

Research Article

ASSESSMENT OF SOIL PHYSICOCHEMICAL CHARACTERISTICS AND THEIR CORRELATION WITH EARTHWORM DIVERSITY IN MAJOR CROPPING SYSTEMS OF MAHENDERGARH, HARYANA, INDIA

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ABSTRACT

This study evaluated soil physicochemical properties and their relationship with earthworm diversity across three major cropping systems in the semi-arid region of Mahendergarh, Haryana, India. A replicated field design compared Mustard–Gram–Barley, Wheat–Cotton, and Vegetable (Pearl/Cluster beans) systems. Soil parameters (pH, EC, moisture, organic carbon, N, P, K, Zn, Cu, Mn, Fe) were analyzed alongside diversity indices (Shannon–Wiener, Simpson, Evenness). Three species (*Lampito mauritii*, *Metaphire posthuma*, *Drawida nepalensis*) were recorded. Vegetable systems exhibited the highest diversity ($H' = 1.08 \pm 0.01$; $D = 0.66 \pm 0.00$). Pearson correlations showed strong positive relationships between earthworm abundance and organic carbon ($r = 0.80$), soil moisture ($r = 0.69$), Zn ($r = 0.71$), and Cu ($r = 0.75$), while pH ($r = -0.58$) and EC ($r = -0.35$) were negatively associated. PCA explained 75% of total variance, with PC1 (48%) driven by organic carbon and moisture and PC2 (27%) by nitrogen and phosphorus. Results highlight that organic inputs and moisture retention are primary drivers of soil biodiversity in semi-arid agroecosystems, emphasizing the need for sustainable management.

Keywords: Earthworms, Soil physicochemical properties, Cropping systems, Semi-arid agroecosystems, PCA.

INTRODUCTION

Earthworm's distribution and abundance are strongly controlled by soil physico-chemical properties such as pH, soil moisture, organic carbon, and nutrient availability (Decaens, 2010). They are widely recognized as key ecosystem engineers due to their ability to modify soil structure, regulate nutrient cycling, and enhance soil fertility (Blouin *et al.*, 2013). Soil organic matter is particularly important because it provides a primary food source for earthworms and supports microbial communities that contribute to nutrient cycling (Edwards and Bohlen, 1996). Earthworms, as a major component of soil biota, play a crucial role in the decomposition of organic matter and soil reconstruction in terrestrial ecosystems (Gupta and Kumar, 2024). Their burrowing and feeding activities improve soil aeration, water infiltration, and organic matter decomposition, thereby influencing soil productivity and ecosystem stability (Lavelle *et al.*, 2006). They have come to be recognized as bioreactors due to their ability to degrade organic waste materials into available vermin-

compost (Kumar, 2020) and their dynamic potential to play a role in sustainable agriculture (Kumar and Tripathi, 2021). They improve the nutrient availability, drainage, texture, and productivity of the soil ecosystem (Kumar, 2021). Agricultural management practices also play a critical role in determining earthworm diversity. Intensive tillage, pesticide use, and excessive chemical fertilizers may reduce earthworm populations, whereas organic farming systems and diversified cropping practices often promote higher soil biodiversity (Pelosi *et al.*, 2014).

Previous studies have shown that soil properties such as moisture, organic carbon, and electrical conductivity significantly influence earthworm distribution across agroecosystems (Singh *et al.*, 2020). Variations in cropping systems can therefore lead to substantial differences in earthworm diversity due to changes in soil nutrient availability and habitat conditions. Earthworms differed in their ecomorphological characteristics and relative abundances in different habitats (Kumar *et al.*, 2021). Despite their ecological importance, information on

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earthworm diversity in semi-arid agricultural landscapes of south-western India remains limited. Therefore, the present study aims to evaluate the relationship between soil physico-chemical properties and earthworm diversity under different cropping systems in Mahendergarh, Haryana.

MATERIALS AND METHODS

Study Area

The study was conducted in different crop fields of Mahendergarh district (Figure. 1) is located in the south-western part of Haryana, India, covering an area of approximately 1899 km². The region lies within the semi-arid climatic zone characterized by hot summers, cool

winters, and limited rainfall. The district experiences strong winds and sandy soil conditions due to its proximity to the Rajasthan desert region. The dominant soil types include sandy, sandy-loam, and loamy and soils with low organic matter content.

Experimental Design and Cropping Systems

A stratified sampling approach was adopted across three representative cropping systems with three independent replicates per system: Mustard–Gram–Barley (MGB), Wheat–Cotton (WC), Vegetable/Pearl–Cluster beans (VC). Replicate fields within each system were selected to ensure comparable management histories and soil types while capturing within-system variability.

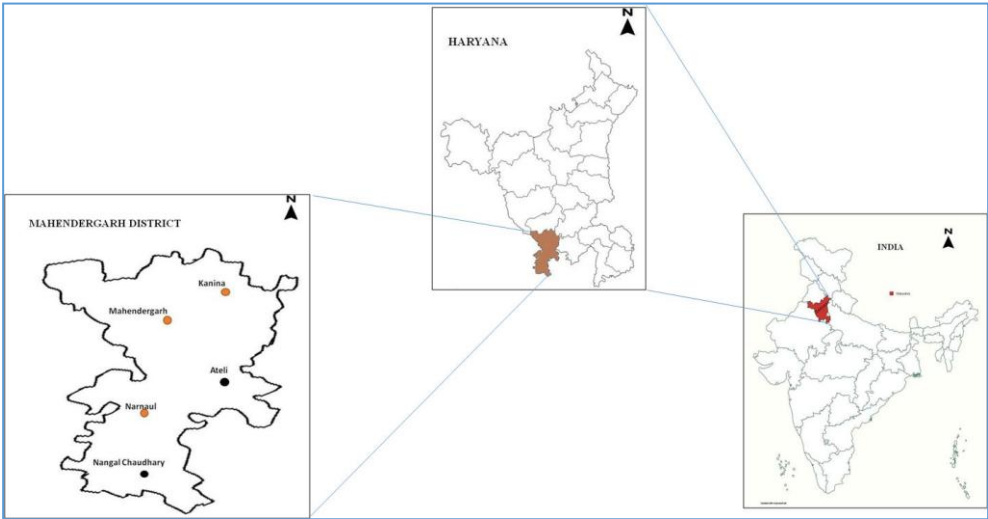


Figure 1. Map showing the study areas of Mahendergarh district tehsils of Haryana.

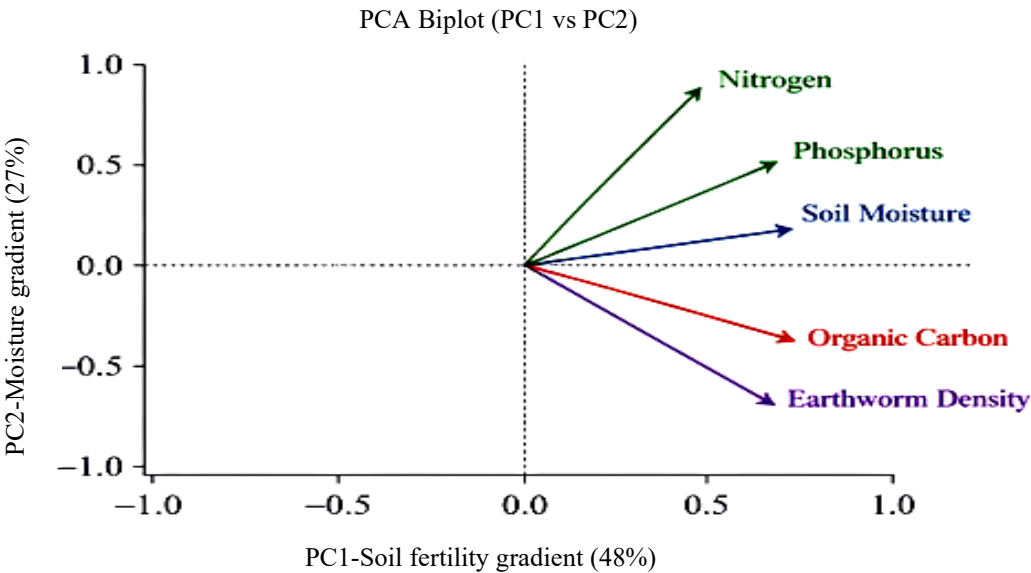


Figure 2. Principal Component Analysis (PCA) showing relationships between soil properties and earthworm diversity.

Table 1. Soil physicochemical properties under different cropping systems (mean $\pm$ SD).

Cropping System	pH Mean $\pm$ SD	EC (dS/m) Mean $\pm$ SD	Moisture (%) Mean $\pm$ SD	Zn (ppm) Mean $\pm$ SD	OC (%) Mean $\pm$ SD	N (kg/ha) Mean $\pm$ SD	P (kg/ha) Mean $\pm$ SD	K (kg/ha) Mean $\pm$ SD	Cu (ppm) Mean $\pm$ SD	Mn (ppm) Mean $\pm$ SD	Fe (ppm) Mean $\pm$ SD
MGB	7.5 $\pm$ 0.1	33.33 $\pm$ 1.53	15.00 $\pm$ 1.00	0.40 $\pm$ 0.03	35.33 $\pm$ 2.55	544.67 $\pm$ 16	17.33 $\pm$ 52	744.33 $\pm$ 04	0.27 $\pm$ 0.03	0.40 $\pm$ 0.03	4.40 $\pm$ 0.43
WC	7.8 $\pm$ 0.1	48.67 $\pm$ 1.53	11.67 $\pm$ 1.53	0.16 $\pm$ 0.02	29.00 $\pm$ 10	234.33 $\pm$ 51	9.67 $\pm$ 2.08	834.33 $\pm$ 13	0.16 $\pm$ 0.02	0.26 $\pm$ 0.03	3.93 $\pm$ 0.02
VC	7.2 $\pm$ 0.1	29.00 $\pm$ 2.00	19.00 $\pm$ 1.00	0.75 $\pm$ 0.02	51.67 $\pm$ 21	711.67 $\pm$ 40	22.67 $\pm$ 53	725.3 $\pm$ 6	0.48 $\pm$ 0.01	0.54 $\pm$ 0.02	4.67 $\pm$ 0.02

Table 2. Earthworm diversity indices (Shannon-wiener, Simpson and Evenness) under different cropping systems.

Cropping System	Species Evenness (Mean $\pm$ SD)	Shannon Index (Mean $\pm$ SD)	Simpson Index (Mean $\pm$ SD)
MGB	0.93 $\pm$ 0.02	1.02 $\pm$ 0.02	0.62 $\pm$ 0.01
WC	0.96 $\pm$ 0.01	1.06 $\pm$ 0.02	0.64 $\pm$ 0.01
VC	1.69 $\pm$ 1.22	1.08 $\pm$ 0.01	0.66 $\pm$ 0.00

Table 3. Showing Pearson correlation of soil properties with earthworm density and Shannon Index (H').

Parameter	Correlation (r) with Earthworm density	Shannon Index
Soil pH	-0.58	-0.29
Organic Carbon	0.80	0.56
Electrical Conductivity	-0.35	-0.09
Soil Moisture	0.69	0.30
Nitrogen	0.50	0.22
Phosphorus	0.54	0.32
potassium	-0.32	-0.05
zinc	0.71	0.46
Iron	0.43	0.14
Copper	0.75	0.51
Mn	0.65	0.36

Earthworm Sampling

Earthworms were collected using the hand-sorting and digging method, which is widely recommended for ecological studies of soil macrofauna (Edwards and Bohlen, 1996). Sampling procedure from prepared quadrat of size 25 $\times$ 25 cm with depth of 30 cm. Sampling was conducted throughout the year. Collected specimens were hand sorted from soil blocks washed with distilled water and preserved in 4% formalin solution or 70% ethanol. Identification was performed using standard taxonomic keys (Julka, 1988; Blakemore, 2008).

Soil analysis

Composite soil samples (0–30 cm) were collected concurrently with earthworm sampling. Analyses included: pH (digital pH meter), electrical conductivity (EC; dS m⁻¹), gravimetric moisture (%), organic carbon (Walkley–Black method), available nitrogen (Kjeldahl), phosphorus (Olsen), potassium (flame photometry), and micronutrients (Zn, Cu, Mn, Fe) using standard protocols.

Diversity Indices

Earthworm diversity was quantified using: Shannon–Wiener index (H'), Simpson index (D), Evenness (E). Indices were computed from species proportions within each sampling unit and averaged per cropping system.

Statistical Analyses

Descriptive statistics (mean $\pm$ SD) were computed for all variables. Pearson's correlation coefficients (r) assessed relationships between soil parameters and earthworm abundance/diversity. Principal Component Analysis (PCA) was performed to identify dominant gradients structuring the data. Analyses were conducted in R/SPSS/PAST.

RESULT AND DISCUSSION

Three species were recorded across sites: *Lampito mauritii* (Megascolecidae; anecic), *Metaphire posthuma* (Megascolecidae; endogeic), and *Drawida nepalensis* (Moniligastridae; endogeic). VC systems exhibited the highest density and more balanced representation of

ecological groups, whereas MGB systems were comparatively depauperated. Soil properties varied markedly among systems (Table 1). pH ranged from 7.2–7.8, with higher values in WC. EC was highest in WC and lowest in VC. Moisture content was greatest in VC (19%) and lowest in WC (11.7%). Organic carbon highest in VC (51.7) and was lowest in WC (29.0). Nutrients (N, P) and micronutrients (Zn, Cu, Mn, Fe) were consistently higher in VC, indicating improved fertility and biological activity. Diversity metrics showed clear system-level differences (Table 2). Shannon index ranged from 1.02 (MGB) to 1.08 (VC). Simpson index followed a similar pattern (0.62–0.66). Evenness was highest in VC, indicating more equitable species distribution. Overall, VC > WC > MGB in diversity. Pearson correlations revealed strong positive relationships between earthworm abundance and organic carbon ($r = 0.80$), soil moisture ($r = 0.69$), Zn ($r = 0.71$), and Cu ($r = 0.75$) (Table 3). Moderate positive correlations were observed with N ($r = 0.50$), P ($r = 0.54$), Mn ($r = 0.65$), and Fe ($r = 0.43$). Negative relationships were found with pH ($r = -0.58$), EC ($r = -0.35$), and K ($r = -0.32$). Overall, the results indicate that organic carbon and soil moisture are the most influential factors positively affecting earthworm abundance in the studied cropping systems. Studies have similarly confirmed that soil organic carbon, nitrogen, and moisture significantly influence earthworm distribution across agroecosystems. Similar trends were observed for Shannon diversity, though with attenuated magnitudes. PCA explained 75% of the total variance. PC1 (48%) was strongly associated with organic carbon and soil moisture (soil fertility–moisture gradient), while PC2 (27%) corresponded to nitrogen and phosphorus (nutrient gradient). Earthworm density and diversity aligned positively with PC1, indicating the primacy of carbon and moisture in structuring communities. Interpretation: PC1 (48%) is strongly associated with organic carbon and moisture. PC2 (27%) is associated with nitrogen and phosphorus.

These results indicate that soil nutrient status and moisture availability are the main drivers of earthworm diversity. Earthworm diversity varied significantly among cropping systems due to differences in soil conditions and management practices (Bhagat *et al.*, 2025). Vegetable fields showed higher diversity due to frequent irrigation and greater organic matter inputs, which provide favorable habitats and food resources for earthworms (Kaur *et al.*, 2023; Bartz *et al.*, 2024). Organic carbon emerged as the most influential factor affecting earthworm abundance. High organic matter content increases microbial activity and food availability for earthworms. Similar observations have been reported in agroecosystems where soil carbon pools were strongly correlated with earthworm diversity indices (Zhang *et al.*, 2023; Singh *et al.*, 2020; Blouin *et al.*, 2025). Soil moisture also showed a strong positive relationship with earthworm density.

Moist soils facilitate burrowing activity and enhance earthworm survival, while dry soils limit their movement and reproduction (Jat *et al.*, 2024; Edwards and Arancon, 2022). Conversely, alkaline soil pH and low organic carbon content in fallow lands resulted in reduced earthworm

diversity (Briones and Schmidt, 2017; Kaur *et al.*, 2024). Advancements in farming systems or nutrient enrichment of agricultural lands may be responsible for the abundance of the earthworm community (Kumar *et al.*, 2021). Overall, the results demonstrate that sustainable cropping practices promoting organic matter addition and moisture retention can enhance soil biodiversity and ecosystem functioning (Lavelle and Spain, 2024; Pelosi *et al.*, 2024; Brussaard *et al.*, 2021).

CONCLUSION

The present study demonstrates that soil physico-chemical properties significantly influence earthworm diversity across cropping systems in Mahendergarh, Haryana. Organic carbon, soil moisture, and nitrogen emerged as the most important factors controlling earthworm abundance and diversity. Vegetable cropping systems supported the highest earthworm diversity due to improved soil conditions, whereas fallow lands showed the lowest diversity. These findings highlight the importance of sustainable agricultural practices in maintaining soil biodiversity and improving soil fertility in semi-arid agroecosystems. Future research should examine seasonal changes and conduct long-term monitoring of earthworm communities to enhance our understanding of their ecological roles in agricultural landscapes.

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CONFLICT OF INTERESTS

The authors declare no conflict of interest

ETHICS APPROVAL

Not applicable

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AI TOOL DECLARATION

The authors declare that no AI and related tools are used to write the scientific content of this manuscript.

DATA AVAILABILITY

Data will be available on request

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