International Journal of Agriculture and Food Science 2026; 8(4): 384-387

ISSN Print: 2664-844X
ISSN Online: 2664-8458
NAAS Rating (2026): 4.97
IJAFS 2026; 8(4): 384-387
www.agriculturaljournals.com
Received: 02-03-2026
Accepted: 03-04-2026

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Industrial Footprints on Soil Biodiversity: Earthworm Communities in Rewari District

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DOI: https://www.doi.org/10.33545/2664844X.2026.v8.i5e.1530

Abstract
Earthworms, recognized as ecosystem engineers, are sensitive indicators of soil health and environmental quality. This study was conducted in Rewari district, Haryana, India, to assess the impact of industrialization on earthworm community structure and diversity, and to evaluate the role of soil physicochemical properties in shaping these communities. A total of 50 sites (25 industrial and 25 non-industrial) were surveyed using soil monolith sampling, and specimens were identified through standard taxonomic literature. Diversity indices were calculated, and soil parameters including bulk density, moisture, pH, organic matter, and nutrient availability were analyzed. Results showed that industrial soils supported fewer tolerant species (Eisenia fetida, Lampito mauritii, Metaphire posthuma) with low richness (3-4 species) and mean density (45 ± 6 ind./m²), while non-industrial soils maintained higher richness (5-6 species), greater density (92 ± 8 ind./m²), and balanced community structures. Soil quality emerged as a decisive factor, with moisture, organic matter, and nutrient availability positively correlated with diversity, whereas bulk density showed a negative correlation. The findings confirm that industrialization degrades soil ecosystems, reducing biodiversity and ecological balance, while non-industrial soils sustain diverse and functional earthworm populations, underscoring the importance of conserving soil quality for ecological resilience.

Keywords: Earthworm diversity, Soil physicochemical properties, Industrialization impact, Bioindicators of soil health, Community structure

Introduction

Earthworms are widely recognized as ecosystem engineers due to their critical role in soil structure, nutrient cycling, and ecological functioning. Their abundance, diversity, and community composition serve as reliable indicators of soil health and environmental quality. Recent studies emphasize that earthworm populations are highly sensitive to anthropogenic pressures such as industrialization, pesticide use, and soil contamination, making them valuable bio indicators of environmental change (Ahmad *et al*., 2023; Isler and Goksu, 2026) [1, 3]. The district of Rewari, Haryana, India, represents a unique landscape where industrial zones coexist with agricultural fields, horticultural gardens, and other non-industrial habitats. This juxtaposition provides an opportunity to assess how industrial activities influence earthworm community structure and diversity. Recent molecular identification studies have highlighted the importance of characterizing native earthworm species to understand their ecological roles and resilience under varying soil conditions (Razia *et al*., 2026) [6]. The community assessment, soil properties such as bulk density, texture, moisture content, pH, organic matter, and nutrient availability strongly influence earthworm distribution and abundance. Contemporary research underscores the need to integrate soil physicochemical analysis with biodiversity indices to capture the complex interactions between soil quality and biological communities (Muthukannan *et al*., 2024; Almaramah *et al*., 2024) [5, 2]. The present study is designed with two primary objectives: (1) to assess the community structure of earthworms in industrial and non-industrial soils of Rewari district, and (2) to evaluate the influence of soil physicochemical properties on earthworm abundance and diversity indices. The outcomes are expected to provide valuable insights into the ecological consequences of industrialization, contribute to biodiversity conservation strategies, and support sustainable soil management practices in the region.

Materials and Methods

Study Area and Site Selection

The study was conducted in Rewari district, Haryana, India, encompassing both industrial and non-industrial zones. Industrial soils included sites within industrial estates and their surrounding habitats, while non-industrial soils comprised agricultural fields, horticultural gardens, and other undisturbed areas. A total of 50 sampling sites were selected, with 25 sites representing industrial soils and 25 sites representing non-industrial soils.

Earthworm Sampling and Preservation

The three soil monoliths measuring 25 × 25 × 30 cm were excavated. Earthworms were hand sorted following the method described by Julka (1990). Collected specimens, along with a small amount of native soil, were placed in labeled plastic bags indicating site name, sampling date, and habitat type. Samples were washed with water, narcotized using 70% ethanol, and subsequently preserved in 5% formaldehyde solution for 4-6 hours in a straight position. Thereafter, specimens were transferred to test tubes containing preservative solution, with labels specifying collection site, date and habitat.

Identification and Diversity Indices

Specimens were identified using standard taxonomic literature. Community structure was assessed using diversity indices, including Shannon Wiener diversity index (H′), Simpson's index (D), Simpson's diversity (1-D), Margalef's species richness index (DMg), and species evenness indices. Relative abundance of each species was calculated to determine dominant and rare taxa.

Soil Physicochemical Analysis

Soil samples from each site were collected for physicochemical analysis. Bulk density was determined using the core sampling method, while soil texture was analyzed using Robinson's pipette method. Soil temperature was measured with a soil thermometer, and moisture content was estimated using the oven drying method. Soil pH was measured using a calibrated pH meter. Organic matter content was determined by the Walkley and Black (1934) titrimetric method. Available nitrogen was estimated using the Micro Kjeldahl method (Bremner and Mulvaney, 1982), and available potassium was measured using a flame photometer.

Results

The comparative analysis of earthworm communities in industrial and non-industrial soils of Rewari district revealed clear differences in species richness, density, and diversity patterns. In industrial soils, earthworm populations were restricted to a few tolerant species such as Eisenia fetida, Lampito mauritii, and Metaphire posthuma (Fig1). Species richness was low (3-4 species), and mean density averaged 45 ± 6 individuals per square metre. Diversity indices reflected reduced heterogeneity, with communities dominated by one or two species. This indicates that industrial activities and associated soil disturbances create stressful conditions that limit the survival of sensitive taxa. The non-industrial soils such as agricultural fields and horticultural gardens supported a broader range of species, including Metaphire posthuma, Eudrilus eugeniae, Perionyx excavatus, and Drawida nepalensis. Species richness was higher (5–6 species), and mean density reached 92 ± 8 individuals per square metre. Diversity patterns were more balanced, with multiple ecological groups (epigeic, endogeic, anecic) contributing to community stability.

Table 1: Earthworm Community Structure in Industrial vs. Non Industrial Soils

Habitat Type	Dominant Species (examples)	Species Richness	Mean Density (ind./m²)	Diversity Pattern
Industrial soils	Eisenia fetida, Lampito mauritii, Metaphire posthuma	3-4	45 ± 6	Low richness, high dominance
Non industrial soils	Metaphire posthuma, Eudrilus eugeniae, Perionyx excavatus, Drawida nepalensis	5-6	92 ± 8	High richness, balanced groups

The analysis of soil properties in relation to earthworm diversity revealed clear contrasts between industrial and non-industrial habitats in Rewari district. Inside industrial soils, bulk density was significantly higher (1.62 ± 0.08 g/cm³), indicating compaction that restricts burrowing activity. Moisture content was low (12.5 ± 1.2%), and organic matter was limited (0.9 ± 0.1%), both of which contributed to reduced food availability and unfavorable conditions for reproduction. Nutrient levels were also lower, with available nitrogen at 210 ± 15 mg/kg and potassium at 145 ± 12 mg/kg. These parameters showed negative or weak correlations with diversity indices, confirming that industrial soils provide a stressful environment for earthworm communities. The non-industrial soils exhibited favorable physicochemical conditions. Bulk density was lower (1.32 ± 0.06 g/cm³), allowing easier burrowing. Moisture content was higher (21.8 ± 1.5%), and organic matter was enriched (2.6 ± 0.2%), creating a rich food base that strongly supported species diversity. Nutrient levels were also elevated, with nitrogen at 320 ± 20 mg/kg and potassium at 210 ± 18 mg/kg. These parameters showed strong positive correlations with diversity indices, highlighting their role in sustaining balanced and diverse earthworm populations (Table 2).

Table 2: Soil Properties and Their Correlation with Earthworm Diversity

Soil Property	Industrial Soils (Mean ± SD)	Non Industrial Soils (Mean ± SD)	Correlation with Diversity	Ecological Implication
Bulk Density (g/cm³)	1.62 ± 0.08	1.32 ± 0.06	Negative (r = −0.78)	Compaction restricts burrowing.
Moisture Content (%)	12.5 ± 1.2	21.8 ± 1.5	Positive (r = +0.82)	Moist soils favor reproduction.
Organic Matter (%)	0.9 ± 0.1	2.6 ± 0.2	Strong Positive (r = +0.87)	Rich food base enhances diversity.
pH	7.8 ± 0.2	6.9 ± 0.3	Moderate (r = −0.45)	Slightly acidic soils support

				more species.
Available Nitrogen (mg/kg)	210 ± 15	320 ± 20	Positive (r = +0.74)	Nutrient enrichment promotes biomass.
Available Potassium (mg/kg)	145 ± 12	210 ± 18	Positive (r = +0.69)	Fertility improves microbial activity.

Fig 1: Vermicomposting Process Demonstrating Earthworm Activity in Organic Waste Decomposition

Discussion

The comparative evaluation of earthworm communities and soil properties in industrial and non-industrial habitats of Rewari district provides clear evidence of the impact of anthropogenic disturbance on soil biodiversity (Verma *et al*., 2021) [7]. In industrial soils, the restricted presence of Eisenia fetida, Lampito mauritii, and Metaphire posthuma reflects the tolerance of these species to compacted and contaminated substrates. The low species richness (3-4 species) and reduced mean density (45 ± 6 ind./m²) indicate that industrial activity exerts selective pressure, favoring only pollution resistant taxa. The dominance of a few species and reduced heterogeneity are characteristic of stressed ecosystems where ecological balance is disrupted. Conversely, non-industrial soils such as agricultural fields and horticultural gardens supported a broader range of species, including Eudrilus eugeniae, Perionyx excavatus, and Drawida nepalensis. Higher richness (5-6 species) and density (92 ± 8 ind./m²) demonstrate that favorable soil conditions promote diverse ecological groups (epigeic, endogeic, anecic). Balanced diversity patterns in these habitats highlight the role of organic matter and nutrient availability in sustaining stable communities (Karwal, 2026) [4]. The analysis of soil physicochemical parameters further substantiates these findings. Industrial soils exhibited higher bulk density, lower moisture, and reduced organic matter, all of which negatively correlated with diversity indices. These conditions restrict burrowing, reduce food resources, and limit reproductive success. In contrast, non-industrial soils showed lower compaction, enriched organic matter, and elevated nutrient levels, which strongly correlated with species richness and abundance. Moisture and organic matter emerged as the most influential factors, providing a favorable microhabitat and food base for earthworm populations.

Conclusion

The study demonstrates that earthworm diversity and abundance are strongly influenced by habitat type and soil quality. Industrial soils, characterized by higher bulk density, reduced moisture, and low organic matter, supported only a few tolerant species with limited richness and density. In contrast, non-industrial soils with favorable physicochemical conditions maintained diverse communities, including multiple ecological groups, resulting in higher richness, density, and balanced diversity patterns. Overall, soil properties such as moisture, organic matter, and nutrient availability showed strong positive correlations with earthworm diversity, while compaction exhibited a negative effect. These findings confirm that industrialization degrades soil ecosystems, whereas non-industrial soils sustain biodiversity and ecological stability.

Credit authorship contribution statement

Anoop: Writing – original draft, Validation, Formal analysis, Data curation, Conceptualization.
Namrata Dangi: Editing, Visualization, Supervision.

Funding

Not applicable.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement: The authors are thankful to Baba Mastnath University, Rohtak, Haryana, India for providing infrastructural facility to conduct the research.

Data availability: all the data is provided with in the manuscript.

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