The Significance of Earthworms to Agricultural Practices and Soil Fertility

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Abstract

The ability of a given kind of soil to perform, under the boundaries of the natural or managed ecosystems and to perpetuate the plant and animal productivity, preserve or enhance water and air quality and human health, and livability, is therefore referred to as soil fertility. The most significant living being in the soil with regard to betterment of the soil health is possibly the earthworm. The earthworms are the most abundant soil animals. Earthworms bring in the organization of organic stuff and stir up the soil. At this mixing, the soil becomes fertile as it helps to distribute the organic matter within the soil as well as freeing the nutrients contained in the organic matter to be available to the plants. An important decomposer of organic material is earthworms. They find their food in microorganisms which are found on organic matters and soil. As earthworms crawl along the surfaces of the ground, they tunnel along their route leaving holes or burrows in them. These are burrows that are long lived underground. Earthworm burrows increase the porosity of soils, thus trapping more air and water into the soil. The soil biota makes all ecosystems sustainable and raises the soil productivity. The cycling of nutrients is one of the important processes required to support life on the earth. Earthworms (EWs) are an important soil fauna community in most of the environments and a considerable volume of macrofauna biomass. They have a positive activity because in some cases it contributes to the optimisation of the soil nutrient cycle through the rapid conversion of detritus to mineral soils. The comminution effect, together with mucus presence due to water extraction in the guts of the earthworms, also leads to the increased activity of many of the beneficial soil microorganisms. The next process is that of organic matter production. Short term, there is a significant impact of high concentrations of nutrients (N, P, K, and Ca) being sequestered in the immediate cast deposits that would be easy to be consumed by plants. Also, earthworms seem to increase the mineralization and rotation of soil organic material. The earthworms may increase the process of nitrogen mineralization through direct and indirect effects on the microbial community. Their increased movement of organic carbon and nitrogen into moving soil aggregates is an indicator that earthworms probably contribute a lot to stabilizing and accretion of human organic matter in agricultural systems and their influence differs greatly depending on land management.

Keywords

Earthworms, Soil Fertility, Nutrients, Soil Characteristics, Population Dynamics

1. Introduction

Soil is the most invaluable asset that humanity has been endowed with. The fact that soil cultivation has been an integral part of human history and the foundation of successful civilizations is what binds us to soil. Human survival in the past depended on food hunting and collecting. This relationship among people, the planet, and the food supplies validates that the soil forms the basis of agriculture [1]. The first step toward a sustainable management of the soil habitat is the protection of the biological character of the habitat that determines a long-term quality and production. Sustainable agriculture describes conservation of societies, the environment, and the animal lives through food which is made through use of plants or animals using a variety of agricultural practices without being destructive to the ecosystem. Good getting yields are some of the benefits associated with deforestation, overgrazing, burning crop wastes, unsystematic use of agrochemicals, which in turn, have the capacity of depreciating the soil on a daily basis all over the world and the less use of organic manures and use of fertile land on non-agricultural or non-fertile uses has not only contributed to declining soil fertility but also declining yield. The latter led to the decrease of soil organic matter (SOM), soil pH, and major and minor nutrients in the soil [2].

Vermicomposting is an easy biotechnological method of composting, whereby some worm's species are used to improve the process of conversion of wastes and this results into a better product. Vermicomposting is contrasted to composting in a number of aspects. It is a mesophilic process which makes use of microorganisms and earthworms which are active in 10oC to 32oC (not in ambient temperature but the temperature in the heap of moist organic matter). It takes less time than composting; due to the fact that the material is ingested by the earthworm and undergoes a substantial but incomplete change, in the form of compartment passes through the gastrointestinal tract of the earthworm, the resulting castings of the earthworm (worm manure) are abundant in microbial activities and plant activity regulators, and are enriched with capabilities of repelling pests also. Put in simple terms, earthworms using some form of bio alchemy can turn garbage into gold [3]

Earthworms are keystone species in soils because they are also ecosystem engineers, both by ingesting soils and burrowing, but also by stimulating the growth of other helpful organisms in the soil. They are common in terrestrial ecosystems, forming frequently the largest animal biomass, and they are of use as soil quality indicators. Earthworm biomass production is also stimulated by management practices that maximize soil environmental conditions [e.g. soil organic carbon (SOM) and soil moisture]. The impacts of the earthworm on the soil stability of aggregates, nutrient quickening and the movement of soil carbon enhancing crop yields on its part [4].

One of the most important soil animals are earthworms; they help to retain the fertility of the soil by which means they contribute significantly. They are also recognized as plowmen of the field, ecological engineers, friend of farmers, biological indicators, earth's intestines. All earthworms, with the exception of those that live in leaf litter, are hermaphrodites and develop slowly. Earthworms can live anywhere from two to eight years, depending on the species, and they only produce one generation every year, with a maximum of eight to twelve cocoons available. With the "genital belt" that encircles the body (Clitellum), one can determine whether or not they have reached sexual maturity. Earthworms can be found in almost all soils, with the exception of deserts and polar regions. There are around 3,000 different species of earthworms that can be found all over the world [5].

Earthworm are generally believed to improve plant growth by various ways that are now well understood. Their relative importance is on the other hand difficult to establish and we also find that the strength and direction of the effects of a particular earthworm species on a particular plant are somewhat difficult to predict a priori. The characteristics of the soil would tend to play a very critical role in defining the effects of earthworm activities on plants. They have the propensity of altering the comparative capacity of the different mechanisms among those that work in the interaction between plants and earthworms. During this paper, we are going to revisit the different explanations applied in justifying changes in the effect of earthworm with soil type. Next, we consistently argue on the effect of key soil features (soil texture, OM and nutrient levels) on the various mechanism swallowing earthworm in an effort to impact growth of plants. At the last, we define the key gaps in our knowledge and highlight the new experimental and meta-analytical plans of approach that should be worked out. An example of this kind of meta-analysis is provided and what to do additionally is proposed. The outcome indicates a positive effect size of high importance in sandy soil and weakly negative effect in clayey soil [6].

As a direct impact on the soil microbiota, the nutrition of earthworms plays an important role. This could be dependent on their eating preference, choice, rate of eating food, digestion, and assimilation as indicated by. The earthworms are able to consume microorganisms thus reducing the microbial biomass particularly fungi. They can also choose or activate soil microbes to aid them in processes of digestion of the soil organic matter because the earthworm gut oftentimes lacks the adequate enzymes in accomplishing this. This can provide soil enrichment of some bacterial taxa, e.g. in bacteria capable of degrading the organic matter that earthworms consume or in denitrifying bacteria capable of surviving in the low-oxygen atmosphere of the earthworm gut [7].

Table 1. Classification and characteristics of different earthworm species

Characteristics	Epigeic species	Anecic species	Endogeic species
Habitat	3–10 cm, surface dwellers	30–90 cm, deep burrowing	10–30 cm, upper layer soil
Body size	Small	Large	Moderate
Color	Uniform body colouration	Pigmentation only at the anterior and posterior end	Weak pigmentation
Life cycle	Short	Long	Medium
Temperature tolerance	Tolerate a wide range of temperature	Poor temperature tolerance	Poor temperature tolerance
Live in	Near the surface litter or dung	Deep soil	Below the surface
Reproduction rate	High	Moderate	Low
Feeding habitat	Plant litter or mammalian dung, undecomposed litter	Decomposed litter, surface litter	Organic rich soil, subsurface soil material
Major role	Efficient bio-degraders and are good for vermicomposting	Distribution and decomposition of organic matter in soil	Soil mixing and aeration processes
Vermicomposting potential	Good	Low	Low
Common species	*Eisenia fetida*, *E. andrei*, *Eudrilus eugenie*, *Lumbricus rubellus*, *L. festivus*, *L. castaneus*, *Bimastus eiseni*, *B. minusculus*, *Drawida modesta*, *Dendrodrilus rubidus*, *Dendrobaena veneta*, *Perionyx excavatus*	*Lumbricus terrestris*, *L. polyphemus*, *Lampito mauritii*, *Aporrectodea trapezoids*, *A. longac*	*Octochaetona thurstoni*, *Aporrectodea caliginosa*, *Allolobophora rosea*, *A. caliginosa*, *Metaphire posthuma*, *Pontoscolex corethrurus*, *Drawida barwelli*, *Amynthas* species

2. Humification by Earthworms

Since Darwin's time in 1881, scientists have studied earthworms in various aspects, including development, physiology, and ecology. However, the relationship between earthworms and microbes has only recently received attention. Earthworms assist to distribute bacteria in soil. Biomass of microbes in worm cast was also recorded to be very high and their activity was needed to release nutrients to the medium, which were absorbed by the plants. The earthworm casts contained enough nutrients (N, P, K, S, Ca, Mg, Fe and Zn) compared to the surrounding soil owing to the mineralization, which has taken place in the stomach as well as in the casts [8].

In spite of the fact that the cleaning up and humification of the biodegradable organic waste materials in the soil is mainly performed by microorganisms in the soil, limited current studies have revealed that earthworms play quite an essential role in humification. Gut micro flora in earthworm is species specific. The microorganisms which are found on the substances that are fed by earthworms are also of much importance. Microbes and earthworms cooperate in mineralizing humified organic matter, as well as assist in chelation of some metal ions. The role of the earthworms and the microbes, therefore, can explain the nutrient flux of the microbe, the earthworm and the plants especially the trace elements.

3. Effects of Earthworms on Soil Ecosystems

Charles Darwin accepted and explained earthworms in soils. With approximately 800 genera and 8000 species, earthworms (class Oligochaeta) can make up to 90 percent of the biomass of invertebrates that are in the soil. Known commonly as keystone species in soil food webs, they are everywhere, abundant creatures, and highly successful ones, which not only participate in creating soil food webs as "ecosystem engineers" but also do so in soils [9]. European earthworms are separated into three ecological groupings based on their distinct digging and eating behavior. Epigeic earthworms inhabit above soil minerals and hardly excavate burrows or prefer to feed on plant litters. Epigeic earthworms feed on huge quantities of mineral soils and humific matter, in their horizontally ramified and subterranean worm burrows. Anaerobic earthworms also permanently burrow into the mineral layer of the soil where they come out to feed on organic remnants left behind like that which is part decomposed plant litter, the manure and other residues. Ecological groups are well defined by a number of but not all species of the earthworm. As an example, Lumbricus buddy is of anaerobic species whereas the species Aporrectodea caliginosa is of the epigenic species [10].

At the terrestrial variety, earthworms are one of the most significant detritus-feeders on biomass and activity. They are recognized to five primary processes of their influence on plant growth:

1. The increase on the mineralization of soil organic matter,

2. Production of plant growth regulators through stimulating activities of microbes,

3. The regulation of the parasites and pests,

4. The stimulation of symbionts,

5. The soil porosity and aggregation modifications that cause alteration in the availability of water and oxygen to plant roots. Even though these mechanisms have been well recognized, it is hard to estimate their relative importance and to be able to predict which effect a particular earthworm species will have on a selected plant species [11].

Earthworms significantly enhance soil fertility through various mechanisms. For instance, earthworms transport nutrients from deeper soil layers and deposit them on the top as castings, so mitigating nutrient leaching. Earthworms integrate soil strata and contribute organic materials to the soil. These amalgamations facilitate the diffusion of organic stuff throughout. These combinations increase the fertility of the soil and enable the spread of the organic matter across it so that plants may easily get the nutrients. By tilling the ground, enhancing soil structure, inclusion, and tiling, earthworms help to build humus generation and boost the accessible plant nutrients. Earthworms' gut bacteria destroy harmful compounds consumed by them and also break down organic wastes. Made in castings of earthworms, plant growth regulator Auxin promotes the roots to develop more quickly and much deeper. Because nitrogen-fixing bacteria present in both worm casts and the earthworm stomach, nitrogen fixation is higher in worm casts than in soil. More importantly, nitrogenase activity in casts is more than in surrounding soil, which helps to explain great nitrogen fixation in casts [12].

4. Importance of Earthworms for Practical Purposes

The impact of EWs on soil biological processes and fertility levels varies across ecological categories. Anecic species construct permanent burrows within the deep mineral layers of the soil, transporting organic matter from the surface into their burrows for sustenance. Endogeic species inhabit exclusively and construct enormous nonpermanent tunnels inside the upper mineral layer of soil, primarily consuming mineral soil matter, and are referred to as "ecological engineers" or "ecosystem engineers." They create physical structures that alter the availability or accessibility of resources for other creatures. Endogeic species inhabit exclusively and construct enormous nonpermanent tunnels inside the upper mineral layer of soil, primarily consuming mineral soil matter, and are referred to as "ecological engineers" or "ecosystem engineers." They create physical structures that alter the availability or accessibility of resources for other creatures [13].

5. How Earthworms Contribute to Soil Nutrient Availability

Earthworms are essential for the initial breakdown and subsequent decomposition of organic matter, facilitating the release and recycling of nutrients contained within it. Earthworms ingest a greater amount of surface organic matter than all other soil organisms combined. The materials are excreted in the form of casts which are nutrients rich, water soluble and accessible to plants easily. Earthworms carry crop wastes, litter and parts that are not completely decayed to the earth surface to the sub surface layer where they are broken down and Labels. These fecal materials released by earthworms are nature cast which are laid on the ground surface of the burrows or in the open grounds under the soil surface. The earthworms are very important in decomposition of organic matter and transference of major and minor mineral nutrients [14].

6. The Significance of Earthworms in Relation to Soil Nitrogen

Earth worms boost mineralization of organic matters in the soil, so the nitrogen content has been increased because of the excellent rate of nitrification in the casts. Nitrogen enters the soil mass of earthworms in sufficient amount in the terrestrial system. Nitrogen is rapidly mineralized because the tissues of earthworms readily decompose. The nitrogen-fixing bacteria occurring in the gut of the earthworm and the earthworm casts lead to increased fixation of nitrogen in the casts than in the soil hence maximizing the catalytic action of the nitrogenase enzyme.

It is important to discuss the physiology, morphology and behavior of earthworm to determine their influence on soil functions (Figure 1, arrow 1). More evidence is however coming forth that the impact of earthworms on soil functions can be mediated by soil microbial communities (Figure 1, arrow 2). The question of how the various ecological groupings can facilitate or choose the soil microorganisms is still unclear and the findings as to whether the earthworms have effects on the microbial community in soil are hardly agreeing. Yet, the drilosphere is widely recognized to be a soil hotspot that produces a beneficial impact on the ecosystem activity including nutrient cycling and plant growth [15].

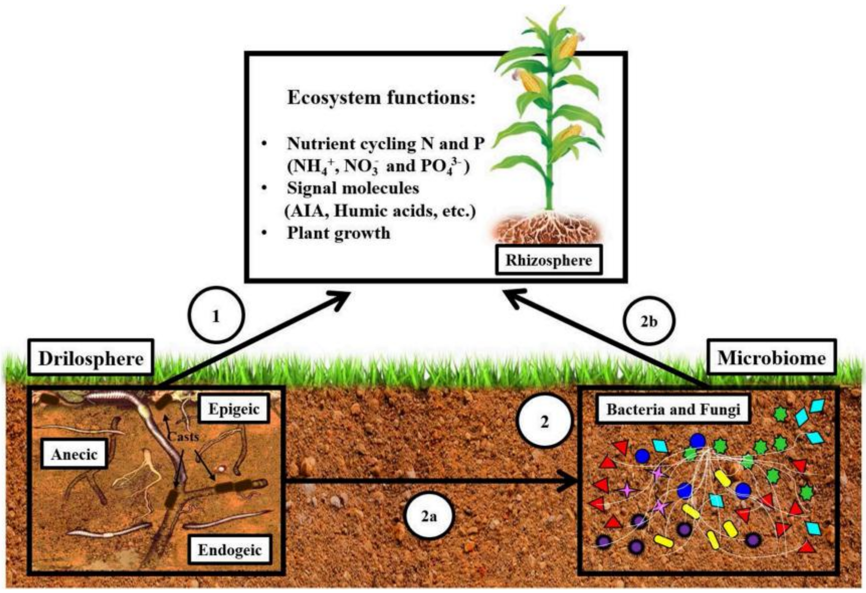

Figure 1 | Hypothesis: effect of the earthworms on nutrient cycling and plant growth is not a simple direct action but is an entirely indirect action mediated by microorganisms. Earthworms have a direct (1), or indirect, effect, namely, through stimulation of the microorganisms (2). Earthworms alter the ecosystem functioning through the ways bacteria are already altering the functions of the ecosystems due to the change in the microbial communities (2a) of the earth. This character is intended to depict that the indirect impact is significant as the direct one.

7. Impact of Earthworms on Soil Phosphorus

Phosphorous is a plant nutrient and essential towards energy storage and transfer in the metabolic process of a cell. It fosters premature vegetative growth thus directing premature maturity of the grain crops. Even though phosphorous is an essential nutrient in the growth of plants, it is the second most significant after the nitrogen. There is less solubility in water and less provision of mobile form to the plants and this implies less of other significant nutrients in the soil. The concentrations of casts produced by the earthworms contain more P as compared to the earthworms deprived soil. Higher phosphatase in the castings leads to the increased availability of P in the earthworm casts. The amount of earthworm casts that can be estimated under the pasture, and secondary forest under an agroforestry system were 41, 38.2, and 26 kg/ha, respectively [16].

8. Conclusion

It is said that earthworms generate a massive effect to the ecological processes through improvement of soil structure, nutrient cycling and development of plan growth. It further has shown that earthworms contribute in the shaping of soil microbial expressions directly through their swallowing or indirectly through priming affect due to augmentation of labile substances. However, the aggregated data of the influence of earthworms on microorganisms in the drilosphere and the reaction of nutrient cycle in soils or the P cycle of the soil, or synthesis of the signal molecules are nowhere in the literature and therefore we are unable to conceptualize the processes involved in the outcomes of microbial hotspots in the drilosphere on the functionality of the soil in a profound way. The effects of earthworms upon nutrient cycling and growth of plants are however both direct as well as indirect since it mainly happens through the modification of the microbial community: this is the hypothesis we have been able to largely confirm in the mini scale (gut, casts, burrows and tunnels).

Although individuals are yet to obtain clear explanations to determine whether earthworms have any form of intestinal microbiome or it is soiled on them; most of the language leads to the soil being the source of this microbiome. We can however highlight on some general patterns: the taxa that are commonly reported to be stimulated by gut passage are Flavobacterium, Actinobacteria, Firmicutes and 7-Proteobacteria and hence figure as a possible good proxies to be expected in regards to the earthworm soil processes. The movement towards Next Generation Sequencing (NGS) technologies in the study of the soil microbial diversity and the community structure will help enhance on the information on how earthworm may impact the same. Information on the role of earthworms in the potential of causing the composition and pattern of fungal communities, particularly a mycorrhizal fungi is also direly needed because of the direct interaction of the said animal to vegetation (Box 1). In other cases, the saprotrophic fungi that the majority of bacteria are significant as modifiers of soil biogeochemicals and their roles have not been taken into account fully during the course of their symbiosis or antagonism with earthworms so far. Earthworms promote N and P mineralization and converts microbial functionality genes, which modify soil functions. It is necessary to learn more microorganisms and microbial genes that are stimulated by earthworms especially on P cycle. Finally, it is impossible to adequately examine the effects of such imported changes in soil functions as a result of the change introduced by earthworms in the development of plants without references to SM that it is formed during the activity of the earthworms or formed most probably by the microorganisms that may be appearing in the wake of the activity of the earthworms. It should be made clear about the contribution of specific microbial taxa in these molecule secretions and this is a multidisciplinary activity requiring the input of sciences such as: a metabolomics, microbiology, transcriptomics and biochemistry so as to be in a position to clearly be able to identify the SM in earthworms or earthworm casts.

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