleries that improve large spaces in the soil macro-porosity by 20–100 percent (Edwards and Bohlen, 1996) [2].

Earthworms can burrow an estimated 400–500 m of galleries per square metre in grasslands. These galleries are denser in the top 40 cm and can represent up to 3 percent of the total soil volume. In these conditions, the water holding capacity of soil can increase by 80 percent and water flux can be from four to ten times faster.

Earthworm activity is very important in agricultural soils with a high degree of compaction and a ploughing pan that prevents water flux. This situation decreases water infiltration and increases surface runoff and erosion. Earthworms pierce the ploughing pan, so improving water infiltration and offering new paths for root penetration. Termite excavation activity has a similar effect on soils (Gullan and Cranston, 1994) [3] and in some cases can reduce the compaction of surface layers.

Jan *et al*., (2007) [4] investigated the effect of earthworms and other saprophagous macrofauna on soil microstructure in reclaimed and un-reclaimed post-mining sites in Central Europe. In this study density of all macrofauna groups, and earthworms in particular, was higher in reclaimed than in un-reclaimed sites. Soil microstructure formation was closely related to soil faunal density and activity. Faster earthworm colonization resulted in more rapid accumulation of earthworm coprolites in topsoil and consequent formation of humus layer in reclaimed than in un-reclaimed sites.

Where organic matter is present in the soil, the bioturbating and decomposing activities of termites can reduce soil compaction, increase its porosity, water infiltration and retention capabilities. Such conditions encourage root penetration, vegetative diversity and the restoration of primary productivity (Mando, 1997) [9].

Thus, galleries make up a draining system that collects rainwater and facilitates its flow. Water drags small material into these tunnels, which become the preferential paths for soil penetration for roots and leached clays. Galleries are also the soil penetration paths for other surface invertebrates with more limited burrowing capacities, e.g. very small earthworms, slugs, insect larvae and mesofauna.

Litter fragmentation

The fragmentation of dead wood, carcass and litter is one of the most important activities of soil fauna. It has a major effect on organic matter evolution in soil, conditioning the activity of bacteria, fungi and microfauna populations. Fragmentation is performed by phytosaprophagous animals (i.e. animals feeding on decayed plant material and dead animals).

The access of soil macrofauna did not increase the carbon mineralization significantly (the loss of organic matter from the whole microcosms) but increased the translocation of organic matter into the mineral layer. Accumulation of organic matter in the mineral layer resulted in higher microbial respiration, biomass and increased water retention in the soil (Jan *et al*., 2006) [4].

Aggregate formation

After litter has been fragmented, it is easier for organic matter to be broken down into the stable form known as "humus", and then to form soil aggregates and clumping together of soil particles forming a crumbly healthy structure. Earthworms, termites, millipedes, centipedes and woodlice ingest soil particles with their food and contribute to aggregate formation by mixing organic and mineral matter in their gut.

Theodore *et al*., (2004) [11] conducted an experiment to evaluate the role of termites on soil formation in the tropical semi-deciduous forest zone, Ghana. They concluded that termites form distinct soil horizons especially at the summits of the landscapes where gravel free soil horizons are formed upon gravel rich horizons and in some cases soil heaps were formed after the decomposition of huge trees. The termites did not change the chemical composition of the soil significantly and they concluded that the transportation of soil to the surface by the termites did not develop a nutrient rich top layer.

Chemical effects of soil macro fauna

The most important chemical effect of macrofauna on soil is the modification of food quality through its passage in the gut and particularly the mineralization of organic matter and the release of nutrients. Soil macrofauna also influences soil chemical composition through the deposition of excrement.

The main indirect chemical effect is the mineralization of N, P and S through the activation of microflora.

Textural differences between the different soil materials confirm that soil modification by fauna alters the particle-size distribution of soil. The chemical properties and macronutrient composition of earthworm casts and nasute termite mound were higher than the macrotermes termite mound. Earthworm casts have significantly higher micronutrients (Cu, Mn, and Mo) than termite mound and unmodified soil (Asawalam and Johnson, 2007) [1].

Biological effects of soil macro fauna

In a natural soil, a complex and dynamic balance exists between the different groups of organisms with different feeding habits. Predation and competition are the main factors controlling this equilibrium. Predation has an important role because it establishes a balance between the number of individuals and the quantity of available resources. Competition is another way to maintain soil fauna populations in balance with soil resources.

Another biological effect of soil macrofauna is the disappearance of dead animal material. This work is realized by necrophagous (which feed on dead and/or decaying animals) and coprophagous organisms (feeding on dung or excrement) such as Diptera larvae, Coleoptera and Lepidoptera larvae and adults. They clean the soil surface and incorporate organic matter into soil. In addition, soil macrofauna disseminates bacteria and spores through excrement dispersion in soils or by on-body transport. Earthworms determine the vertical repartition depth in soil.

Functional Roles of Arthropods in Maintaining Soil Fertility

The term "soil fertility" denotes the degree to which a soil is able to satisfy plant demands for nutrients (including water) and a physical matrix adequate for proper root development, which is significantly influenced by biological processes. Arthropods function on two of the three broad levels of organization of the soil food web they are "litter transformers" or "ecosystem engineers." Litter transformers, of which the microarthropods comprise a large part, fragment, or comminute, and humidify ingested plant debris, improving its quality as a substrate for microbial decomposition and fostering the growth and dispersal of microbial populations. Ecosystem engineers are those organisms that physically modify the habitat, directly or indirectly regulating the availability of resources to other species (Jones *et al*., 1994) [6]. In the soil, this entails altering soil structure, mineral and organic matter composition, and hydrology. Ants and termites are the most important arthropod representatives of this guild, the latter group having received the greater share of research attention (Lobry de Bruyn and Conacher, 1990) [7].

Influence of soil organisms on nutrient cycling

Upwards of 90% of net terrestrial primary production ultimately may enter detritus food webs where it is decomposed and recycled. Much of it originates in leaves and woody materials falling to the soil surface. However, the below-ground contribution to detrital mass has been estimated at 1.75 times that of all above-ground litter inputs and roots may provide 2.3 times more nitrogen to the soil pool than all other inputs. Plant litter is a mixture of labile substrates (e.g., sugars, starch) easily digested by soil biota and other components (cellulose, lignins, tannins) more resistant to breakdown. Decomposition of this material results from an interaction between physical and biological processes. Litter first must be physically weathered before it becomes suitable for further degradation by the soil microflora and fauna. Fungi are the important initial colonizers of plant litter. With increasing disintegration and solubilization of the substrate, bacteria increase in importance. After this initial microbiological phase, the breakdown process slows, and might come to a halt altogether were it not followed by animal activity. Saprophagous arthropods affect decomposition directly through feeding on litter and adhering microflora, thus converting the energy contained therein into production of biomass and respiration and indirectly, through conversion of litter into feces and the reworking (re-ingestion) of fecal material, mixing of litter with soil and regulation of the microflora through feeding and the dissemination of microbial inoculum. With the exception of some termite groups, only a small proportion of net primary production is assimilated by soil fauna (e.g., <10% in oribatids, 4%–20% in millipedes and isopods). Thus, the indirect influences of these consumers on decomposition and soil fertility are considered, in general, to be of greater importance.

Influence of soil macro fauna on soil structure

Biology plays a major role in the stabilization of soil structure. Among the more biologically significant attributes of soil are the spatial organization of soil particles and of the pore spaces and voids among them, the combination of the particles into aggregates and the stability of the aggregates in water. A favorable soil structure ensures adequate nutrient retention, aeration and water-holding capacity below ground, facilitates root penetration, prevents surface crusting and erosion of topsoil.

Formation of Soil Aggregates

Soil aggregates (or peds) the basic units of soil structure and they are formed by natural processes, commonly involving the activity of organisms. Fecal pellets, combining fine mineral particles with undigested organic matter are the major contribution of invertebrates to the formation of soil aggregates. Mucilaginous substances, byproducts of microbial decomposition, bind the feces with other soil components into stable microstructures. These organomineral complexes are substrates on which inorganic nutrients may become adsorbed and so available to plants. The resulting humus, an amorphous colloidal material comprising partially decomposed organic matter that makes up topsoil and increases the soil's capacity to store nutrients (e.g., cations) and prevent their rapid leaching, thus is largely derived from animal feces. The humus of well-developed soils represents a significant pool of macronutrients, such as N, P, K, Ca, and Mg, which may be stored in amounts exceeding 1 tonne ha^{-1}. It also involved in chelation reactions, which aid in the micronutrient nutrition of plants, buffers the soil against rapid changes in pH, supports an abundance of micro-organisms and promoting increased mineralization activity (Thomas W. Culliney, 2013) [11].

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