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# Taxonomic Composition and Functional Diversity of Ground-Dwelling Macroinvertebrates in Western Ghat, Maharashtra, India

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**Abstract:**
Soil and ground-dwelling macroinvertebrates are essential components of ecosystems, contributing to nutrient cycling, decomposition, and biological regulation. The present study, conducted during 2024, assessed the diversity of macroinvertebrates in a heterogeneous landscape with a focus on their taxonomic representation and ecological roles. A total of 126 individuals were documented, representing 28 species across 17 orders. Coleoptera was the most diverse order with eight species, followed by Orthoptera with three species, while most other orders were represented by one or two species each. Diversity analysis revealed high species richness and evenness, with the Shannon–Wiener index (H′ = 3.32), Simpson's reciprocal (1–D = 0.97), Margalef's richness (d = 7.44), and evenness (J′ = 0.99), indicating a stable and balanced community structure. Functionally, the assemblage included decomposers such as earthworms, millipedes, and isopods; predators including carabid beetles, spiders, and pseudoscorpions; and agricultural pests such as *Agrotis ipsilon* and *Nezara viridula*. The occurrence of the invasive land snail *Achatina fulica* reflects anthropogenic influences on soil faunal assemblages.
Comparative evaluation with earlier studies in Maharashtra and other Indian regions showed recurring patterns of coleopteran dominance, alongside the ecological importance of detritivores in soil processes. The coexistence of beneficial and pest taxa highlights both the ecological services and potential challenges associated with soil macroinvertebrate communities. These findings underscore the role of landscape heterogeneity in supporting diverse and resilient macrofaunal assemblages and provide a baseline for long-term ecological monitoring and sustainable soil management practices in the region.

**Keywords:** Coleoptera, diversity indices, Maharashtra, and soil macroinvertebrates.

## INTRODUCTION
Soil and ground-litter macroinvertebrates are integral to ecosystem function, contributing substantially to decomposition, soil structure formation, nutrient cycling, and regulation of pests (Pant *et al.,* 2020; Krishnapriya & Binoy, 2020). Their diversity and community composition are widely recognized as sensitive indicators of habitat quality, moisture regime, and human land use (Singh *et al.,* 2020; Bhagawati *et al.,* 2021). In many tropical and subtropical Indian landscapes, orders such as Coleoptera, Orthoptera, and Ephemeroptera dominate in taxonomic richness, while decomposers like earthworms, isopods, and millipedes contribute disproportionately to soil health (Krishnapriya & Binoy, 2020; Pant *et al.,* 2020).

In Maharashtra, recent research by Shirbhate and Shirbhate (2020) has highlighted that beetle assemblages exhibit considerable diversity within mixed forest and agroecosystem interfaces, with species richness positively correlated to habitat heterogeneity. Nonetheless, existing regional investigations have largely concentrated on insect taxa or specific functional guilds. Consequently, there remains a significant knowledge gap regarding the diversity and ecological roles of non-insect macroinvertebrates such as earthworms, gastropods, and myriapods, as well as the integrated assessment of taxonomic and functional diversity across soil, litter, and shallow subsurface layers.

Previous work in Karnataka, Kerala, Assam, and the Himalayan agroecosystems has demonstrated high values of diversity indices (Shannon, Simpson, and Margalef) when sampling includes multiple microhabitats and seasons (Bhagawati et al., 2021; Pant *et al.,* 2020; Singh *et al.,* 2020). For example, Bhagawati *et al*. (2021) found substantial diversity of Collembola across forest, vegetable, and tea ecosystems in Assam, while Singh et al. (2020) reported that soil physico-chemical factors strongly influenced earthworm diversity across land-use types in Punjab. Similarly, in the Himalayas, macrofaunal richness decreases with increasing altitude and changes in land use (Pant *et al.,* 2020).

The present study was carried out in Radhanagri Tehsil of Kolhapur district, Maharashtra, a region situated within the northern Western Ghats, recognized as one of the world's biodiversity hotspots. The landscape of Radhanagri is characterized by a mosaic of semi-evergreen forests, lateritic plateaus, agricultural fields, and riparian habitats, providing heterogeneous microenvironments for soil and ground-dwelling fauna. The area experiences a tropical monsoon climate with distinct wet and dry seasons, which strongly influence soil moisture and organic matter dynamics, thereby shaping macroinvertebrate assemblages. In addition, Radhanagri includes parts of the Radhanagri Wildlife Sanctuary, a protected area known for its high floral and faunal diversity, as well as adjoining agricultural lands that are subjected to varying degrees of anthropogenic disturbance. This ecological gradient makes the tehsil an ideal site for assessing soil macroinvertebrate diversity and evaluating their role in ecosystem functioning and landscape health.

## MATERIALS AND METHODS

### a. Study Area

The study was conducted in Radhanagri Tehsil, Kolhapur district, Maharashtra, a region within the northern Western Ghats biodiversity hotspot. Four sampling sites, Aini, Durgamanwad, Dajipur, and Turambe (Fig. 1), were selected to represent forest edges, agricultural lands, and semi-natural habitats. The landscape is characterized by lateritic plateaus, semi-evergreen forests, and riparian zones, which provide diverse microhabitats for soil macroinvertebrates (Krishnapriya and Binoy, 2020). The climate is tropical monsoon, with high rainfall from June to September and drier conditions in the pre-monsoon and post-monsoon seasons (Pant *et al.,* 2020).

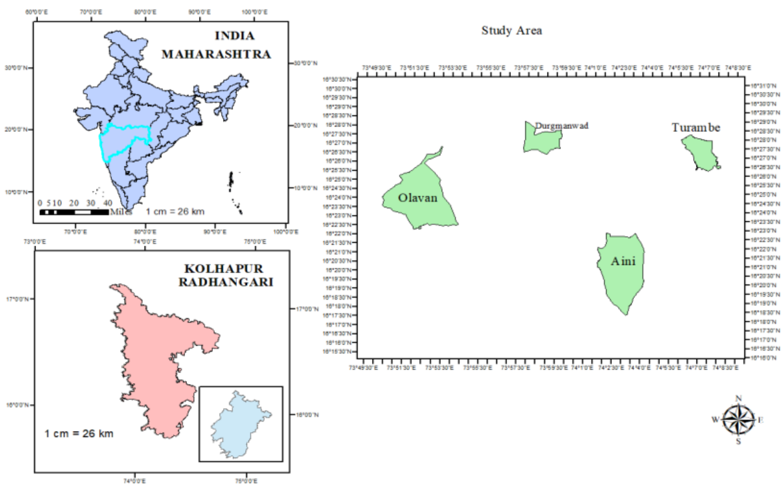

Fig. 1. Location of selected study area in Radhanagari Tahsil, Kolhapur District, Maharashtra, India, including study sites Dajipur (Olvan), Aini, Durgamanwad, and Turambe.

Study Period

Sampling was carried out from January 2024 to December 2024, covering the pre-monsoon (Feb to May), monsoon (Jun to Sept), and post-monsoon (Oct to Jan) periods to capture seasonal variation in community composition.

**b. Sampling Methods**

Multiple collection methods were used to ensure representative coverage of soil and litter macrofauna, as recommended in earlier ecological surveys (Bhagawati *et al.,* 2021).

- Line transects (100 m) were established in each site, and surface-dwelling macroinvertebrates were hand-collected along the transect line (Anderson & Ingram, 1993).
- Pitfall traps (plastic containers, 10 cm diameter × 12 cm depth) with 70% ethanol and a drop of detergent were placed at 10 m intervals along transects and operated for 48 h, a widely used method for capturing ground beetles, ants, and crickets (Work *et al.,* 2002).
- Quadrat sampling was performed using 1 m × 1 m quadrats placed randomly in each habitat, where soil and litter macrofauna were extracted by hand-sorting and sieving (Majer, 1983).

These combined techniques effectively sample both mobile and sedentary invertebrate groups and reduce sampling bias (Magura *et al.,* 2017).

**c. Identification of Species**

All specimens were preserved in 70% ethanol (arthropods, molluscs) or 4% formalin (annelids, soft-bodied taxa) and transported to the laboratory. Taxonomic identification was conducted using standard Zoological Survey of India (ZSI) keys and relevant monographs, following protocols used in Indian soil faunal studies (Shishodia and Hazra 1984; Venkataraman et al., 2020). Additional cross-checks were performed using available entomological literature and online open-access resources such as the *Catalogue of Life*. Identification was carried out to the lowest possible taxonomic level (species or morphospecies).

**d. Data Analysis**

Diversity indices including Shannon–Wiener diversity (H′), Simpson's dominance (1–D), Pielou's evenness (J), and Margalef's richness index (d) were calculated to assess taxonomic diversity and community structure. All indices were computed using PAST software version 4.03 (Hammer, Harper, & Ryan, 2001).

**RESULTS**

A total of 28 soil and ground-dwelling macroinvertebrate species were documented during the present study, representing diverse taxonomic groups including Annelida, Mollusca, Arthropoda, and Platyhelminthes. These species were distributed across 13 orders and 28 families, indicating considerable faunal diversity within the study area. The detailed checklist is provided in Table 1.

Among the Annelida, a single species of earthworm, *Lumbricus terrestris* (Lumbricidae), was recorded. The Mollusca were represented by two gastropod taxa: *Achatina fulica* (Achatinidae), a well-known invasive species, and *Arion ater* (Arionidae), the large black slug. The Platyhelminthes were represented by the terrestrial flatworm *Bipalium kewense* (Geoplanidae).

The phylum Arthropoda contributed the maximum diversity with representatives from Crustacea, Arachnida, Myriapoda, and Insecta. Within Crustacea, *Porcellio scaber* (Porcellionidae) was documented. Arachnid fauna included two spiders: *Plexippus paykulli* (Salticidae) and *Neoscona theisi* (Araneidae); one pseudoscorpion, *Chelifer cancroides* (Cheliferidae); and the velvet mite *Trombidium holosericeum* (Trombidiidae). Myriapods were represented by four species: the centipede *Scolopendra hardwickei* (Scolopendridae), the millipedes *Anoplodesmus saussurii* (Paradoxosomatidae) and *Thyropygus indicus* (Harpagophoridae), and the pill millipede *Glomeris marginata* (Glomeridae).
Insects formed the most dominant group, accounting for 15 species across diverse orders. The order Coleoptera was the richest, with eight taxa: *Blaps sp.* (Tenebrionidae), *Harpalus sp.* (Carabidae), *Dorcus titanus* (Lucanidae), *Anomala cf. rufocuprea* (Scarabaeidae), *Oxycetonia versicolor* (Cetoniidae), *Anthrenus flavipes* (Dermestidae), *Harmonia axyridis* (Coccinellidae), and wireworm larvae (*Elateridae*). Lepidoptera was represented by *Agrotis ipsilon* (Noctuidae), an agriculturally important cutworm pest. Hemiptera included *Nezara viridula* (Pentatomidae), a cosmopolitan phytophagous bug. Orthoptera was represented by three taxa: *Gryllus bimaculatus* (Gryllidae), *Gryllotalpa gryllotalpa* (Gryllotalpidae), and *Diestrammena asynamora* (Rhaphidophoridae). Dermaptera was represented by *Forficula auricularia* (Forficulidae). Hymenoptera was represented by *Camponotus pennsylvanicus* (Formicidae), a common carpenter ant.

The dominance of coleopterans followed by orthopterans and arachnids reflects the ecological adaptability of these groups in soil and litter habitats. The occurrence of both beneficial taxa (e.g., *Harmonia axyridis*, *Camponotus pennsylvanicus*) and pest species (e.g., *Agrotis ipsilon*, *Achatina fulica*, *Nezara viridula*) suggests a complex interaction of soil macrofauna with agricultural ecosystems.

Table 1: Checklist of soil and ground-dwelling macroinvertebrates recorded during the study period.

| Sr. No. | Order | Family | Scientific Name | Authority & Year | Common Name |
|---|---|---|---|---|---|
| 1 | Haplotaxida | Lumbricidae | *Lumbricus terrestris* | Linnaeus, 1758 | Earthworm |
| 2 | Stylommatophora | Achatinidae | *Achatina fulica* | Bowdich, 1822 | Giant African Land Snail |
| 3 | Stylommatophora | Arionidae | *Arion ater* | Linnaeus, 1758 | Large Black Slug |
| 4 | Isopoda | Porcellionidae | *Porcellio scaber* | Latreille, 1804 | Common Rough Woodlouse |
| 5 | Araneae | Salticidae | *Plexippus paykulli* | Audouin, 1826 | Pantropical Jumper Spider |
| 6 | | Araneidae | *Neoscona theisi* | Walckenaer, 1841 | Orb-weaving Spider |
| 7 | Pseudoscorpiones | Cheliferidae | *Chelifer cancroides* | Linnaeus, 1758 | House Pseudoscorpion |
| 8 | Trombidiformes | Trombidiidae | *Trombidium holosericeum* | Linnaeus, 1758 | Velvet Mite |
| 9 | Scolopendromorpha | Scolopendridae | *Scolopendra hardwickei* | Newport, 1844 | Hardwicke's Centipede |
| 10 | Polydesmida | Paradoxosomatidae | *Anoplodesmus saussurii* | Humbert, 1865 | Millipede |
| 11 | Spirostreptida | Harpagophoridae | *Thyropygus indicus* | Pocock, 1892 | Giant Millipede |

| | | | | | |
|---|---|---|---|---|---|
| 12 | Glomerida | Glomeridae | *Glomeris marginata* | Verhoeff, 1915 | Pill Millipede |
| 13 | Tricladida | Geoplanidae | *Bipalium kewense* | Moseley, 1878 | Terrestrial Flatworm |
| 14 | Coleoptera | Tenebrionidae | *Blaps* sp. | Latreille, 1802 | Darkling Beetle |
| 15 | | Carabidae | *Harpalus* sp. | Latreille, 1802 | Ground Beetle |
| 16 | | Lucanidae | *Dorcus titanus* | Boisduval, 1835 | Stag Beetle |
| 17 | | Scarabaeidae | *Anomala cf. rufocuprea* | Motschulsky, 1857 | Leaf Chafer Beetle |
| 18 | | Cetoniidae | *Oxycetonia versicolor* | Fabricius, 1775 | Flower Beetle |
| 19 | | Dermestidae | *Anthrenus flavipes* | LeConte, 1854 | Furniture Carpet Beetle |
| 20 | Lepidoptera | Noctuidae | *Agrotis ipsilon* | Hufnagel, 1766 | Black Cutworm / Greasy Cutworm |
| 21 | Hemiptera | Pentatomidae | *Nezara viridula* | Linnaeus, 1758 | Southern Green Stink Bug |
| 22 | Orthoptera | Gryllidae | *Gryllus bimaculatus* | De Geer, 1773 | Two-spotted Cricket |
| 23 | | Gryllotalpidae | *Gryllotalpa gryllotalpa* | Linnaeus, 1758 | European Mole Cricket |
| 24 | | Rhaphidophoridae | *Diestrammena asynamora* | Adelung, 1902 | Greenhouse Camel Cricket |
| 25 | Dermaptera | Forficulidae | *Forficula auricularia* | Linnaeus, 1758 | Common Earwig |
| 26 | Hymenoptera | Formicidae | *Camponotus pennsylvanicus* | De Geer, 1773 | Black Carpenter Ant |
| 27 | Coleoptera | Coccinellidae | *Harmonia axyridis* | Pallas, 1773 | Harlequin Ladybird |
| 28 | | Elateridae | *Elateridae larvae* | — | Wireworm (Click Beetle larva) |

Table 2: Diversity indices of soil and ground-dwelling macroinvertebrates recorded during the study period.

| Sr. No. | Parameter | Value |
|---|---|---|
| 1. | Total number of species (S) | 28 |
| 2. | Shannon–Wiener Index (H′) | 3.32 |
| 3. | Simpson's Index of Diversity (1–D) | 0.97 |
| 4. | Pielou's Evenness (J′) | 0.99 |
| 5. | Margalef's Richness Index (d) | 7.44 |

The diversity of soil and ground-dwelling macroinvertebrates was evaluated using standard ecological


indices (Table Z). A total of 28 species were recorded during the study. The Shannon–Wiener diversity index (H′ = 3.32) indicated a high level of species diversity, while Simpson's index (1–D = 0.97) reflected a low dominance of any single species within the assemblage. Pielou's evenness (J′ = 0.99) suggested a nearly uniform distribution of individuals across species, and Margalef's richness index (d = 7.44) confirmed the substantial species richness in the study area.

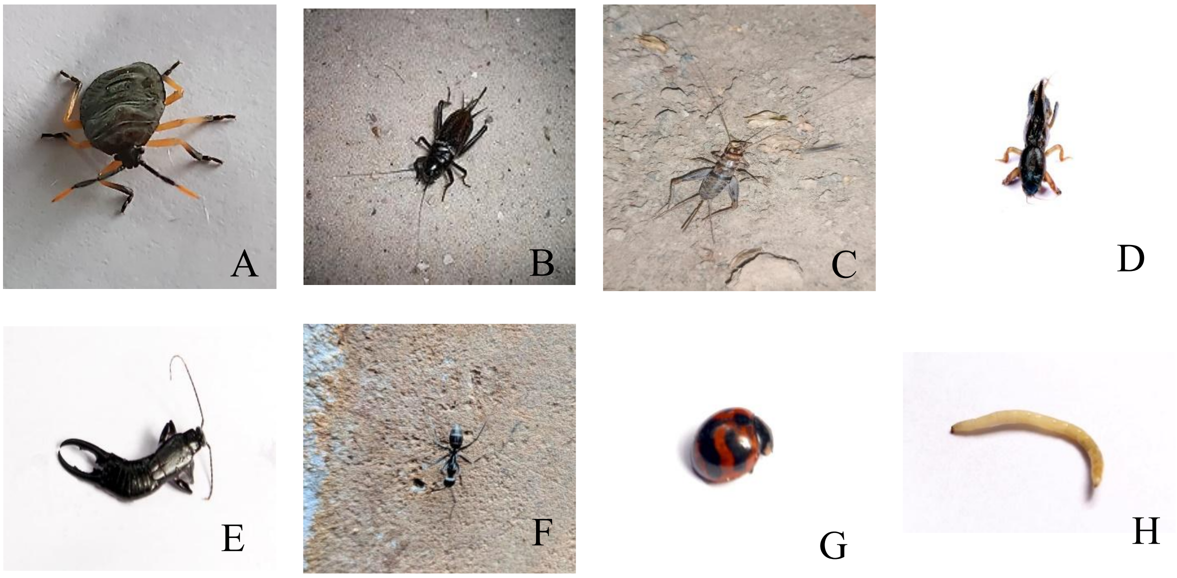


Fig.2: A *Lumbricus terrestris;* B *Achatina fulica;* C *Arion ater;* D *Porcellio scaber;* E *Plexippus paykulli;* F *Neoscona theisi;* G *Chelifer cancroides;* H *Trombidium holosericeum;* I *Scolopendra hardwickei;* J *Anoplodesmus saussurii;* K *Thyropygus indicus;* L *Glomeris marginata;* M *Bipalium kewense;* N *Blaps* sp.; O *Harpalus* sp.; P *Dorcus titanus ;* Q *Anomala cf. rufocuprea;* S *Oxycetonia versicolor;* R *Anthrenus flavipes;* T *Agrotis ipsilon.*

Fig.3: A *Nezara viridula;* B *Gryllus bimaculatus;* C *Gryllotalpa gryllotalpa;* D *Diestrammena asynamora;* E *Forficula auricularia;* F *Camponotus pennsylvanicus;* G *Harmonia axyridis;* H *Elateridae larvae.*

**DISCUSSION**

The present study documented 28 species of soil and ground-dwelling macroinvertebrates, representing 17 orders across 126 individuals, with Coleoptera emerging as the most dominant group. This order-level dominance mirrors the pattern reported in several Indian habitats, where beetles consistently contribute the greatest species richness among soil arthropods (Shirbhate & Shirbhate, 2020; Krishnapriya and Binoy, 2020). Coleopterans inhabit a wide range of ecological niches and play multiple functional roles, including decomposition, predation, and herbivory. Their ability to exploit diverse habitats and trophic levels accounts for their high abundance and taxonomic dominance across various ecosystems (Maikhuri & Rao, 2012).

The eight coleopteran species identified in our samples (Carabidae, Tenebrionidae, Scarabaeidae, Cetoniidae, Coccinellidae, Dermestidae, Cerambycidae, and Lucanidae) reflect both pest and beneficial groups. Similar findings were noted in Akola District by Shirbhate and Shirbhate (2020), who reported that beetle assemblages in forest and agricultural lands show high family-level diversity and a mixture of saprophagous and predatory taxa. Comparable results were obtained from Kerala Forest ecosystems, where coleopteran richness was associated with litter depth and microhabitat variability (Krishnapriya and Binoy, 2020).

Orthoptera emerged as the second most diverse order in the present study, represented by *Gryllus bimaculatus*, *Gryllotalpa gryllotalpa*, and camel crickets. This observation is consistent with several Indian and regional surveys that highlight Orthoptera as a conspicuous component of ground macrofaunal communities, particularly in semi-natural and disturbed habitats. For instance, a detailed survey in Pune District documented 20 orthopteran species belonging to 15 subfamilies and 5 families, indicating high species richness in mixed agricultural and scrub habitats (Dhamke, Bhawane, & Dhamke, 2014). Similarly, a comprehensive faunal inventory from Chandoli National Park, Kolhapur, recorded 62 species or subspecies from 8 families, emphasizing the ecological adaptability of this group in Western Ghats landscapes (Koli, Bhawane, & Nikam, 2010). In the Tilari forest of Chandgad (Kolhapur District), 17 grasshopper species from 3 families were identified, with Acrididae being dominant in open and degraded habitats (More & Nikam, 2016). Comparable results were also observed in Nashik District, where 9 species representing 3 families were recorded, and Acrididae accounted for nearly 56% of all individuals collected (Kale, Chaudhari, & Sonawane, 2023).

Ecologically, orthopterans play essential roles as herbivores and as prey for birds, reptiles, and small mammals, thereby linking primary production with higher trophic levels (More & Nikam, 2016). Their abundance and distribution are strongly influenced by microclimatic conditions, particularly soil moisture, vegetation height, and temperature, which makes them reliable indicators of habitat disturbance and ecosystem health (Koli *et al.,* 2010; Kale *et al.,* 2023). The occurrence of field and mole crickets in our samples similarly reflects their adaptation to variable moisture regimes and vegetation cover, a trend consistent with earlier Maharashtra studies (Dhamke *et al.,* 2014).

Among the non-insect macrofauna, the occurrence of *Lumbricus terrestris* (Haplotaxida) is particularly notable because earthworms are keystone taxa that regulate soil aeration, aggregation, and nutrient mineralization. Comparable roles have been emphasized in Indian soil macrofauna studies where earthworms dominate biomass, even when arthropods dominate species richness (Kumar and Khan 2013). Similarly, the detection of the invasive land snail *Achatina fulica* aligns with recent reports of its expansion across Maharashtra and adjoining states, where it is frequently associated with disturbed urban and peri-urban habitats (Shirbhate & Shirbhate, 2020). Its presence in our samples confirms the encroachment of invasive species into natural–agricultural mosaics, a trend of ecological concern (Maikhuri and Rao 2012).

Isopods (*Porcellio scaber*) and myriapods (*Scolopendra hardwickei*, *Polydesmus angustus*, *Spirostreptus spp.*) add functional breadth to the community. Isopods, as litter comminuters, are especially important for the initial stages of decomposition, whereas millipedes regulate organic matter breakdown rates. Both groups have been documented in Indian forest and agricultural soils, often in low species numbers but with disproportionate functional influence (Krishnapriya and Binoy 2020). Their representation in our study, albeit by single species, is consistent with the trend reported in Kerala and Andhra Pradesh where decomposer guilds are species-poor but functionally irreplaceable (Kumar and Khan 2013).

The diversity indices calculated here provide quantitative evidence for a balanced and heterogeneous assemblage. The Shannon index ($H' \approx 3.32$) and Simpson's reciprocal ($1–D \approx 0.97$) are comparatively high, indicating not only species richness but also equitable distribution. Similar high diversity values have been reported in tropical forest litter communities in Kerala (Krishnapriya and Binoy 2020) and in agroforestry soils of southern India (Kumar and Khan 2013). Evenness ($J' \approx 0.99$) suggests minimal dominance by a single taxon, unlike monoculture systems where pest groups such as hemipterans may dominate numerically (Shirbhate & Shirbhate, 2020). The Margalef richness index ($d \approx 7.44$) also exceeds values reported in highly disturbed sites, supporting the interpretation that habitat heterogeneity underlies the diversity in our study area (Maikhuri and Rao 2012).

Seasonal variation is recognized as an important factor influencing soil arthropod assemblages in India (Kumar and Khan 2013). Although the present study covers only one annual cycle, the observed proportions of detritivores such as earthworms, millipedes, and isopods and predators including spiders, pseudoscorpions, and carabids indicate a relatively stable community structure under changing moisture regimes. Evidence from long-term assessments in Kerala shows that rainfall events strongly affect species visibility and diversity measures, and similar patterns are likely relevant for Maharashtra (Krishnapriya and Binoy 2020).

Comparative research from Maharashtra provides useful context for interpreting our findings. Surveys of beetle diversity in the Vidarbha region (Thakare 2011) and macroinvertebrate inventories from Nashik and Ahmednagar districts (Jagdale & Magdum, 2017) reported several of the same dominant families observed in our study, notably Tenebrionidae and Scarabaeidae. Their repeated occurrence across geographically distinct locations indicates the broad ecological tolerance of these coleopteran groups within agro-forest transition zones. Furthermore, the presence of agricultural pest taxa such as *Agrotis ipsilon* (Lepidoptera: Noctuidae) and *Nezara viridula* (Hemiptera: Pentatomidae) reflects the strong influence of cropland systems adjoining forest fragments, corroborating trends documented in field studies of farm-associated entomofauna (Jasrotia *et al.,* 2023).

From a functional standpoint, our faunal assemblage demonstrates the dual ecological roles that macroinvertebrates play in terrestrial ecosystems. Predatory guilds represented by carabid beetles, spiders, and pseudoscorpions are known to suppress herbivore populations, offering natural pest regulation services. Conversely, phytophagous hemipterans and lepidopteran larvae may impose economic losses in cultivated fields. This interplay between beneficial and harmful species has been emphasized in Indian agroecological assessments, which advocate for conservation strategies that consider not only species richness but also trophic balance and ecosystem function (Pant *et al.,* 2020; Jasrotia *et al.,* 2023). The relatively even distribution of functional groups in our study implies that the heterogeneous landscape matrix supports regulatory interactions typically absent in monoculture-dominated areas.

On a broader scale, global literature frequently reports that coleopterans dominate terrestrial invertebrate species richness, whereas decomposer taxa such as earthworms and termites contribute disproportionately to nutrient cycling and biomass (Lavelle *et al.,* 1994). Our dataset reflects this pattern, with beetles comprising the most taxonomically diverse group and annelids and isopods playing a primary role in organic matter turnover. These findings highlight the need to link taxonomic inventories with functional trait assessments to obtain a more integrated understanding of ecosystem processes, a recommendation increasingly promoted in contemporary soil biodiversity research (Philpott *et al.,* 2009).

## CONCLUSION

The present survey recorded 28 species of soil and ground-dwelling macroinvertebrates from 17 orders, with Coleoptera showing the highest richness, followed by Orthoptera. Diversity indices indicated a well-balanced community with high species evenness and richness, suggesting stable ecological conditions. The occurrence of both decomposers and predators alongside agricultural pests reflects the functional complexity of the assemblage. Comparison with previous studies in Maharashtra and other regions of India confirmed the recurring dominance of beetles and the importance of earthworms, isopods, and myriapods in soil processes. These results highlight the role of landscape heterogeneity in supporting diverse and resilient macroinvertebrate communities and provide a baseline for future ecological and conservation assessments.

### Applied Implication

The balanced composition of decomposers, predators, and agricultural pests recorded in this study underlines the need for conserving soil macroinvertebrate diversity as a natural regulator of ecosystem services. Protecting habitat heterogeneity and reducing chemical disturbance can enhance soil health and support sustainable agricultural practices in the region.

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