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Do Earthworms Truly Always Assist Farmers or is There Another Fact ?

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Abstract

Among all the soil creatures, earthworms are regarded as the most crucial. They are found in the areas where the soil contains enough water and temperature. They also exhibit a variety of environmental adaptations to the various environments. Earthworms may live in local microsites, even in unsuitable areas, when the conditions are favorable (such as urban gardens, desert oasis, etc.), especially if well-adapted species have been introduced. Despite the fact that earthworms have many positive effects on the soil ecology, certain of their activities are deemed undesirable. The destructive behaviors of earthworms include removing and burying surface residues that would otherwise protect soil surfaces from erosion, producing fresh casts that promote erosion and surface sealing, increasing soil compaction on the surface, leaving castings on lawns where they are an annoyance, dispersing weed seeds in gardens and agricultural fields, transmitting plant or animal pathogens, and riddling irrigation canals that reduce their ability to function. Although being little understood, there is a surge in exotic earthworm invasions as a result of worldwide commerce in agriculture, waste management, and bioremediation. Exotic earthworm invasions are spreading globally and having a significant impact on plant populations and soil processes. It has been documented that at least 100 different species of earthworms are found outside of their natural habitats. Non-native earthworms can potentially colonize new places despite disturbance and interference. The present study discusses on the impact of invasive earthworms on the agroecosystem and analyzes the importance of earthworms in all soil ecosystems.

Keywords: Exotic earthworms, disturbance, native earthworms, colonization of species, biological invasion, competition.

Introduction

In many situations, earthworms constitute the most prevalent and significant animals found in soil. Their feeding and burrowing activities have a substantial impact on the physical and chemical properties, nutrient cycling, and plant development in the soil, making them crucial to agroecosystems. Darwin (1881) was the first to demonstrate that earthworms have a substantial influence on soil processes that are crucial to the operation of terrestrial ecosystems. Earthworms are often beneficial to soils, especially in systems that are managed for conservation, according to subsequent research, which focuses mostly on agricultural and pastoral systems (e.g., no tillage). Earthworms are important detritivores, ecosystem designers, and contributors to soil formation (Eisenhauer *et al.*, 2007). Invasive species gradually reduce native populations by outcompeting or devouring native species. Certain elements of earthworm activity are deemed undesirable despite the numerous documented and speculated positive impacts of earthworms on soil structure, nutrient dynamics, and plant development (Edwards and Bohlen, 1996; Lavelle *et al.*, 1998; Parmelee *et al.*, 1998). Earthworm activity has been found to hasten the breakdown of plant litter, boost nutrient transformation and plant nutrient absorption, increase soil aggregation and porosity, and enhance water infiltration and solute movement (Satchell, 1983; Lee, 1985; Hendrix, 1995; Edwards and Bohlen, 1996; Edwards, 1998; Lavelle *et al.*,

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1999). Although these effects are usually seen as positive in agricultural soils, Hendrix and Bohlen (2002), Bohlen *et al.* (2004a, 2004b), and James and Hendrix (2004) conversed about the negative effects that invasive/exotic earthworms have on soil processes. The profiles of soils, the dynamics of nutrients and organic matter, other soil creatures, and plant communities are all possible targets of exotic earthworms. These detrimental activities include removing and burying surface residues that probably protect soil surfaces from erosion; producing fresh casts that increase erosion and increasing surface soil compaction by surface sealing; depositing castings on the surface of lawns where they are inconvenience in gardens and agricultural fields; transmitting plant or animal pathogens; riddling irrigation ditches, making them less able to carry water increasing soil nitrogen losses through leaching and denitrification; and increasing soil carbon losses through enhanced microbial respiration. Earthworms have a wide range of environmental adaptations and may exist in a number of settings if the soil's water and temperature are favourable for at least a small part of the year. Earthworms can colonize nearby microsites with favorable circumstances, even in inappropriate habitats (such as urban gardens or desert oasis), especially if well-adapted species have been introduced.

There are around 7000 species of earthworms recorded worldwide (Grdisa, 2013; Reynolds and Wetzel, 2012); however, only 3000–3500 of these species are thought to be authentically described (Csuzdi, 2012). Misirlioglu *et al.* (2023) recently published a comprehensive checklist comprising 5,738 species/subspecies, including 5,406 species and 332 unique subspecies, that are distributed globally across 382 genera and 23 families. India is home to a diverse array of earthworm species and subspecies, with a total of 453 identified across 67 genera and 10 families (Lone *et al.*, 2021, 2022; Tiwari *et al.*, 2021; Hasan *et al.*, 2023). Although a few exotic and peregrine species are also documented, the majority of these species are native to the nation (Narayanan *et al.*, 2019; Narayanan, 2020; Anuja *et al.*, 2022). Earthworm have emerged on every continent except for Antarctica, and some groups have spread globally due to human transport. Due to its diverse geographic locations, which include a large latitudinal range (between 8.4°N and 37.6°N) and longitudinal range (between 68.7°E and 97.22°E), edaphic conditions, and climatic elements (ranging from temperate to tropical), India is known for having a high diversity of earthworm species (Zodinpuii *et al.*, 2019; Lalthanzara *et al.*, 2020). The geological past of the ancient supercontinent of the Gondwana Land, from which it split in the late Jurassic and drifted until crashing into the Asian mainland in the Eocene, provides additional support for this fact (Julka *et al.*, 2009). Also, there are deficiencies in the genetic diversity and biogeography of a number of earthworm species that are either exotic or peregrine and have a broad distribution. For example, the Megascolecidae family of exotic earthworms, *Metaphire houlleti* (Perrier, 1872), is extensively distributed in various areas of India, including the north (Jaswinder *et al.*, 2015), north eastern (Thounaojam *et al.*, 2020), central (Prakash, 2017), and southern regions (Narayanan *et al.*, 2016). Comparable exotic earthworm species with widespread populations in India include *Amynthas corticis* (Kinberg, 1867), *A. morrisi* (Beddard, 1892), and *Pontoscolex corethrurus* (Müller, 1857). Consequently, it is crucial to comprehend both the invasion's effects and those on native earthworm populations. The objective of the present investigation is to analyse the effects of invasion on the recipient ecosystem, including above and below-ground species, the interactions between native and exotic earthworms, and native and exotic plants.

Materials and Methods

A data set of previously published literature over five decades was gathered for the study using searches on the Wiley Online Library, Science Direct, Google Scholar Database, Biodiversity Heritage library, and ResearchGate, as well as specific requests to the authors. In order to search the database, the keywords "earthworm invasion," "invasive species," "invasive earthworms and plants," "biological invasion," "exotic earthworm and plant herbivory," "peregrine," "introduced earthworms," "belowground invasion," and "invasion biology" were used either alone or in conjunction with others. The following criteria were used to choose 170 articles of published literature for the study from both national and international journals: (1) described that exotic earthworms affect forest ecosystems; (2) documented negative impacts of invading earthworms on soil biodiversity; (3) shown beneficial relationships between exotic earthworms and exotic plants; and (4) demonstrated negative effects of earthworm invasion on plant defense features. Out of 170 papers, 90 showed the effects of earthworm invasion on forest ecosystems, primarily in North American forest ecosystems; 40 focused on the effects of exotic worms on native worms; 25 on soil vertebrates; and the remaining 15 showed the facilitative relationships between exotic worms and exotic species (Figure 1).

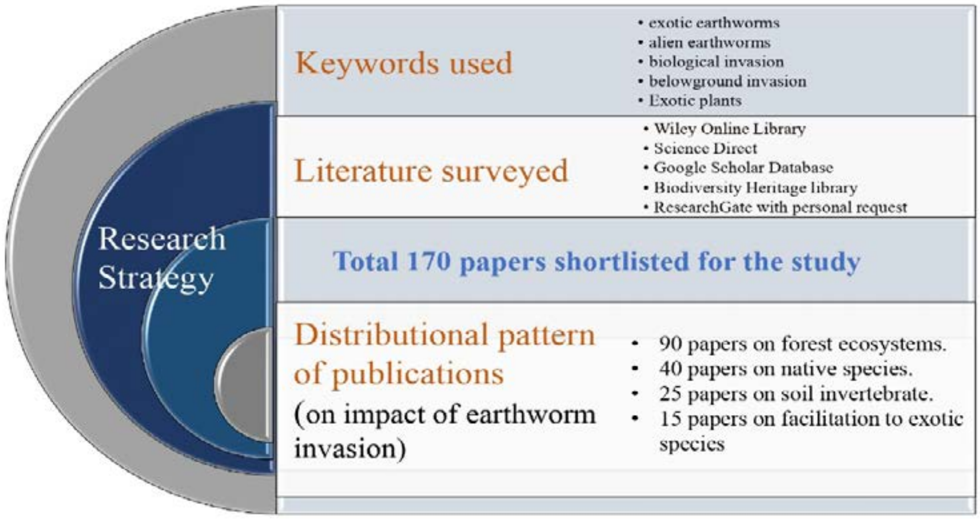

Figure 1. Layout of the methodology used in the study.

Results and Discussion

Anthropogenic biotic exchange endangers biodiversity and can impair ecosystem function (Sala *et al.*, 2000). Invasion by exotic earthworms, in particular, has been shown to have dramatic effects in recipient ecosystems. For instance, invasion by earthworms, in previously earthworm-free ecosystems, alters the physico-chemical characteristics of the soil. Soil changes can have far-reaching consequences on soil organisms, which account for a large portion of terrestrial biodiversity. When earthworms invade previously earthworm-free forests, they cause a long cascade of ecological effects, including changes in soil nutrient status, soil bulk density, soil microbial processes, and a reduction in native plant and soil microarthropod species richness as shown in Figure 2 (Frelich *et al.*, 2006; Eisenhauer *et al.*, 2007; Hendrix *et al.*, 2008).

Changes in soil properties caused by earthworms can lead to changes in plant communities *via* ecological cascades (Lavelle *et al.*, 1997; Frelich *et al.*, 2019). Earthworms also have a significant impact on the soil microbial community and the activity of microbial enzymes (Jana *et al.*, 2010; Tao *et al.*, 2009; Zhang *et al.*, 2010).

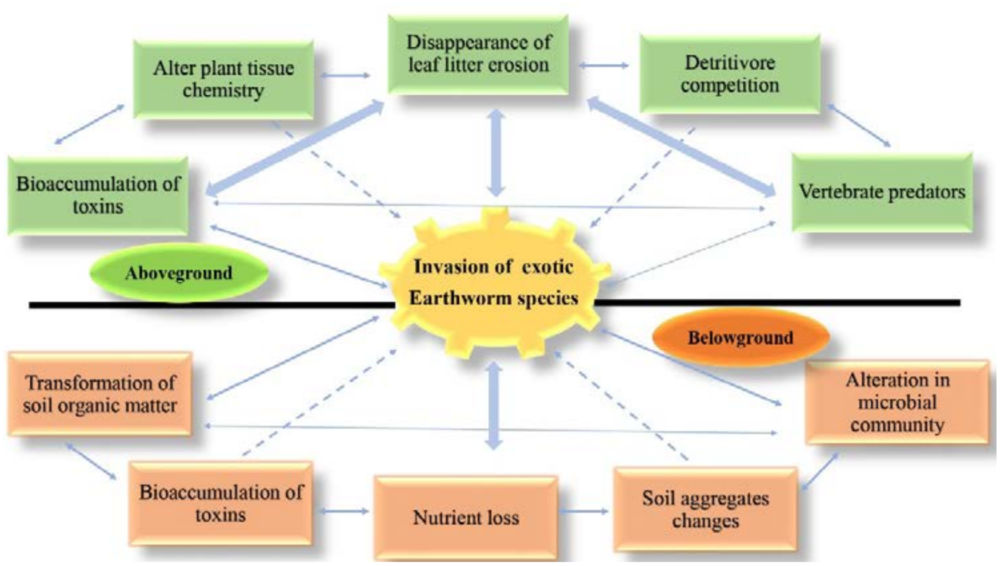

Figure 2. Earthworm invasion's layout and consequences on the soil ecosystem.

Impact of exotic earthworms on soil invertebrates:

Invasive earthworms are known to reduce soil biodiversity (Ferlian *et al.*, 2018). Earthworms have the ability to interact with other subterranean fauna, both through direct devouring and indirect modification of soil properties *via* chemical or physical means. The findings of Gao *et al.* (2017) indicate that the presence of the invasive earthworm species, *Amynthas agrestis*, may lead to a decline in the abundance of springtail (Collembola) in a microcosm study. That decrease may be attributed to alterations in the habitat and a reduction in the availability of food resources. The literature on the effects of invasive earthworms on soil invertebrate communities includes both positive and negative effects. The increased habitat complexity provides short-term benefits to soil micro-arthropod communities in earthworm-invaded soils (Migge-Kleian *et al.*, 2006). In contrast, the long-term effects of earthworm invasion on soil invertebrates are widely acknowledged to be negative due to significant loss of organic layers (Migge-Kleian *et al.*, 2006). The organic layers of the soil are home to the majority of soil invertebrate communities. Habitat loss may thus force soil invertebrates to disperse deeper into the soil, or their densities may eventually decline (Brown, 1995). The presence of all three ecological groups (epigeic, aneceic and endogeic) of earthworms can significantly reduce the organic material in the soil's organic layer, resulting in a significant depletion of resources for soil invertebrates (Ferlin *et al.*, 2018). Furthermore, endogeic and anecic earthworms are more harmful to other soil invertebrates than epigeic earthworms (Eisenhauer, 2010; Migge-Kleian *et al.*, 2006).

Impact of Invasion of exotic earthworms and soil vertebrates:

Only two vertebrates—birds and salamanders—have been investigated regarding the consequences of earthworm invasion**.** The disappearance of leaf litter layers caused by invasive earthworms in recipient ecosystem reduces habitat quality for forest floor salamanders and ground-nesting birds in general (Loss and Blair, 2011; Ransom, 2012). However, earthworms may become food for some species. As a result, the interaction of these factors is likely to determine the overall influences.

Salamanders are an important component of food webs in forest ecosystems. By consuming and controlling arthropod populations, they serve as the top predators in the leaf litter food web (Wyman *et al.*, 1998, Walton and Maerz *et al.*, 2006). These are particularly lungless vertebrates and need to allow gaseous exchange across their skin, which have moist membrane, and because of this they are very much sensitive to soil pH (Sugalski *et al.*, 1997). In North American forests it has been shown that biological invasion affects the population of these vertebrates. These particular forests are invaded by invasive shrub, *Berberis thunbergii*; its expansion alters the soil chemistry, e.g., it increases soil pH and composition of the soil and leaf litter layers, and facilitates the invasion of exotic earthworms, which prefer higher pH to survive (Laverack *et al.*, 1961). By reducing leaf litter, earthworms alter the amounts of microhabitats that are accessible, which is crucial for the survival of many terrestrial salamanders in the northeastern United States These invasions may affect salamanders as well as their predators as a result of a decline in soil arthropods and leaf litter, which might cause a trophic cascade that alters the function of eastern deciduous forest ecosystems.

Impact of exotic earthworms on soil microbiota:

The soil profile, which serves as a home for soil microorganisms, is significantly impacted by earthworm invasion (McLean *et al.*, 2006). During invasion, earthworm activity disrupts the soil layer, which changes the structure and activities of the microbial community in the soil. Microorganisms in soil exhibit a wide range of genetic and functional diversity. In addition, the enzymatic activities of microbes have the ability to break down a wide variety of organic substrates. Organic layers are the habitat for the majority of microbial biomass and activity site. The invasion affects the organic layer thickness, which results into disruptions of microhabitats. As a result of the earthworms' burrowing activities, it is probable that the invasion of earthworms may have an effect on the distribution of soil microorganisms. Mycorrhizal fungi are an important component of the microbial community, which as a whole is responsible for regulating the way plants interact with the soil. Both the stimulating effects of their mucus and the feeding behavior may have an influence on the microbial diversity pattern in the soil (Chapuis-Lardy *et al.*, 2010). As earthworms are fed, microorganisms move through their guts, where some species thrive while others cannot survive due to the microhabitat of the gut. It decreases the ratio of fungus to bacteria (Brown, 1995; Lavelle *et al.*, 1995).

Impact of exotic earthworms on defense trait of plants:

Plants in natural populations are frequently attacked by a variety of adversaries, such as diseases and herbivores. Despite the fact that many plants have all-purpose defenses against diseases and herbivores. These defensive substances are plant secondary metabolites that have distinct effects on either herbivores or plant diseases, which are plants' natural enemies. There are several kinds of secondary metabolites that can influence both pathogens and herbivores function (Schönbeck and Schlösser, 1976; Barbosa, 1991; Krischik, 1991; Harborne, 1993; Hammerschmidt and Schultz, 1996; Karban and Baldwin, 1997). Certain secondary metabolites altered their chemical structure in order to become effective against infections, whereas others, like flavonoid, may not need these kinds of alterations. With continuous influence on the biochemistry of the soil, non-native earthworms have the ability to change the ways in which plants defend themselves against herbivores and pathogens. A change in the concentration of chemical defense compounds in plants caused by the invasion of earthworms is associated with increased leaf herbivory. The invasive earthworms cause a reduction in the amount of leaf dry matter and an increase in the tree's vulnerability to infection by fungal pathogens (Thakur *et al.*, 2020). Salicinoids and flavonoids are two primary classes of phenolic compounds that have a function as chemical defense in plants. These chemicals have capabilities of being both anti-herbivore and anti-pathogen. The percentage of leaf dry matter reduces by invasive earthworms. A lower palatability indicates a higher leaf dry matter content, which is frequently related to the vulnerability of a tree's leaves to be damaged by leaf-chewing insects.

Interaction between native and exotic species of earthworms:

Native species are quickly overrun by invasive earthworms, which also severely deplete the variety of native species and, in some cases, lead to extinctions (Kemp *et al.*, 2009). Like some other exotic species, including invasive plant species, non-native earthworms have a friendly and helpful interaction. According to the hypothesis "Invasive meltdown," one invasive species creates an environment that is favourable for other invasive species, which results in an increase in invasion (Simberloff and Von Holle, 1999). The modifications to the soil's qualities were brought about by the invasive plant species *Berberis thunbergii,* a Japanese barberry that has spread to deciduous woods in North America. Sites where the Japanese barberry has invaded have higher pH values, less leaf litter, a thinner organic layer under the soil, and more rapidly nitrifying soil due to the shrub's leaf litter.

Due to its sharp spines, this plant avoids deer herbivory and thrives (Ehrenfeld *et al.*, 1997). By altering soil chemistry through the chemistry of leaf litter, it speeds up its invasion (Ehrenfeld *et al.*, 2001; Li *et al.*, 2008). The invasive earthworms, which prefer basic soil to dwell in, were harmed by the alterations created in the deciduous forest by that invading plant. Consequently, invasive plants encourage the invasion of exotic earthworms.

Conclusions

The study found that ecological invasion has expanded into a global problem. A disturbed soil fauna that lacks native earthworms makes it easier for exotic earthworm invasion. Earthworm invasion is highly correlated with anthropogenic activities and infrastructure, such as forest roads, fishing sites, cottages, and timber harvesting. Successful invasion by exotic earthworms causes soil's chemical and physical composition to change. In plant communities, exotic earthworms have a species-specific effect. They have an impact on native ecosystem diversity, soil microbes, soil invertebrates, and soil vertebrates. The invasion has the most harmful impact on the mycorrhizal fungus group of microbes. Earthworm invasion lowers soil faunal diversity and density as well as invertebrate diversity and density. In India's agro-ecosystem, it is important to evaluate the effects of introduced earthworm species.

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