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Earthworms under Threat: Their Possible Consequences and Conservation Measures

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ABSTRACT

Earthworms are keystone organisms in terrestrial ecosystems and play a fundamental role in maintaining soil structure, fertility, and biological productivity. Often described as "ecosystem engineers," Earthworms influence soil porosity, nutrient cycling, organic matter decomposition, and microbial dynamics. Despite their ecological and agricultural importance, Earthworm populations worldwide are increasingly threatened by intensive agricultural practices, excessive pesticide and fertilizer use, soil pollution, habitat destruction, invasive species, and climate change. The decline of Earthworms poses serious consequences for soil health, crop productivity, biodiversity, and ecosystem services essential for sustainable development. This paper provides a comprehensive review of the ecological importance of Earthworms, the major threats contributing to their decline, and the potential environmental and socio-economic consequences of reduced Earthworm populations. Furthermore, it discusses effective conservation and management strategies, emphasizing sustainable agriculture, pollution control, habitat restoration, policy frameworks, and public awareness. Protecting Earthworm populations is crucial for ensuring long-term soil sustainability, food security, and ecological balance.

Keywords Earthworms, Soil biodiversity, Ecosystem engineers, Soil degradation, Conservation strategies, Sustainable agriculture.

INTRODUCTION

Soil is a living system that supports terrestrial life, and the organisms living in the soil play a vital role in maintaining its structure and fertility. Among these organisms, Earthworms are particularly significant due to their direct and indirect influence on physical, chemical and biological soil properties. Darwin (1881) famously highlighted the importance of Earthworms, stating that few animals have played such a crucial role in the history of the world as these lowly organized creatures. Earthworms are widely regarded as ecosystem engineers because they modify the physical, chemical and biological properties of soil in ways that benefit other organisms. They are crucial for maintaining soil structure, functioning, and productivity (Liu *et al.* 2019, van Groenigen *et al.* 2019) and they also serve as an important food

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source for many predators (King *et al.* 2010). In agricultural systems, soil organisms perform a wide range of essential activities, including nutrient recycling, regulating the local microclimate, detoxifying chemicals, and controlling the populations of harmful organisms. The survival of these soil organisms relies on preserving biological integrity and diversity within the agroecosystems (Altieri 1999). In the composting process, as described by Kumar (2018), they reduce the time required for waste stabilization and produce an efficient bio-product called organic fertilizer. They were also act as biological tools for assessing soil pollutants (Gupta and Kumar 2024).

Despite their importance, Earthworms are increasingly under threat due to rapid industrialization, urbanization, intensive farming and climate change. Modern agricultural practices, particularly the widespread use of chemical fertilizers and pesticides, have significantly altered soil environments, making them inhospitable for Earthworm survival. The decline of earthworm populations has raised concerns about soil degradation, reduced crop yields, and the loss of ecosystem services. This paper aims to (1) Examine the ecological role of Earthworms, (2) Identify the major threats to their survival, (3) Analyze the possible consequences of their decline, and (4) propose conservation measures to protect and restore Earthworm populations.

Ecological role of earthworms

Earthworms play a vital role in decomposing organic matter, cycling nutrients, improving soil structure, and ultimately supporting plant growth.

Soil structure and aeration

Through their burrowing activities, Earthworms create extensive networks of channels that enhance soil porosity and improve its structure. These burrows facilitate the movement of air and water within the soil profile, reducing compaction and increasing root penetration. Improved soil structure also minimizes surface runoff and soil erosion. Earthworms are among the most vital soil organisms, playing a crucial role in maintaining soil fertility and supporting sustainability. They significantly contribute to soil formation as well as the structure and functioning of soil ecosystems, with their diverse species earning them the title of "ecosystem engineers" (Jones *et al.* 1994).

Organic matter decomposition and nutrient cycling

Earthworms feed on organic material, including leaf litter, plant debris and microorganisms. During digestion, they break down to produce nutrient-rich casts. These casts have higher concentrations of nitrogen, phosphorus, potassium, and micronutrients compared to the surrounding soil, making these nutrients more readily available to plants. Vermicompost acts as an effective soil amendment, characterized by a lower content of volatile solids and is enriched with readily available nitrogen (N), phosphorus (P), and potassium (K) for plants (Edwards 1998). Soil organisms, including Earthworms, play a crucial role in enabling soil to store and release carbon. This process helps regulate the flow of greenhouse gases, which in turn affects the global climate system. The implications of this are significant, as it directly influences human health, crop productivity, water resources, and food security (European Commission 2010). The material produced after the processing of organic waste in the Earthworm gut is significantly different from the original waste and is commonly referred to as "black gold" or vermicast (Patangray 2014).

Earthworms play a significant role in soil health through their burrowing, humus formation, and casting activities. They enhance the incorporation of plant residues into soil aggregates, improve soil porosity, stabilize soil structure, and influence the distribution of organic matter (Lavelle and Spain 2001, Bossuyt *et al.* 2004, Jouquet *et al.* 2014). A healthy population of Earthworms is crucial for soil health because they help recycle organic matter efficiently. Therefore, adopting Earthworm-friendly agricultural practices is essential to sustain their populations and ensure long-term soil productivity (Rajkhowa *et al.* 2017). Kumar *et al.* (2021a) documented that using earthworms to convert agricultural waste into nutrient-rich biofertilizer through vermicomposting is an environmentally friendly method. Earthworms contain hormone-like substances, which encourage the health and growth of plants (Ahmed and Al-Mutairi 2022).

Table 1. Illustrates the main characteristics features of ecological categories of Earthworms.

Ecological categories	Epigeic species	Anecic species	Endogeic species
Habitat	Live on surface	Live in vertical burrows in soil	Live in horizontal burrows in deep horizons
Food habits	Phytophagous	Geophytophagous	Geophagous
Pigmentation	Highly pigmented	Less pigmented	Less pigmented
Ecological function	Improve soil fertility	Improve soil structure	Improve soil structure
Examples	*Eisenia fetida*, *Eudrilus eugeniae*	*Lampito mauritii* *Lumbricus terrestris*	*Pheretima posthuma* *Apporectodea caliginosa*

Enhancement of microbial activity

Earthworm activity enhances soil microbial populations by creating favorable conditions for their growth. Microorganisms play a crucial role in nutrient mineralization, and their interaction with Earthworms accelerates decomposition and nutrient turnover. Earthworms influence microbial communities by selectively digesting certain micro-organisms and promoting the growth of beneficial bacteria (Omokaro 2024).

Ecological categories of earthworms

Earthworms are generally classified into three ecological groups based on their habitat and behavior. These are known as ecological categories as described by Bouche (1977) and mentioned in the Table 1. Each group contributes uniquely to soil processes and ecosystem functioning.

Major threats to earthworm populations

Five major factors contribute to the decline of Earthworm diversity, as reported by Moore *et al.* (2013) are as follows:

(1) Soil degradation and habitat loss.

(2) Climate change.

(3) Excessive nutrient input and other forms of contamination.
(4) Over-exploitation and unsustainable soil management, and

(5) Invasive species.

The global rise in human population and demand for resources has led to the rapid conversion of forests into agricultural or urban land. This transformation is a primary driver of the loss of Earthworm biodiversity. Among the various pressures, habitat destruction and soil degradation, particularly caused by agricultural practices and unsustainable forest management, pose the most significant threats. Table 2 highlights the major threats to Earthworms and their impacts.

Habitat loss, soil degradation and urbanization

Habitat loss and soil degradation, primarily driven by agricultural expansion and unsustainable forest management, pose significant threats to Earthworm diversity. Since soils are the main habitat for earthworms, any form of soil degradation jeopardizes their survival and diversity (Lavelle *et al.* 2006, Lavelle 2009). Inappropriate irrigation practices or the excessive extraction of groundwater, especially in coastal regions, can cause bacterial species to enter a dormant phase and can also kill beneficial soil organisms such as Earthworms. This ultimately leads to reduced plant growth and crop productivity, as well as an increased risk of desertification (European Commission 2010). In fact, soil degradation is regarded as one of the most serious threats to Earthworm populations in this century and requires urgent global attention (Skubala 2013).

Table 2. Major threats and their impacts on Earthworms.

Threat	Impact on Earthworms
Intensive tillage	Physical injury, habitat destruction
Pesticides	Toxicity, reduced reproduction
Heavy metals	Mortality, bioaccumulation
Urbanization	Complete habitat loss
Climate change	Altered survival and distribution

Understanding how Earthworm species adapt to disturbances and persist in agricultural soils is vital for developing effective biodiversity conservation strategies. It is also important to convey the role of Earthworm diversity in supporting ecosystem services and human well-being to a wide range of stakeholders, especially farmers. Incorporating local ecological knowledge can facilitate better communication between farmers and scientists, thereby enhancing efforts to conserve Earthworm biodiversity (Zuniga *et al.* 2013).

Research has shown that converting forests to farmland and the spread of invasive species have significantly reduced Earthworm diversity, leading to the complete disappearance of some native species. This loss has harmful repercussions for ecosystem services (Dewi and Senge 2015, Loss *et al.* 2012, Hairiah *et al.* 2014). Additionally, urban expansion transforms natural and agricultural land into roads, buildings, and other impervious surfaces, resulting in the total loss of suitable habitats for Earthworms. Deforestation and changes in land use further decrease the organic matter inputs essential for Earthworm survival.

Climate change

Climate change is altering temperature and precipitation patterns, which in turn impacts soil moisture and the decomposition rates of organic matter. Prolonged droughts can decrease soil moisture, while excessive rainfall may lead to waterlogging, both of which have negatively affect Earthworm populations. Additionally, climate change may alter the distribution patterns of Earthworms. The relative density, frequency, and species diversity of Earthworm species also vary across different habitats and locations (Kumar *et al.* 2021b). The effects of climate change on soils and soil processes are mainly influenced by alterations in temperature and rainfall patterns. Rising temperatures, drought conditions, and increased winter rainfall will change soil moisture and temperature regimes. These changes have been shown to impact Earthworm populations in various ways (Wever *et al.* 2001, Perreault and Whalen 2006, Staley and Johnson 2008).

In order to comprehend how climate change affects soil fauna distributions and ecosystem processes, further research is essential on the climatic tolerances of these key soil invertebrates (Sutherland *et al.* 2006, Moreau-Valancogne *et al.* 2013, Eisenhauer *et al.* 2014). Although Earthworms are widely recognized as vital for ecosystem functioning and face significant risks from climate-related changes (Cock *et al.* 2013, Eisenhauer *et al.* 2014, Siebert *et al.* 2019), there is still a lack of comprehensive understanding regarding how climate change affects Earthworm communities. Hughes *et al.* (2019) documented that climate change will not only affect the extent of the distribution but will also promote significant fragmentation and a geographical shift outside of the currently recognized geographical boundaries.

Intensive agricultural practices

Modern agriculture depends significantly on the use of machinery, monoculture cropping, and chemical inputs. Recurrent ploughing and tillage disrupt earthworm burrows and can directly injure or kill these organisms. Research on the impact of agricultural practices on Earthworm communities has been extensive and well-documented (Pelosi *et al.* 2009, Datta *et al.* 2016, Briones and Schmidt 2017). Key areas of focus include soil tillage (Emmerling, 2001, Crittenden *et al.* 2015, Pelosi *et al.* 2014a), pesticide application (Krogh *et al.* 2007, Pelosi *et al.* 2014b, Maggi and Tang 2021), and both organic and mineral fertilization (Leroy *et al.* 2008,). Niswati *et al.* (2022) observed that minimum tillage and fertilization significantly improve soil biological quality and enhance Earthworm biomass and abundance in agricultural soil.

Pesticides and chemical pollution

Many commonly used pesticides, including insecticides, fungicides, and herbicides, are toxic to earthworms. These chemicals can cause physiological stress, reduce cocoon production, and lead to population decline. Heavy metals such as lead, cadmium, and mercury accumulate in soil and can be lethal to Earthworms even at low concentrations. This practice also introduces harmful substances, which negatively impact the survival, growth, and reproduction of Earthworms. Additionally, synthetic fertilizers and pesticides contaminate the soil and decrease its organic matter content.

Animals that live in close association with soil are directly exposed to pesticides and can be adversely affected by them. Recent studies indicate that the concentrations of current use pesticides (CUP) in pesticide-treated agricultural soils have surpassed toxicological thresholds for Earthworms and other soil invertebrates (Vasickova *et al.* 2019). Research indicates that Earthworm abundance increases when pesticide use is reduced (Pelosi *et al.* 2013) and tends to be lower in conventional fields compared to organic systems (Pelosi *et al.* 2015). However, it remains difficult to disentangle the specific effects of pesticides from other interacting biotic and abiotic factors. At present, no data are available on Earthworm contamination by multiple classes of CUPs under natural field conditions in either treated or untreated agricultural habitats. Generating such data would provide valuable insights into pesticide bioaccumulation, their unintended impacts on Earthworm populations, and the potential risks of transfer along the food chain to their predators.

Research from both field and laboratory studies indicates that the alteration of soil layers, particularly the removal of organic horizons, along with soil disturbance, changes in understory vegetation, and direct competition for food resources, collectively lead to considerable declines in the populations of soil microfauna and mesofauna.

Possible consequences of earthworm decline

Earthworm populations play a crucial role in both natural ecosystems and human activities, and their decline can lead to significant ecological and economic consequences. When Earthworm populations decrease, it can cause widespread disruptions that affect soil health, agricultural productivity, and the stability of ecosystems. New research highlights a dramatic decline in Earthworm populations in the UK, which have decreased by an estimated 33–41% over the last 25 years (Barnes *et al.* 2023). This reduction has significant implications for soil health, biodiversity, and ecosystems nationwide. A summary of the possible consequences of Earthworm decline is provided in Table 3.

Table 3. Consequences of Earthworm decline

Aspect	Consequence
Soil fertility	Reduced nutrient availability
Soil structure	Increased compaction and erosion
Agriculture	Lower crop productivity
Biodiversity	Decline in soil microorganisms
Ecosystem services	Reduced carbon sequestration

Impact soil health and fertility

Decreased aggregation and increased compaction result in fewer burrows and less casting, which in turn diminishes aggregate formation and structural stability. Compaction is caused by both natural and human activities, particularly the use of heavy machinery in farming on wet soils. This threatens all underground habitats and restricts nutrient availability (European Commission 2010). Vasquez (2023) documented that soil compaction significantly reduces the burrowing rates of Earthworms. An experimental analysis of the temporal dynamics of Earthworm burrowing under semi-field conditions showed that Earthworm burrowing rates were in the range between 1 and 4 cm^3 d^{-1}, while casting rates were between 1.3 and 3.3. cm^3 d^{-1}, and the fraction of ingested soil increased towards autumn, after 24 weeks. This results in higher bulk density and reduced resistance to root growth, making soils more susceptible to surface runoff and erosion. Erosion results from farming practices, deforestation, overgrazing, forest fires, and construction, and is expected to worsen due to climate change. The build-up of water-soluble salts in soil, known as salinization, can be considered a form of poisoning (European Commission 2010).

Altered water dynamics

Loss of macro-pores reduces infiltration and preferential flow, increasing surface runoff during storms and decreasing rapid recharge and internal drainage; soils can become more drought-sensitive and more prone to waterlogging at the surface. Macropores are recognized as primary routes for preferential infiltration in soils (Guo and Lin 2018). Research indicates that soils lacking Earthworms can be 90% less efficient at absorbing water. This means more water run-off, which can lead to erosion and flooding (soilassociation.org). Worms don't like living in very poor-quality soil. To survive, worms need moist soils that contain enough organic matter for them to feed on. So, by counting the number of worms in soil, farmers can get a pretty good idea of their soil's health.

Effect on ecosystem services

Water cycle

Earthworm burrows serve as macropores, which facilitate infiltration and percolation of water. Their decline reduces soil porosity, resulting in increased surface runoff, water logging during rainfall, and higher erosion risk (Blouin *et al.* 2013). Casting activity promotes aggregate stability and enhances soil's ability to retain water. Without Earthworms, soil aggregates are weaker, leading to decreased water retention and greater vulnerability to drought stress (Lavelle and Spain 2024). Earthworm-mediated macropores improve groundwater recharge and act as filters for sediments and nutrients. A decline in Earthworm activity can reduce recharge rates while increasing nutrient leaching and surface contamination (Blouin *et al.* 2013).

Carbon sequestration

Earthworms accelerate the breakdown and incorporation of litter into deeper soil horizons, promoting humus formation and long-term carbon storage. In their absence, organic residues remain on the surface and decompose more rapidly, leading to higher CO_2 release (Brussaard *et al.* 2007). Stable micro- and macro-aggregates formed through earthworm activity protect soil organic carbon from microbial decomposition. Declining Earthworm populations weaken aggregate stability, leaving carbon more exposed to mineralization and loss. Although Earthworms can increase short-term CO_2 fluxes due to stimulated microbial activity, their long-term effect enhances carbon stabilization (Lubbers *et al.* 2017). Declines in Earthworm populations reduce this stabilization potential, lowering soil carbon sequestration and weakening soils' role as a carbon sink (Singh *et al.* 2022).

Consequences for agriculture and food security

Food security

Earthworms play a crucial role in supporting crop yields; their decline poses a significant threat to food security, particularly in areas with limited access to synthetic inputs where soil fertility relies heavily on biological processes. The Nature Communications study highlights that Earthworms contribute approximately 10% to total grain production in Sub-Saharan Africa and about 8% in Latin America and the Caribbean (Fonte *et al.* 2023). The loss could disproportionately impact these regions. Declines in soil fertility, structure, and water regulation will lead to increased vulnerability to droughts or heavy rains, more soil erosion, lower nutrient use efficiency, all of which worsen yield stability, increasing food insecurity.

Effect on agriculture

The presence of Earthworms in agricultural soils has been shown to enhance crop yields by approximately 25% and increase the above-ground biomass by 23% (van Groenigen *et al.* 2014). Earthworms improve nutrient availability and promote root growth by incorporating organic residues and stimulating microbial activity. A decline in earthworm populations can reduce these positive effects, resulting in decreased agricultural productivity. Globally, Earthworms are estimated to contribute around 6.5% of grain production and 2.3% of legume production, which amounts to over 140 million tons annually (Fonte *et al.* 2023). Therefore, a decline in Earthworm populations could have direct implications for food availability and agricultural output.

Conservation measures

Habitat preservation and restoration

Protection of undisturbed soils

Minimizing physical disturbances such as ploughing or deep tillage is vital to conserve earthworm populations. Conventional tillage has been shown to significantly reduce Earthworm abundance and diversity, whereas conservation tillage and no-till practices support higher densities (Briones and Schmidt 2017).

Conservation of natural ecosystems

Forests, grasslands, and wetlands serve as reservoirs of native Earthworm species. Preventing the conversion of these ecosystems into intensive agriculture or urban land is critical for maintaining Earthworm biodiversity (Lavelle *et al.* 2006).

Maintenance of buffer strips and shelter belts

Vegetated buffer zones along rivers or field edges help preserve soil microhabitats rich in organic matter and moisture, creating refuges for Earthworm populations (Blouin *et al.* 2013).

Organic matter amendments

Applying organic inputs such as compost, manure, and crop residues restores soil food sources for Earthworms and enhances habitat quality. Organic matter additions can increase Earthworm abundance by 50–100% compared to mineral fertilizers alone (Edwards *et al.* (1996). Rovelito and Cerenia (2021) suggested that use of legume leaves, banana leaves, grass clippings and cassava leaves blended with cow dung in vermicomposting experiment showed significant result in an increase biomass, reproduction rate and growth of Earthworm. Roy (2026) documented and discussed 10 common weeds that naturally attract Earthworms and enhance soil health, including Plantain, Dandelion, and Clover. Each weed serves a unique purpose, such as improving soil aeration, providing nutrients, or retaining moisture, making them beneficial allies in gardening. Additionally, it suggests using compost tea to further boost the effectiveness of these plants in promoting Earthworm activity and soil vitality.

Saini *et al.* (2025) found that a nitrogen-rich diet promotes growth and reproduction of Earthworms. Microbial degradation increases palatability and nutrient content. Toxins, such as those found in eucalyptus or lucerne residues, can be harmful. Earthworms consume significant amounts of food, approximately 10-30% of their biomass per day, and 8–32 mg of dry plant litter per gram of wet worm weight per day. Vermicomposting Earthworm species, particularly like *Eisenia fetida*, *Eudrilus eugeniae* and *Perionyx excavatus*, thrive on organic waste rich in specific nutrients (Singh and Sinha 2022), rather than direct vitamin supplementation. They mostly feed on microbes, particularly fungi, for their protein/nitrogen requirement to maintain their growth and reproduction (Das *et al.* 2021). Their growth is optimized by a diet high in nitrogen, calcium, and microbes.

Soil moisture and microclimate improvement

Between 60% and 70% of humidity is optimal for the growth and production of Earthworms (Ahmed and Mutairi 2022). Mulching, cover cropping, and reduced removal of crop residues regulate soil temperature and moisture, factors critical for Earthworm survival and reproduction (Lavelle *et al.* 2006).

Pollution mitigation

Reducing pesticide and heavy metal contamination is necessary for restoring Earthworm habitats. Many chemical pesticides reduce survival and reproduction in Earthworm populations (Pelosi *et al.* 2014b). Restoring soils through bioremediation and reducing chemical inputs can aid to recovery.

Sustainable agriculture practices

Organic farming

Organic farming practices have been shown to play an important role in conserving Earthworm populations. For example, Pulleman *et al.* (2003) reported higher soil organic matter (SOM) content and increased Earthworm activity under organic systems in the southwest Netherlands. Similarly, Hole *et al*. (2005) emphasized that organic amendments, commonly applied in organic farming, enhance SOM and provide favorable conditions for Earthworms. Numerous studies further demonstrate that organic farming supports greater Earthworm abundance (Pfiffner and Mader 1997, Hole *et al.* 2005, Kragten and Herder 2010) and higher species richness (Pfiffner and Mader 1997, Flohre *et al.* 2011) than conventional systems, highlighting its conservation potential. However, not all results are consistent, as Pelosi *et al.* (2009) observed no significant differences in abundance, biomass, or diversity between farming systems over

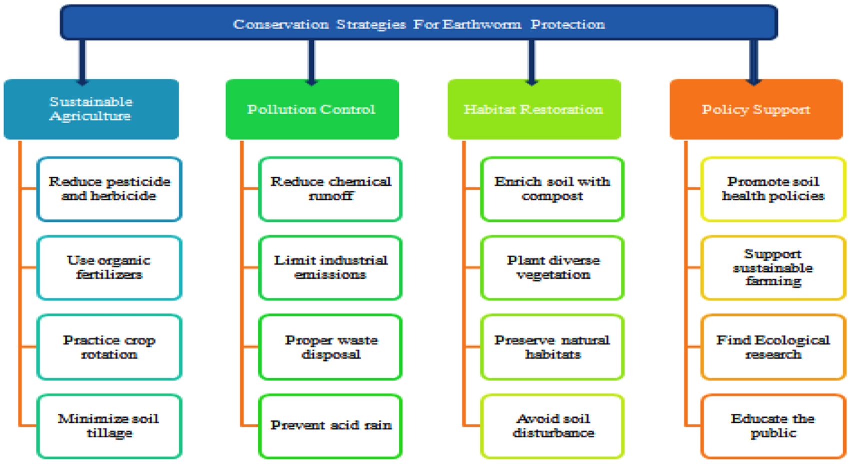

Fig. 1. Conservation strategies for Earthworm protection.

a three-year study in France. These findings were suggested that organic farming promotes Earthworm conservation mainly through improvements in SOM and soil moisture. The conservation strategies aimed at protecting Earthworms are illustrated in Fig. 1.

Redundancy analysis (RDA) showed that these factors were positively correlated with *Lumbricus rubellus* and *Eisenia tetraedra*, while correlations with endogeic species such as *Aporrectodea caliginosa* and *Aporrectodea rosea* were weaker. Nonetheless, earlier research by Ernst and Emmerling (2009) confirmed that endogeics also benefit from SOM in ploughed systems, reinforcing the importance of organic matter inputs in sustaining Earthworm populations. Moreover, organic farming often involves practices that reduce soil compaction, another key factor in conserving Earthworms. In this study, soil compaction negatively affected *A. caliginosa* and *A. rosea* but not epigeic or anecic species. Prior studies have similarly shown that soil compaction, especially under reduced tillage systems without organic inputs, negatively impacts endogeic Earthworms (Wyss and Glasstetter 1992, Langmaack *et al.* 1999, Capowiez *et al.* 2015). The growth and reproduction of earthworms directly depend upon the organic matter and N content of the soil (Kabi *et al.* 2020). By enhancing SOM, improving soil structure, and reducing reliance on intensive tillage, organic farming creates conditions that conserve both earthworm abundance and diversity, thereby maintaining their crucial role in soil health and ecosystem functioning.

Reduced tillage

Reduced tillage helps conserve Earthworms by minimizing the negative impacts of soil compaction associated with intensive ploughing, which has been shown to harm endogeic species (Wyss and Glasstetter 1992, Capowiez *et al.* 2009). While the incorporation of organic matter through ploughing may temporarily favor endogeics (Chan 2001, Ernst and Emmerling 2009, Van Capelle *et al.* 2012), reduced tillage provides long-term conservation benefits by preserving habitat structure and protecting Earthworm ecological groups from excessive disturbance. Thus, by maintaining surface residues, reducing mechanical disruption, and limiting compaction, reduced tillage serves as an important strategy for conserving Earthworm populations and sustaining their functional role in soil ecosystems.

Reduction of pesticide use and chemical pollution

Animals that live in close association with soil, such as Earthworms, are highly vulnerable to pesticide exposure. Recent evidence shows that concentrations of chemical pesticide residues (CUPs) in agricultural soils often exceed toxicological safety thresholds for Earthworms and other soil invertebrates in more than one-third of studied sites (Vasickova *et al.* 2019). Since Earthworms play a crucial role in maintaining soil structure, fertility, and ecosystem productivity

(Van Groenigen *et al.* 2015, Liu *et al.* 2019), and also form a vital part of the food web as prey for numerous predators (King *et al.* 2010), their conservation is essential.

Research indicates that Earthworm abundance rises when pesticide application is reduced (Pelosi *et al.* 2013) and is generally higher in organic farming systems compared to conventional ones (Pelosi *et al.* 2015). This highlights the importance of minimizing pesticide inputs to protect Earthworm populations. Although the individual effects of pesticides are often difficult to separate from other biotic and abiotic influences, reducing their use lessens direct exposure, lowers soil contamination, and decreases the risk of toxic bioaccumulation in Earthworms. By limiting pesticide applications, through organic farming practices, integrated pest management, or the preservation of non-treated habitats such as grasslands and hedgerows, Earthworm populations can be safeguarded. This not only supports their ecological functions in soil health but also reduces risks of contaminant transfer through the food web. Thus, decreasing reliance on pesticides is a practical conservation strategy to sustain Earthworm biodiversity and the critical ecosystem services they provide.

CONCLUSION

Earthworm populations are increasingly threatened by habitat loss, soil degradation, agrochemical use, climate change, and invasive species, all of which disrupt their survival and ecological functions. Their decline adversely affects soil structure, fertility, nutrient cycling, water retention, and carbon sequestration, ultimately reducing agricultural productivity and threatening food security. Sustainable management practices, such as habitat conservation, reduced tillage, organic amendments, and minimized pesticide use, are essential to protect Earthworm diversity. Conserving these key ecosystem engineers is critical for maintaining soil health, enhancing crop productivity, and ensuring long-term environmental sustainability.

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