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Diversity of Earthworms in Different Land use Systems: A Review

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Abstract: Land use systems, including natural forests, agricultural fields, grasslands, and urban areas, have a major impact on the diversity of earthworms. To illustrate the trends of earthworm variety throughout diverse habitats, this abstract compiles data from a number of studies.Earthworm diversity is found to be the highest in natural forests.Numerous earthworm species find perfect homes in forests because of their rich organic matter and steady microclimate. These earthworms are essential to the cycling of nutrients and the improvement of soil structure. On the other hand, because of chemical application and tillage-induced soil disturbance, agricultural fields frequently exhibit decreased biodiversity.Earthworm diversity is moderate in grasslands and is impacted by soil type, moisture content, and land management techniques. Healthy earthworm communities are essential for soil aeration and organic matter decomposition, and they can be found in well-managed grasslands.Urban environments present particular difficulties for earthworm variety because of fragmented habitats, pollution, and compacted soil. Although a variety of earthworm communities can be found in some urban green spaces, more disturbed areas tend to have fewer species. Urban earthworm assemblages are largely shaped by human activity, with introduced species usually predominating.Comprehending the variations in earthworm variety among various land use regimes is crucial for efficient soil management and preservation of biodiversity. Future studies should concentrate on how certain land management techniques affect earthworm ecosystems and investigate methods to increase their diversity, especially in environments where humans predominate.

Keywords: Earthworm Diversity, Natural Forests, Agricultural Lands, Grasslands, Organic Matter, Environmental Impact.

Introduction

Earthworms, members of the phylum Annelida, are fascinating organisms that play a crucial role in soil health and ecosystem functioning. Earthworms are soft bodied organisms having segmented body and help in decomposition of organic matter. Earthworms are also called as farmer friends because they help in decomposition and make soil nutrient rich which results in good crop yield. Suresh Kumar et. al.,(2021) observedthe population of earthworms found more in undisturbed areas and less in cultivated areas this is because the cultivation and regular ploughing of soil expose them for predation. The climatic conditions like temperature and moisture also effect the diversity of earthworms. Mariappan et al.,(2013) observed that the presence of diversity of earthworm in different habitats are greatly determined by soil physiochemical characteristics such as pH, electrical conductivity, organic carbon, organic matter, total nitrogen, phosphorus, potassium and C:N ratio.Kale et.al (2014); Nainawatet.al., (2001) Earthworms are a significant category of soil animals that are found all over the world, especially in temperate and tropical regions, and their populations.Sinhaet.al., (2013) In several pedoecosystems, they account for about 8% of total soil biomass and 80% of macrofaunal biomass.Mohan et al.,(2013) mentioned the organization and relative plentitude of six earthworm species in Amritsar. Researchers found 19 different species of earthworms in a study carried out in the Kottayam District of Kerala, India. These land use systems included woods, grasslands, home gardens, rubber plantations, and paddy fields. The greatest species richness was observed in residential gardens, which is noteworthy since it shows how land management techniques affect earthworm variety(Narayanan et.al., 2023).Similarly, a study in Himachal Pradesh revealed that earthworm diversity varied with cropping intensity and elevation, with traditional cropping systems supporting greater species richness compared to more intensive agricultural practices. Monocropping systems, which heavily employ pesticides and inorganic fertilizers, have become more common(Ahmed et.al., 2022). Soil deterioration and loss of soil biodiversity are major concerns related with monoculture farming (Vitousek, 1994; Chapin et al., 2000; Steffan-Dewenteret et al., 2007). The species composition, functionality, and dynamics of soil organisms have all been shown to be impacted by changes in land use systems, which has a significant impact on essential soil functions (Lavelle et al., 1994; Frogoso et al., 1997; Barros et al., 2004; Senapati et al 2005; Decaens 2010; Bartz et al., 2014). Because of the tremendous increase in the human population and the resulting rise in industrial and agricultural activities, Earth is currently dealing with a significant problem of an increase in organic wastes. The most beneficial organic waste converters in nature are earthworms, with their unique eating and living behaviours. The use of earthworms to break down organic wastes and residues has attracted a lot of attention lately (Atiyeh et al., 2000; Karmegam and Daniel, 2009; Pattnaik and Reddy, 2010). By converting organic resources into energy and breaking down organic materials, they contribute significantly to the cycle of nutrients in the earth's food web and food chain. They can digest and use lignocellulose and are known to control the process by which organically bound nutrients are transformed into an accessible form through mineralization (Julka, 1993; Brown and Doube, 2004). The earthworms' ability to break down organic materials is ascribed to the variety of microorganisms that inhabit their digestive tracts (Edwards and Bohlen, 1996).(Feijoo, 2011;Nunes, 2006) Similar to agricultural fields, grasslands frequently see less soil disturbance, which helps to sustain a significant diversity of earthworms. Because pastures have a lot of organic matter and cause little disturbance to the soil, they create an ideal habitat for earthworms, as studies have demonstrated. Sharanpreetet. al.,(2020) stated that a mixed picture is presented by agricultural areas. Non-conventional farming methods, like no-till farming and organic agriculture, can increase earthworm populations by improving soil structure and increasing the availability of organic matter. On the other hand, conventional farming methods, like soil tillage and pesticide use, may cause a decline in earthworm diversity. Research conducted in Punjab, India, demonstrated how various farming methods had a major impact on the diversity and quantity of earthworms, with less disturbed soils supporting a more diverse earthworm community.On the other hand, because of soil compaction, pollution, and habitat fragmentation, earthworm diversity is generally reduced in metropolitan settings. Due to the absence of organic matter and microbial communities in urban soils, invasive species such as Pontoscolex corethrurus, which are able to flourish in disturbed settings, tend to predominate.In this exploration, we will delve into the diversity of earthworms in four distinct land use systems: agricultural lands, forests, urban areas, and industrial zones. Each of these systems represents a unique set of challenges and opportunities for earthworm populations, and studying their responses provides valuable insights into the complex interactions within terrestrial ecosystems. Understanding the diversity and distribution patterns of earthworm communities across different land use systems is crucial for informing sustainable management practices and conservation efforts. By identifying the factors that influence earthworm diversity and the ecological roles played by different species, we can develop strategies to maintain or enhance these important soil organisms and the ecosystem services they provide(Sharanpreet, 2020; Narayanan et.al 2023).

Different Land Use Systems

Agricultural land use system

Cultivable land is mostly used in growing crops and rearing of animals for food and other purposes. They are characterized by:

Land Use Change: This is precipitated by the expansion of agriculture that in most cases involves replacement of natural ecosystems thus bringing about a loss of species and habitat division.

Soil Degradation: There is a danger of high soil erosion, soil nutrients washing away, and consequently, low fertility of the soil when farming fast, affecting future yields.

Carbon Emissions: Another industry that plays a great role in emitting greenhouse gases is agriculture; especially through deforestation and mechanical tilling of seeds.

Biomass Recovery: Although, biomass can be recovered easily from the abandoned agricultural land the kind of farming done affects recovery where high intensity farming tends to produce higher biomass than traditional farming (Rebola, et al., 2021).

Grasslands

Grasslands are those biomes that are characterised by grasses as the dominant vegetation species in serving their utility and ecosystem values. Their properties include:

Ecosystem Services: Grasslands are essential for generic carbon, biosphere, water purification, and species support including many species threatened or endangered.

Biodiversity: The above stated areas accommodate array of species of plants and animals hence needs to be preserved or conserved.

Threats: Grasslands are threatened by factors that include competition for resources with agriculture and habit expansion as well as physical transformation of the land for house building.

Biomass: Grassland biomass can change with practices and the level of intensity of use of the land, and hence help in the absorption of carbon (Feurdean, et al., 2017).

Urban Areas

Urban areas are crowded centres with the amenity of infrastructural facilities more enhancedthan in the rural areas. Their key properties include:

Land Use Change: Urbanization causes changes in the area of land cover, replacing the natural environment with the necessary infrastructure, meaning buildings and roads, affecting the environment.

Heat Island Effect: For instance, large built-up areas such as cities are known to have higher temperatures that other open country areas because of human activities, and because of structures such as concrete roads or pavements (Rebola, et al., 2021).

Biodiversity Challenges: Urbanization compacts the habitats thereby decreasing the level of diversity since the natural grounds are developed, paving ways, and other cemented structures covered most of the grounds.

Biomass: Urban environment commonly exhibits lower biomass density compared to natural habitat, but objects like parks or green roof may have certain impact on biomass and species richness of urban area (Rebola et al., 2021).

Natural Forests

Natural forests are one of the most significant parts of the natural environment with various possibilities of ecological functions. Their properties include:

Carbon Sequestration: Since forests have been reputed to be big store of carbon, they contribute to storing of large quantities of CO_2 thereby slowing down the effects of climate change.

Biodiversity Hotspots: Forests co-exist with many species some of which are many of which rely on the habitats that forests offer and thus contribute to the world's species diversity.
Ecosystem Services: These they offer both utilities and goods ranging from water supply regulation, conservation of soils and products such as timber and non-timber products.
Biomass Characteristics: Natural forests have a large quantity of above and below ground growing carbon stocks and have good potentials to meet Carbon pool hence countering climate change(Rebola, et al., 2021).

Fig: (a) Agricultural land

Fig: (b) Grassland

Fig: (c) Natural Forest

Fig: (d) Urban Area

Table of properties of different land use systems:

Land Use System	Key Properties	Biomass Characteristics	References
Agricultural Lands	-Large amounts of carbon in released because of the change of land use -Amendment and deterioration of the soil and its nutrient content -The hazard which comes with monoculture practices is the reduction of biodiversity.	-Biomass recovery is not constant; where it is noted to be higher is in the traditional agricultural systems than in the intensive ones.	Rebolaet al., (2021).
Grasslands	-Significant carbon sinks - Intensify ecosystem services which might be useful to man - As has been earlier noted, this pace of militating for the advancement of row of agricultural activities.	Sustain a variety of animal and plant species; management techniques affect biomass.	Lepchaet. al., (2020)
Urban Areas	High infrastructure and population density. The heat island effect and the effects of habitat fragmentation on biodiversity	Has less biomass than ecosystems found in nature; local biomass is increased by urban vegetation	Cornejo et al., (2023)
Natural Forests	Significant carbon sinks; essential for controlling the climate High biodiversity; sustains a wide range of species Provision of essential ecosystem services	High biomass both above and below ground; substantial potential for storing carbon	Vera et al., (2022).

Different land management techniques and their positive and negative impact on earthworm diversity:

Sr. no.	Land Management Technique	Positive Impacts on Earthworm Diversity	Negative Impacts on Earthworm Diversity	References
1.	**Conventional Agriculture**	Because minimal tillage preserves soil structure and burrows, earthworm populations can be increased. - Manure and other organic amendments can enhance soil quality and encourage earthworm activity.	By eliminating habitats and upsetting soil structure, intensive tillage and pesticide use lower earthworm diversity and abundance. - Monoculture techniques result in a decrease in species richness.	Muliaet al., (2021). Sharanpreet et al., (2021)
2.	**Agroforestry**	Promotes biodiversity by giving different earthworm species a place to live and food sources. - Increases soil structure and fertility, which is good for earthworm populations.	Inadequate management can lead to competition between species for resources, which could have detrimental effects on less dominant species of earthworms.	Jouquet et al., (2007). Mulia et al., (2021).
3.	**Reforestation**	Improves soil health and restores natural habitats to increase earthworm diversity. - Increases organic matter input, which is good for earthworm populations.	Earthworm populations may be momentarily decreased by planting disturbances until the habitats are completely recovered.	Jouquet et al., (2007). Muliaet al., (2021).

4.	**Urbanization**	Urban green spaces can support local biodiversity by serving as habitats for specific earthworm species.	Earthworm variety and abundance are greatly reduced by habitat fragmentation and soil compaction caused by construction operations. - Soil organisms may be negatively impacted by pollution from urban runoff.	Jouquetet al., (2007). Sharanpreet et al., (2021).
5.	**Organic Farming**	Encourages more earthworm diversity as a result of better soil health and less chemical inputs. Crop rotation increases the diversity of earthworms.	Earthworm populations may be momentarily disrupted while switching from conventional to organic farming as soil health improves.	Sharanpreet et al., (2021)

<u>Diversity of Earthworms</u>

Earthworms are a significant taxon of soil that offer vital services and functions to ecosystems. They play roles in climate regulation, nutrient cycling, and decomposition. Since earthworms are rather simple to sample, a wealth of information about their distribution and diversity is at our disposal.Phillips,et.al., (2021) reported that earthworm diversity from 10,840 sites was compiled globally into a dataset that identified 184 species from 60 different nations. This demonstrates how common earthworm species are and how many of them have evolved to live in cities.

Saikiaet. al.,(2021) demonstrated eight different species of earthworms were detected from five different soil environments (agricultural fields, cow dung, grasslands, alluvial soil, and tea gardens) in a study conducted in the Golaghat area of Assam, Northeast India. Lampito maruitii was the species that was most prevalent. Nineteen earthworm species have been identified in the forests, meadows, home gardens, rubber plantations, and paddy fields of Kerala, India's Kottayam region. With twelve species, home gardens had the highest species richness. Kerala was home to 7 endemic species(Anuja et. al., 2013). According to Sharanpreet et. al.,(2020) five different kinds of earthworms were discovered in fields, meadows, and woods in Himachal Pradesh, India. The endogeic species with the highest abundance, Metaphire posthuma, was present in all habitats.

Diversity of Earthworms in Natural forests

Particularly in natural forests, earthworms are essential to the upkeep of ecosystem functionality and soil health. Numerous factors, including soil characteristics, the availability of organic matter, and habitat layout, have an impact on their variety.Because natural forests offer diverse and stable environmental conditions, they are known for their enormous diversity of earthworm species. In a study conducted in the Vietnamese province of Quang Nam, 21 distinct species of earthworms were found in natural forests, underscoring the high level of biodiversity seen in these environments. By comparison, the species richness of planted forests and agroforestry was lower, with 14 and 15 species, respectively, reported. This implies that, as comparison to managed landscapes, wild forests provide a more favourable home for earthworms, probably because of their greater availability of organic matter and lower levels of disturbance(Mulia et.al., 2021).According to Suresh Kumar et. al., (2021)a study conducted in a subtropical forest ecosystem in India, twelve earthworm species were identified, demonstrating the variation in species composition across different forest types. The presence of diverse earthworm species is crucial for ecosystem processes, as different species contribute uniquely to soil aeration, organic matter decomposition, and nutrient cycling.Certain earthworm species have preferences for particular types of environments, which affects where they are found in natural forests. Certain species, such Amynthas morrisi and Pontoscolex corethrurus have been shown to flourish in specific soil conditions, demonstrating their adaptation to the microhabitats present in forests. Many earthworm species are supported by niches created by the diversity of habitats found in natural forests, including differences in soil type, moisture content, and organic matter content.The pH, moisture content, and organic matter content of soils have a major impact on earthworm variety in natural forests. According to studies, the abundance of earthworms is generally higher in soils that have the right pH and moisture content. As an illustration of how earthworms can change soil chemistry and structure through feeding, areas with high earthworm diversity frequently have shallower forest floors and higher mineral soil carbon contents.Since organic matter is the main source of food for earthworms, it is especially important to their survival. The buildup of leaf litter and decomposing plant matter in natural forests produces a rich organic layer that is home to a variety of earthworm communities. On the other hand, disturbances like logging or farming operations can reduce organic matter, which lowers earthworm diversity and abundance(Ross et.al., 2024).Since organic matter is the main source of food for earthworms, it is especially important to their survival. The buildup of leaf litter and decomposing plant matter in natural forests produces a rich organic layer that is home to a variety of earthworm communities. On the other hand, disturbances like logging or farming operations can reduce organic matter, which lowers earthworm diversity and abundance(Philips et. al.,2021).Non-native earthworms, for example, have been demonstrated to modify the organic layer of the forest floor in Vermont, USA. This reduces the amount of habitat available for native plant species and may result in changes to the composition of plant communities. This demonstrates how crucial it is to comprehend earthworm variety for managing and protecting forest ecosystems in addition to their ecological value(Ross et.al., 2024).

Diversity of Earthworms in Agricultural Lands

In agricultural environments, earthworms are significant soil creatures that are vital to the fertility and health of the soil. Different patterns of land use and management techniques can have an impact on their diversity and abundance. The diversity and abundance of earthworms across various land use patterns and agricultural intensity gradients have been the subject of several studies. The diversity and number of earthworms differed among diverse land use patterns, including cultivated and non-cultivated soils, according to a study done in Punjab, India.Six earthworm species from four genera were identified by the study, with non-conventional farming practices showing the largest diversity in earthworm diversity.(Sharanpreet et. al.,2020).Another study assessed the abundance and species composition of earthworm communities across six replicated long-term experimental ecosystems in Michigan, USA, spanning an agricultural land-use intensity gradient. The results showed that earthworm abundance and species composition differed among the systems, with the highest diversity observed in the deciduous forest system and the lowest in the annual crop rotation system. The study highlighted the potential impact of agricultural intensification on earthworm communities and the importance of understanding their role in ecosystem functioning(Smith et.al.,2008).

A study conducted in Uttaradit Province, Thailand, investigated the diversity of terrestrial earthworms in agricultural lands and adjacent areas. The study found 24 earthworm species belonging to five families, with the family Megascolecidae being the most abundant. Ten of the species were considered potentially new. The highest diversity was observed in the Pasao sub-district, and the most abundant species were Metaphire posthuma, Metaphire peguana, and Metaphire houlleti. The study also found significant differences in earthworm population density among different land use types, with the highest density observed in vegetable plantation areas followed by residential areas(Somniyam et.al., 2021).

Earthworm variety and abundance in agricultural areas can be influenced by a number of factors, such as environmental factors, management techniques, and soil qualities. An investigation conducted in Punjab, India, discovered a correlation between earthworm diversity and several soil characteristics, including texture, pH, electrical conductivity, and nutrient content. A different study conducted in Michigan, USA, hypothesized that the variations in earthworm populations among the systems under examination may have beencaused by elements such soil acidity, litter inputs, and landscape structure(Smith et.al.,2008).

Impacts of non-conventional agricultural practices onEarthworm diversity:
It has been demonstrated that, in contrast to conventional farming methods, non-conventional agricultural approaches, such as organic farming and reduced tillage, have a positive impact on earthworm variety.Studies show that unconventional farming practices, especially organic farming, promote more earthworm variety. For example, an investigation conducted in Puducherry, India, discovered that five different kinds of earthworms were detected in organic agricultural systems, compared to just four in conventional and sustainable farming systems. This implies that a wider range of earthworm species can thrive in an environment that is more conducive to organic farming methods.Unconventional methods improve soil health, which increases earthworm population health. Earthworm homes and food sources are enhanced by organic agricultural practices, which also increase the amount of organic matter in the soil. These systems produce earthworm casts that enrich the soil with nutrients and increase biodiversity(Sudhakaran et.al.,2023).
Compared to traditional tillage, non-conventional methods frequently require less mechanical disturbance of the soil. The preservation of soil structure is facilitated by this decrease in soil disturbance, which is essential for earthworm existence and activity. Because tillage alters their habitat and decreases their population, earthworm populations may be harmed(Mazur et.al.,2024).

Impact of conventional Practices on Earthworm Diversity:
Sharanpreet et. al.,(2020)has been demonstrated that conventional farming methods, which include heavy tillage and chemical inputs, reduce the diversity of earthworms. Research shows that these methods reduce the biomass and density of earthworms, which has an adverse effect on the soil ecology as a whole.Earthworm variety is influenced by the physico-chemical characteristics of the soil, which are frequently negatively impacted by conventional farming. In order to support a variety of earthworm populations, non-conventional approaches often increase soil qualities including pH, organic carbon content, and nutrient availability.

Diversity of earthworms in organic and sustainable farming:
While both organic and sustainable farming strive to increase agricultural sustainability, their methods and effects on biodiversityparticularly with regard to earthworm populationsdiffer.

Organic Farming: Sudhakaran et.al.,(2023)research continuously demonstrates that, in comparison to conventional farming, organic farming maintains a higher diversity of earthworms. For example, a study carried out in Puducherry, India, indicated that five different species of earthworms were detected in organic agricultural systems, while only four species were found in conventional and sustainable farming systems.A thorough analysis that shows that using organic methods produces almost twice as many earthworms and with more diversity than using conventional ones supports this trend.

Bavec et. al.,(2015) demonstrated thatincreased soil biological activity is linked to organic farming practices. The habitat of earthworms is improved by the presence of organic matter, which permits higher population densities. According to a study, the abundance of earthworms in organic and biodynamic farming plots was around double that of conventional systems.

According to Sudhakaran et.al.,(2023)Earthworm survival depends on a higher organic matter content in the soil seen in organic farming systems. Earthworm casts improve soil enzyme activity, which is essential for plant growth, and enrich soil with nutrients. According to this relationship, organic farming improves soil health generally, which is advantageous for crop productivity, in addition to supporting earthworm populations.

Sustainable Farming:

As stated by Sudhakaran et.al.,(2023)Sustainable farming methods, which frequently include some organic techniques, seek to strike a balance between environmental health and productivity. Studies do, however, show that compared to organic farming systems, earthworm diversity is typically lower in sustainable farming systems. Four earthworm species were produced by sustainable farming in Puducherry, one less than by organic systems, according to the same study.Reduced tillage and integrated pest management are examples of sustainable agricultural techniques that can help earthworm populations. The degree to which these methods are implemented, however, can differ greatly, having varying effects on the diversity of earthworms. The importance of organic inputswhich are essential for improving earthworm habitatsmay not always take precedence over sustainability.Sustainable farming may not produce the same levels of soil enzyme activity as organic farming, even though it still improves soil health when compared to conventional methods. Earthworm biomass and diversity are higher in organic systems, and this has a major impact on soil enzyme activities, which are crucial for soil fertility and nutrient cycling.

Diversity of Earthworms in Grasslands

In line with Sharanpreet et. al.,(2020)The variety of earthworms found in grasslands is essential to the health of the soil and the operation of the ecosystem. Earthworms are important for the breakdown of organic matter, improving soil structure, and cycling nutrients. This article examines the variety of earthworm species found in grassland environments, emphasizing the 2 functions of these species, the variables that affect their diversity, and the consequences for land management.Based on their activity and preferred habitats, earthworms are categorized into a number of ecological groupings, mainly endogeic, epigeic, and anecic species. Anecic earthworms improve soil aeration and drainage because of their deep burrowing behaviors. One example of such an earthworm is Lumbricus terrestris,Aporrectodea caliginosais one example of an endogeic species that lives in the higher soil layers and aids in nutrient cycling and soil mixing. Living in the litter layer, epigeic organisms are essential for breaking down organic matter and adding nutrients to the soil.These species existence and abundance can have a big impact on the texture, moisture retention, and nutrient availability of the soil. According to studies, earthworm activity enhances the structure of the soil, increasing water infiltration and porosity—two factors that are critical for plant growth and soil health(Bora et.al.,2021).

Factors Affecting the Diversity of Earthworms in Grasslands

As stated by Singh,et al.,(2021) Features of the soil play a major role in influencing the diversity of earthworms. Studies reveal that fertility and soil moisture are important factors that influence the variety of earthworm species found in grasslands. For example, research conducted in north temperate semi-natural grasslands found that species richness varied by site, from 1.3 to 11.3 species, on average 6.2 species. Greater diversity of earthworms can be found in soils with higher soil moisture content and higher nutrient content, as these conditions favour earthworm survival and reproduction.

Torppa et.al.,(2024) stated thatearthworm communities are greatly impacted by grassland management. Earthworm populations can be impacted by alterations in habitat structure and soil qualities caused by various land-use practices, including fertilization, mowing, and grazing. For instance, a study comparing intensively managed grasslands to more natural settings revealed that the abundance of earthworms was lower, indicating that earthworm diversity may be increased through sustainable management techniques.(Singh, et al.,2021).

Bora et.al.,(2021) reported thevariations in soil types and vegetation cover found in grasslands create environmental heterogeneity that encourages species diversity and co-occurrence. Higher species richness can be facilitated by the existence of diverse plant species, which can offer earthworms a variety of microhabitats and food sources. Conversely, because of greater competition and scarcer resources, homogeneous habitats typically support fewer species(Torppa et.al 2024).

Hoeffner et.al.,(2021) reported the diversity of earthworms in grasslands can be significantly impacted by land management techniques. For instance, it has been demonstrated that conventional tillage changes the community structure of earthworms and reduces their biomass and abundance. Earthworm biomass, dispersion, and abundance can all be regulated by soil compaction. However, it has been discovered that earthworm populations benefit from organic farming and the existence of field edge strips. In bioenergy environments, perennial grasslands can also improve biodiversity and offer a variety of ecosystem services.

In line with Julia et.al.,(2016) through a variety of processes, earthworms are known to affect plant communities and ecosystem function. They alter the physical, chemical, and microbiological characteristics of the soil, and they can affect the makeup of plant communities by the selective ingestion and vertical movement of seeds from the soil seed bank. In tall, encroached grasslands in particular, earthworms can increase the diversity of seedlings and encourage their emergence. This may cause the plant composition to change in favour of the vegetation found in woodlands or other last successional stages.

Diversity of Earthworms in Urban Areas

The health of the soil and the cycling of nutrients are vital functions that earthworms play in urban settings. Urbanization, however, can have a substantial effect on earthworm diversity because it can alter the quality of the habitat and the qualities of the soil. In exploring the diversity of earthworm species found in urban environments, this article focuses on the variables that affect these species' distribution and the consequences for managing soil in urban areas.

Toth et.al.,(2020)Research has demonstrated that a comparatively large diversity of earthworm species may coexist in urban settings. Nine genera and four groups including a total of nineteen species were discovered during a survey conducted in five different cities: Potchefstroom, South Africa; Helsinki and Lahti, Finland; Baltimore, USA; and Budapest, Hungary. Baltimore had the highest documented species richness (16 species), while Budapest and the Finnish cities had comparatively low species counts (5–6).Lumbricus terrestris (common earthworm), Eiseniafetida (red wiggler),Dendrobaena veneta (European nightcrawler), Amynthas spp. (Asian earthworms, which are often introduced). Rather of being arranged geographically, habitat type had a major structuring influence on earthworm populations. The lawns and remnant forests had the highest biomass, suggesting that urban green spaces had a beneficial effect on earthworm variety.According to a different study conducted byGlasstetter et.al.,(2012) in Basel, Switzerland, earthworms outnumber all other animal species in cities in terms of biomass, with humans being the sole exception. Because of their endurance and capacity to adapt to urban environments, earthworm diversity in urban habitats can be compared to that of natural ecosystems.

According to Xie, et al.,(2024),urbanization modifies the characteristics of the soil and can result in biotic homogenization, a phenomenon in which a small number of adaptive species predominate and species diversity declines. This phenomenon is most noticeable in urban areas when soil conditions are impacted by human activity.

Factors Influencing Earthworm Diversity in Urban Areas:

Due to a multitude of natural and human-caused variables, earthworm diversity has particular problems and potential in urban environments. It is essential to comprehend these elements in order to preserve biodiversity and enhance the health of urban soil.

Soil Properties

According to Xieet al.,(2022)The presence of moisture is necessary for earthworm activity and survival. Studies show that because moisture promotes motility and eating, higher soil moisture levels are correlated with higher earthworm densities and biomass.The pH of the soil has an impact on microbial activity and nutrient availability, which in turn affects earthworm populations. Toth et.al.,(2020)Variations from this range can lead to a decrease in earthworm variety. In general, earthworms prefer neutral to slightly acidic soils.Xieet al.,(2022) stated thatorganic materials must be present in order for earthworms to eat because earthworms feed on decaying plant matter, soils richer in organic matter tend to have bigger numbers of these critters.In comparison to recently built places, earthworm populations are more established in older urban parks and green spaces. This is probably because earthworm homes are supported by longer-lasting flora and organic materials in older sites.
Gift et.al.,(2009) stated thatdifferent types of landsuch as lawns, gardens, and parksshow different degrees of earthworm diversity. For example, compared to severely paved or compacted areas, urban parks frequently offer superior habitats for earthworms.Earthworm species are more diverse in areas with less human interference, such as natural reserves or older parks. On the other hand, species richness usually declines in frequently disturbed areas, such as building zones or areas with high traffic.Toth et.al.,(2020)demonstrated that the biomass and diversity of earthworms are higher in remnant woods and well-kept parks than in heavily developed regions with disturbed soil. Earthworms thrive in these areas because they have less compacted soil and more organic materials. According to Xieet al.,(2022)Microbial biomass carbon (MBC) is an additional important component that impacts earthworm communities. Earthworms get their nourishment from the decomposition of organic materials, which is facilitated by a robust microbial population. Higher MBC levels have been linked to greater biomass and diversity in earthworms, according to studies.By changing the chemistry of the soil and lowering the availability of organic matter, fertilizers and pesticides can have a negative impact on earthworm populations(Xie, et al., 2024). Giftet.al.,(2009) mentioned that earthworm diversity can be increased by soil health practices like composting and less tillage since they improve the soil's organic content and structure.Toth et.al.,(2020)declared that geographical variables can also affect local earthworm diversity, in addition to the effects of urbanization. Because of differences in the local temperature, soil composition, and past land use patterns, different cities have different species compositions.

Studies conducted in cities such as Baltimore, Budapest, and Helsinki, for example, demonstrate that although urbanization has an impact on earthworm communities, variations in species richness and community structure are also influenced by the local climate and soil conditions.

Implications for Urban Soil Management:

In order to encourage plant growth, preserve healthy ecosystems, and lessen the effects of climate change in urban areas, urban soil management is essential.Khan et. al.,(2022) affirmed thatfor the purpose of evaluating the health of the soil and pinpointing areas that require improvement, regular evaluation of soil parameters such as pH, organic matter content, and nutrient levels is crucial.In order to reduce health risks from contaminated soils and to inform land use decisions, it is imperative to evaluate the concentrations of hazardous elements.Ensuring biological connection is essential for ecosystem functioning, and this requires taking into account not only green and blue corridors but also the "brown corridor," or the connectivity of urban soils.Bary et.al., (2016) affirmed theurban soil quality can be greatly increased by adding organic amendments, such as compost, which also increase plant growth, water-holding capacity, and nutrient levels. It has been demonstrated that methods like surface application and compost incorporation are useful for improving the soils and shrub plantings beside urban highways.Incorporating low-impact development (LID) strategies, such permeable pavements and rain gardens, can lessen stormwater runoff and enhance soil health.

Bonilla-Bedoya et.al., (2022)mentioned that sustainable city development requires an understanding of the significance of urban soils and the incorporation of soil management measures into urban design. When making decisions about urban design, such as creating new green areas or maintaining existing ones, taking soil health into account can improve ecosystem services and help communities adapt to climate change. De Kimpe et.al.,(2000) reported that soil carbon sequestration and climate change mitigation can be achieved by investments in green infrastructure, such as parks and urban forests.

Table of diversity of earthworms in different land use systems across India

Sr. no	**Species Name**	**LandUseSystem**	**State**	**Reference**
1.	Pontoscolex corethrurus, Amynthas morrisi, Lampitomauritii,Metaphire posthuma, Metaphire houlleti	Agricultural Land	Rajasthan	Suresh Kumar et.al., [2021]
2.	Pontoscolex corethrurus, Drawida	Natural Forest	Kerala	Narayanan et al., (2023)

	impertusa, Lampito mauritii			
3.	Eudrilus eugeniae, Drawida spp., Lumbricus spp.	Mixed Forests	Meghalaya	Chakraborty et al., (2023)
4.	Metaphire houlleti, Ramiella bishambari, Ocnerodrilus occidentalis	Home Gardens	Haryana	Goel et.al., (2017)
5.	Ocnerodrilus occidentalis, Metaphire birmanica, Lennogaster pusillus	Agroforestry	Haryana	Goel et.al., (2017)
6.	Pontoscolex corethrurus, Eukerria kuekenthali, Megascolex avicula	Rubber Plantations	Kerala	Narayanan et al., (2023)
7.	Eudrilus eugeniae, Metaphire spp., Octochaetus spp.	Agricultural Fields	Punjab	Vig et al., (2020)
8.	Drawida spp., Eudrilus eugeniae, Octochaetidae spp.	Agricultural Land	Nagaland	Chakraborty et al., (2023)
9.	Metaphire spp., Eudrilus eugeniae, Drawida spp.	Natural Reserved Forests	Manipur	Thounaojam et. al., (2012)
10.	Eudrilus eugeniae, Metaphire spp., Drawida spp.	Agricultural Fields	Assam	Hijam et. al., (2022)
11.	Eudrilus eugeniae, Lumbricus terrestris, Drawida spp.	Agricultural Land	Jammu & Kashmir	Thounaojam et.al., (2020)
12.	Metaphire spp., Eudrilus eugeniae, Drawida spp.	Agricultural Fields	Odisha	Chakraborty et al., (2023)

Limitations and Future Perspectives

Even while this worldwide dataset represents a considerable advancement, not all regions and land use types are fully covered. Particularly from underrepresented regions and land uses like urban ecosystems, more data are required.Various sample techniques used in different research might create unpredictability and complicate comparisons. The uniformity and quality of data would be enhanced by standardizing sampling procedures.Only over 60% of sites have data on their soil properties available. A more thorough examination of the chemical, physical, and biological characteristics of the soil would make it possible to identify the variables influencing earthworm diversity.Focused sampling initiatives in underrepresented land uses and regions, particularly in cities, would be helpful in bridging important data gaps and presenting a more comprehensive picture of earthworm diversity worldwide. Standardized sampling procedures should be created and promoted in order to enhance data quality and provide more reliable comparisons between studies and geographical areas. Compiling more thorough data on land use and managementsuch as tillage techniques, fertilizer inputs, and pesticide usagewill help shed light on how human activity affects the diversity of earthworms.Creating long-term monitoring sites and conducting frequent samplings would highlight significant temporal patterns and trends in earthworm communities, such as adaptations to changing land uses or climate change. Hotspots of earthworm variety can be found using the data, which can also help guide conservation initiatives. Additionally, it can direct sustainable land management techniques that support the diversity of earthworms and the services they offer to the environment.

Conclusion

The diversity of earthworms seen in natural woods, agricultural fields, grasslands, and urban settings emphasizes the intricate relationships that exist between ecological processes, land management techniques, and soil health. Earthworm numbers, diversity, and ecological roles are influenced by specific variables that are present in each land use system.The greatest diversity of earthworms is usually found in natural forests because of their abundance of organic materials, steady microclimate, and low levels of disturbance. Numerous earthworm species find perfect homes in the intricate root systems and copious amounts of leaf litter. Significant soil disturbance occurs frequently on agricultural grounds as a result of tillage, pesticide use, and crop rotation techniques. These practices may have a negative impact on earthworm variety by decreasing the supply of organic matter and the complexity of the ecosystem.The variety of earthworms in grasslands is moderate and is determined by various factors, including soil composition, moisture content, and land management techniques. Healthy earthworm populations can be found in well-managed and maintained grasslands, and they aid in the breakdown of organic matter and soil aeration.Earthworm variety can be increased through sustainable agricultural and urban planning methods, which will benefit soil health and ecosystem services. Subsequent investigations have to concentrate on comprehending the dynamics of earthworm populations inside these heterogeneous land use systems, in order to provide valuable insights for management tactics that foster ecological resilience and biodiversity.

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