# Bolstering the Soil Environment—Earthworms and the Soil Ecosystem

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Earthworms have generally been underestimated and overlooked as major contributors to physical, chemical and biological processes occurring in soils. They are often viewed as good for fish bait and less so as an important component of the soil ecosystem. This article will summarize the present state of knowledge of the influence of earthworms on the soil ecosystem with specific reference to orchard soils.

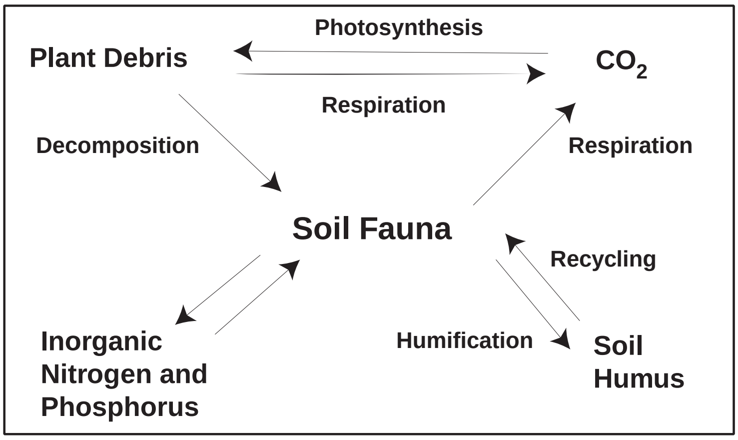
## SOILS WITHIN LANDSCAPES

Soils are natural bodies that occur as unique entities within the landscape. Understanding the processes that occur to develop and "build" soil is of utmost importance for the maintenance of an optimum soil quality. Optimizing the soil quality in agroecosystems involves balancing inputs (fertilizer, pesticides, herbicides, energy from machinery, etc.) with economic outputs (i.e., yield of crop) such that the inputs are minimized and the outputs maximized. Soil management for optimization of soil quality aims to ensure a sustainable soil resource base for years to come.

Soils develop over time as a function of climate, their position within the landscape, the make-up of the original geologic parent material and biological components. The true importance of organisms as major factors in soil function has been realized only in the last few decades. Understanding the roles of various soil organisms in this ecosystem may work to minimize inputs through the mindful management of the soil resource.

FIGURE 2

Fauna are central to soils as a source of life (from Juma, N.G. 1999. The Pedosphere and its Dynamics: Soil Ecology. [www.soils.rr.ualberta.ca/Pedosphere/content/section10/page03.cfm]).

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## THE SOIL ENVIRONMENT AND ORGANISMS

A healthy soil is a porous medium composed of solids, liquids and gases and is biologically active. Minerals and organic materials combine to create aggregates. The arrangement of aggregates and airspace within the soil constitutes the physical structure. The physical structure of the soil is analogous to a steel framework of a building. It holds the soil world together; the collapse of this physical structure results in an unproductive, unhealthy soil. If this structure is maintained, it provides a healthy habitat for soil flora and fauna.

Soil fauna are responsible for major processes occurring within soil (Figure 1). If there were no soil fauna for important roles such as decomposition and humification of organic matter, leaves and twigs dropped from plants would simply accumulate at the soil surface and would not become incorporated. Instead soil fauna make vital components such as nitrogen and carbon available for use by growing plants and other organisms. In other words, fauna are essential members of the dynamic cycle of life in soils.

Earthworms are a major group of large fauna that play a significant role in the dynamics of a healthy soil. Earthworms are pegged as ecosystem engineers, the organisms that affect the availability of resources through modifications of the physical environment.

FIGURE 2

Earthworm burrows created by the anecic species L. terrestris (nightcrawler).

## EARTHWORMS AS ECOSYSTEM ENGINEERS

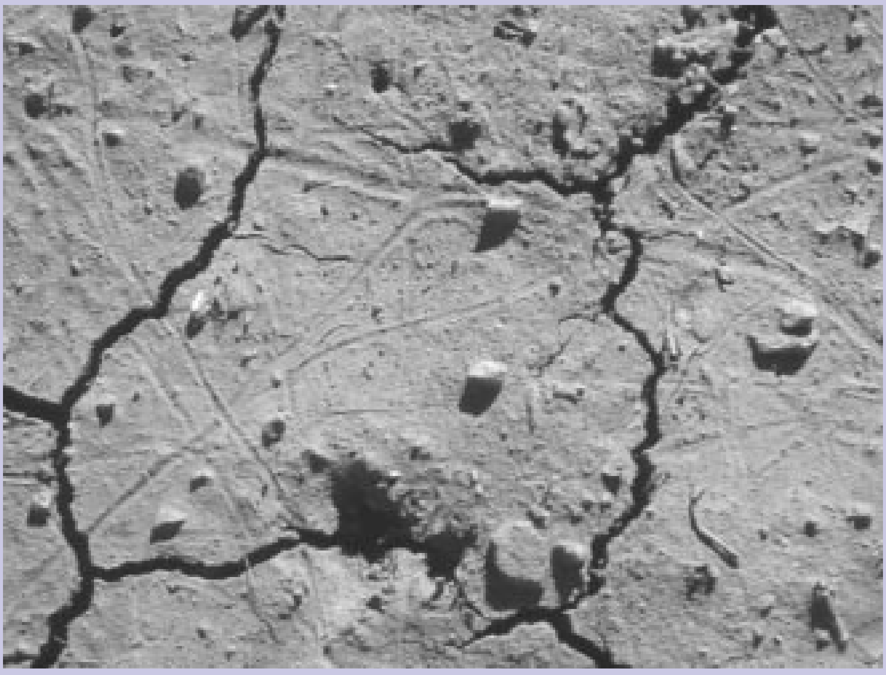
Earthworms move through soil by creating channels and burrows (Figure 2). They ingest and excrete both organic and mineral components as they travel through the soil in search for food. They feed on dead plant tissue and the fungi, bacteria and other microorganisms associated with it. Therefore they are important soil ecosystem engineers because as they burrow through the soil they are modifying the physical soil environment. They create the environments for other living organisms in the soil and thus affect the availability of various resources. Therefore earthworm activity has profound implications for physical, chemical and biological processes occurring in soil.

## EARTHWORMS AND SOIL PHYSICAL AND CHEMICAL PROPERTIES

Most research on earthworms in soils has focused on their influence on the physical properties. Extensive review papers on this topic have recently been published (see Additional Reading below). Macroporosity is the most significant physical property influenced by earthworms. Generally earthworm activity increases overall porosity in soils. This is attained through the creation of burrows and channels. However, variations in earthworm ecological groups influence porosity and the functional behavior of burrow systems in soils.

FIGURE 3

Earthworm tracks created by nightcrawlers during their search for food.



There are three main ecological groups of earthworms, 1) anecics, 2) endogeics and 3) epigeics.

1. Anecic species tend to create long vertical burrows often extending to beyond 2 m (6.5 ft) depth. The worm will pull plant material into its burrow, ingesting it as it moves through the channel. The earthworm will continue to maintain the same channel until other circumstances such as stress and availability of food force it to evacuate and create a new one. Lumbricus terrestris (or the “nightcrawler” or “dew worm”) is the most common member of this group.
2. Endogeic species feed on organic-rich mineral soils, usually within the top 10 cm (4 inches) of the soil profile. They likely do not maintain the same burrow since they randomly scavenge through the mineral layers, feeding as the soil passes through their bodies.
3. Epigeic species live in organic soil layers and therefore are generally found only above the soil mineral surface.

The work of the anecic and endogeic species in soils alters the water status, gas diffusion and the stability of soil aggregates in different ways. More specifically, vertical channels created by anecic “nightcrawlers” have been shown to significantly affect water seepage through the soil profile (Figure 3). Endogeic species play an important role in the ability of the soil to store and transfer water and air by creating channels within the near surface of the soil profile. This has major implications for adequate root development and growth both through creating voids which roots may follow and providing a conduit for water and air to be made available to the rooting system. The burrows of earthworms increase the surface area available for absorbing water, and their channels increase conductivity, aiding in adequate drainage during intense rainfall events. The increase in porosity by earthworm channeling also allows for the soil to transmit nitrogen and oxygen to living organisms throughout the soil.

Earthworms create casts which are the soil materials formed by their excretion. Through casting within and on top of the soil, they create new structural units that have been shown to be more stable than surrounding aggregates. Also by channeling and casting they translocate soil materials, resulting in "bioturbated" or thoroughly mixed surface layers. In fact, in some soils the entire top 10 cm (4 inches) of the profile has been identified as being formed entirely of earthworm casts.

## EARTHWORMS AND ORCHARD SOILS

### Soil Compaction

Soil compaction can be a serious problem in orchard soils, particularly in the rows between trees where machinery passes. Earthworm numbers and diversity have been shown to be detrimentally influenced by soil compaction in agricultural soils. In an apple orchard soil a researcher found that younger worms were the most influenced by compaction because they usually occupy the upper few centimeters of the soil profile where machinery compaction is most influential. The adult earthworms usually live lower in the soil profile where the soil is less affected by machinery compaction. Another factor may be that cocoons are often deposited on or near the soil surface and could be destroyed by the machinery. Similar results were also found for a study in conventional agricultural fields with varying amounts of machinery compaction. The loss of younger earthworms would likely reduce the ability of the species to properly reproduce itself in the compacted soil.

Alternatively, earthworms have been shown to ameliorate compacted soil through their burrowing and creation of macropores. However, some soils can be so compact that even earthworms cannot penetrate them. Also, a compacted soil is usually relatively infertile, and healthy earthworms may avoid these areas and migrate to more suitable soils. This can leave the compacted soils lacking in earthworms, and therefore the soil may remain in a deteriorated state until temporarily ameliorated, possibly by a tillage event.

### Influence on Pathogen Distribution

Research being conducted in pathology of orchard trees has noted earthworms as major influences on spatial distribution of pathogens. More specifically, pathogens such as Pseudomonas syringae and Venturia inaequalis that have been linked to fruit rot and apple scab are often found in large amounts in the leaf litter beneath trees. Earthworms play a major role in the incorporation of leaf litter into the soil which may isolate pathogen-bearing organic materials. Anecic earthworm species such as "nightcrawlers" are likely the most important in isolating the litter since they pull organic debris deeper in the soil profile within their permanent burrows. If there are sufficient earthworms present, the litter can be completely incorporated into the soil before budbreak in the spring, effectively reducing the potential for disease outbreak.

However, another study has shown that surface earthworm casts in apple orchards can contain high populations of Phytophthora cactorum, pathogens linked to crown or collar rot in apple trees. Further studies are warranted on the influence of different earthworm species and ecological groups on the spatial distribution of disease pathogens.

### Pesticides and Herbicides

The control of various pests using pesticides and herbicides in orchard soils can influence earthworm populations. Copper used in some fungicides and pesticides has been shown to reduce earthworm numbers. In one study the reduction of earthworms due to copper in a pesticide resulted in the build-up of tree litter on the soil surface, indicating the importance of earthworms as decomposers of the raw organic materials in orchards. It has also been shown that cadmium, lead and zinc have accumulated in the tissues of earthworms, however the degree of toxicity varies between earthworm species and heavy metals.

## CONCLUSIONS

A healthy soil often contains significant populations of earthworms. This is due to the manipulations and creation of structures supporting many healthy processes that occur in soils for supporting life and biodiversity. Management of orchard soils should move toward maintaining an environment for sustaining a healthy population of earthworms.

## ADDITIONAL READING

Edwards, C.A. (ed.) 1998. Earthworm Ecology. St. Lucie Press, Boca Raton, FL.

Hendrix, P.F. (ed.) 1995. Earthworm Ecology and Biogeography in North America. Lewis Publishers, Boca Raton, FL.

Lee, K.E. 1985. Earthworms: Their Ecology and Relationships with Soils and Land Use. Academic Press, Toronto.