Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 44 No. 4 (2023)

Earthworm population and Community structure with reference to Soil ecological parameters from different agroecosystem in Cuddalore district, Tamil Nadu, India

[1]S.Devanathan, [2]S. Senthilmurugan

[1]Research Scholar, Department of Zoology, Annamalai University, Annamalai Nagar-608002.
[2]Associate Professor, Department of Zoology, Annamalai University, Annamalai Nagar-608002.

Abstract: Earthworms are fundamental to the dynamics of our ecosystems. The six species of earthworms (*Pondoscolex corethrurus* (Muller, 1856), *Perionyx ceylanensis* (Michaelsen, 1904), *Perionyx excavates (*Perrier, 1872*)*, *Lambitomauritti (*Kinberg, 1867*)*, *Amynthas gracilis (*Kinberg, 1867*)* and *Drawida willsi (*Michaelsen, 1907*)*) belonging to three families (*Glossoscolecidae*, *Megascolecidae*, *Moniligastridae*), five Genera (*Pondoscolex*, *Perionyx*, *Lambito*, *Amynthas*, *Drawida*) and three orders (*Opisthopora*, *Heplotaxida*, *Moniligastrida*) were identified from the study site in Cuddalore district, Tamil Nadu, India.Selected two types of cultivated lands in present study: Wet Lands (Paddy, Banana, Sugarcane), Dry Lands (Coconut, Groundnut, Oil palm).Totally six species find in the study sites, two species (*Perionyx excavates*, *Perionyx ceylanensis*) were epigeic category, one species (*Pondoscolex corethrurus*) were endogeic category, one species (*Lambito mauritti*) anecic category, one species (*Amynthas gracilis*) were epiendogeic and last one species (*Drawida willsi*) were epianecic category. The wet land cultivable fieldshave three types of earthworm category (epigeic, endogeic, epianecic) and cultivable dry land fields have two types of earthworm category (anecic and epiendogeic).The statistical analysis of data was also performed by using ANOVA software and different types of soil ecological parameters (pH, moisture, temperature, organic carbon, nitrogen, phosphorous, potassium, C:N ratio, microbial activity, earthworm density, earthworm biomass, relative density, frequency, richness index, diversity index, dominance index, evenness index, Lm/Oratio[a], Pe/O ratio[b]).

Keywords: Earthworm survey, Population dynamics, Hand sorting, Soil ecological parameters.

1. Introduction

Earthworms play a crucial role as soil-dwelling organisms in the processes of soil formation and thepreservation of soil fertility. Soil biodiversity stands out as a significant topic in ecological studies, land use planning, and efforts to conserve diversity. Earthworms belong to the Class Oligochaeta and are related to the Class Polychaeta (bristle worms) and the Class Hirudinea (leeches).The Oligochaeta are the second largest group of the Annelida, with more than 5000 terrestrial earthworms comprising about one third of the phylum (Reynolds & Wetzel, 2016).The Oligochaetes category comprises over 8,300 species, with approximately half of them being earthworms that dwell on land (Reynolds& Wetzel, 2023).In India, 505 species and subspecies of earthworms belonging to 67 genera and 10 families are reported (Ahmed & Julka, 2017).The alteration of native plant cover of shifts in land use practices are influencing the makeup and population distribution of earthworm species in various agricultural and climatic zones (Julka, 2014). Earthworms, renowned for their unique dietary preferences and soil-burrowing behaviors, are regarded as some of nature's most effective ecosystem architects.

Earthworms are among the most plentiful macrofauna in soil and play a vital role in soil formation and preserving soil fertility. India, with its diverse range of habitats, hosts numerous earthworm species characterized by various biological traits. However, there is a pressing need for comprehensive research on different earthworm populations and communities. Conducting surveys of earthworms would be beneficial for recognizing indigenous earthworm species and for their conservation efforts. Population dynamics, diversity, distribution and community structure in natural ecosystems of the tropics and sub-tropics have received

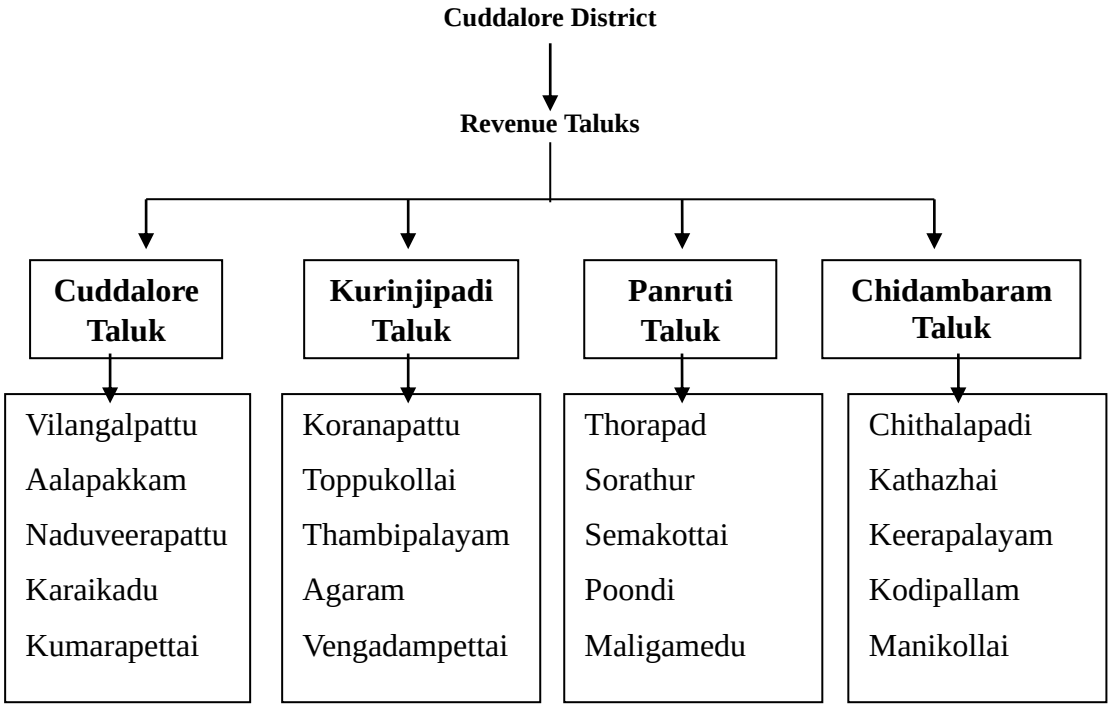
considerable attention in recent years (Bhadhuria et al., 2012; Chaudhuri & Singh, 2014). Soil communities make up a significant portion of terrestrial biodiversity and deliver essential ecosystem services to humans. However, the majority of these communities remain unidentified or undescribed (Lavelle et al., 2006**;** Decaens 2010). Therefore, modification of natural habitat for agricultural purpose may harm population density, species diversity, richness and activities of earthworm communities (Ponge et al., 2013). In the context of India, limited information exists regarding the variety and geographic spread of earthworms, and the state of Kerala is no different in this regard (Mohan et al., 2011).

Earthworms are well-known worldwide, including in India, for their significant role in the recycling of organic waste (Saikia et al., 2021). Population dynamics, diversity, distribution and community structure in natural ecosystems of the tropics and sub-tropics have received considerable attention in recent years (Fragoso & Lavelle, 1992; Chaudhuri & Singh, 2014). Extensive research has been conducted worldwide to examine the population dynamics of earthworms in various soil types and environments (Khan et al., 2021).

2. Materials and Methods:

2.1 Selection study area:

A present study was carried out during January 2022 – December 2022 in four taluks and twenty villages area of Cuddalore district covering an area of 702 km2 (1,820/sq mi) Tamil Nadu State, India. It is a state in the southern part of Indian. The locations selected for the earthworm survey encompassed two distinct agroecosystems: the wetland cultivable area (WLCA), encompassing crops like paddy, banana, and sugarcane, and the dryland cultivable areas (DLCA), which included fields with coconut, groundnut, and oil palm cultivation.



2.2 Collection of earthworm species:

The sampling was conducted during the month of January 2022 - December in 2022. Frequent survey was conducted in all the four taluks and twenty villages area of Cuddalore district. Earthworms were collected during morning (6–8 am) from different agroecosystems, once a month by conventionally digging of the soil (0–30 cm) (25 x 25 x 30 cm) and hand sorting method (Parthasarathi et al., 2013). Sampling was done bimonthly for one year (January 2022–December 2022).The procedure involved placing all the earthworms directly into a solution containing 5-10% formalin.After approximately 5-6 hours of fixation in formalin, they were subsequently stored in 70% ethanol for preservation. Worms that were directly fixed in this manner exhibited

uniform contraction, allowing for more consistent observations. The preserved earthworms were then carefully sealed in vials before being transported to the laboratory, where they were later identified, counted, and weighed as part of the analysis.

2.3 Soil analysis:

The soil samples were collected from three different depths (0-10cm, 10-20cm and 20-30cm depths) were collected; The soil sample was air dried on a clean sheet of paper and kept in a polythene bag for further physical and chemical analysis. The soil samples of different layers were thoroughly mixed, air-dried, ground and passed through sieves (0.2 mm size) and kept in plastic bag for laboratory analysis by using standard methods. The pH of the soil was recorded by the method (Jackson, 1973), organic carbon (Walkley & Black, 1934), total nitrogen (Jackson, 1962) phosphorus (Olsen et al., 1954), potassium (Stanford & English, 1949) and dehydrogenase activity (Stevenson, 1959).

2.4 Statistical analysis

SAS (Statistical Analysis System)version 9.4, One-way ANOVA, Two-way ANOVA was used to examine the occurrence of relationship between soil ecological parameters of on earthworm's experimental study. All the experiments were done with n=5 repetitions from each sampling sites. Principal component analyses SAS is used to characterize the effect of different soil properties on the distribution of earthworm population across six different habitats. The means were separated using test (CD value, F value).

3. Results

3.1 Selection of Study area:

The present study was carried out during January 2022–December 2022 in 4 taluks and 20 villages of Cuddalore district (Table 1). The sampling sites for earthworm survey comprised two different agroecosystems: wet land cultivable area (WLCA) which includes paddy, banana and sugarcane and dry land cultivable areas (DLCA) which includes coconut, groundnut and oil palm fields.

Table 1: Twenty blocks of Cuddalore district

Block No	Block Names
1	Vilangalpattu block
2	Aalapakkam block
3	Melakuppam block
4	Karaikadu block
5	Kumarapettai block
6	Koranapattu block
7	Toppukollai block
8	Thambipalayam block
9	Agaram block
10	Vengadampettai block
11	Thorapadi block
12	Sorathur block
13	Semakottai block
14	Poondi block
15	Maligamedu block
16	Chithalapadi block
17	Kathazhai block
18	Keerapalayam block
19	Kodipallam block
20	Manikollai block

3.2 Collection of Earthworm species:

This survey was done from January 2022 - December 2022. In this present study have found 117 earthworms belonging to six species (Table 2). The 6 species of earthworms *Pondoscolex corethrurus* (Muller, 1856), *Perionyx ceylanensis* (Michaelsen, 1904), *Perionyx excavates* (Perrier, 1872), *Lambito mauritti* (Kinberg, 1867), *Amynthas gracilis* (Kinberg, 1867) and *Drawida willsi* (Michaelsen, 1907)) belonging to 3 families (*Glossoscolecidae, Megascolecidae* and *Moniligastridae*), 5 Genera (*Pondoscolex, Perionyx, Lambito, Amynthas, Drawida*) and 3 orders (*Opisthopora, Heplotaxida, Moniligastrida*) were identified from the study site in Cuddalore district, Tamil Nadu, India.Totally 6 species find in the study sites, 2 species (*Perionyx excavates, Perionyx ceylanensis*) were epigeic category, one species (*Pondoscolex corethrurus*) were endogeic category, one species (*Lambito mauritti*) anecic category, one species (*Amynthas gracilis*) epiendogeic and last one species (*Drawida willsi*) were epianecic category. The wet land cultivable fields have sandy loam and three types of earthworm category found (epigeic, endogeic and epianecic) and dry land cultivable fields have clay loam and two types of earthworm category found (anecic and epiendogeic). The number of earthworms was slightly higher in wet land than in dry land, this is because food for earthworms is naturally available in wetlands.

Table 2: Occurrence of collected earthworm species in the study area (January 2022- December 2022)

Order	Family	Genus	Species	Agroecosystems					
				Paddy	Banana	Sugarcane	Coconut	Groundnut	Oil palm
Opisthopora	Glassoscolecidae	Pondoscolex	P.corethrurus	+	+	+	-	-	-
Opisthopora	Megascolecidae	Perionyx	P.cyelanensis	+	+	+	+	+	+
Opisthopora	Megascolecidae	Perionyx	P.excavates	+	+	+	+	+	+
Heplotaxida	Megascolecidae	Lambitto	L.mauritti	+	+	+	-	+	+
Opisthopora	Megascolecidae	Amynthas	A. gracilis	-	+	+	-	-	-
Moniligastrida	Moniligastridea	Drawida	D. willsi	+	+	+	-	-	-

(+) Present, (-) Absent

3.3 Sampling

The six different cultivable lands use pattern of Cuddalore district, Tamil Nadu, India (Figure1 & 2) was used for study. Selected two types of agroecosystems in present study: Wet lands (Paddy, Banana and Sugarcane), Dry lands (Coconut, Groundnut and Oil palm). Earthworms were counted separately in two types of cultivable lands.

Wet Land Cultivable Area

Fig 1: Photographs of collected indigenous earthworm species of Cuddalore district, Tamil Nadu, India (January 2022 – December 2022)

Dry Land Cultivable Area

Coconut

Groundnut

Oil palm

Fig 2: Photographs of collected indigenous earthworm species of Cuddalore district, Tamil Nadu, India (January 2022 - December 2022)

3.4 Soil analysis

Sampling was carried out across six distinct cultivable regions within the Cuddalore district. Two soil types, specifically sandy loam and clay loam, were identified. This variation in soil types within the study areas can be attributed to past agricultural practices and the inherent texture of the soil. Sandy loam predominated in dry land areas, while clay loam was prevalent in wet land areas. Generally, numerous ecological factors are recognized as significant contributors to the earthworm population dynamics. The soil selected for the study underwent a comprehensive drying process before conducting the tests.

Table 3: Occurrence of earthworms in six different cultivated lands of soil ecological-parameters, periods of survey (January2022-December 2022)

Soil Ecological parameters	Cultivable lands						F-Value	CD-Value
	Wet lands			Dry lands				
	Paddy	Banana	Sugarcane	Coconut	Groundnut	Oil palm		
Soil texture	Sandy loam	Sandy loam	Clay loam	Clay loam	Sandy loam	Clay loam	-	-
pH	6.38	6.40	6.10	6.59	6.39	6.55	1,063.89	0.016
Moisture (%)	21.19	19.07	18.47	16.59	15.90	17.35	5,378.62	0.078
Temperature (°C)	17.38	14.65	18.51	15.45	16.35	15.55	5,554.48	0.057
Organic carbon (%)	0.39	0.46	0.52	0.32	0.58	0.62	4,865.13	0.005
Nitrogen (%)	0.29	0.33	0.21	0.13	0.17	0.26	2,132.18	0.005
Phosphorus (Kg-ha^{-1})	22.6	16.05	18.41	20.85	16.75	23.35	9,381.33	0.094
Potassium (kg ha^{-1})	80.71	74.65	71.65	77.75	68.35	60.75	6,226.06	0.269
C:N ratio	1.48	1.38	1.19	3.67	2.80	2.20	16,917.25	0.022
Microbial activity (µlH/5 g soil)	2.13	1.95	1.89	1.42	1.18	2.53	10,840.24	0.014
Earthworm density (Ind.m^{-2})	290.65	189.75	239.95	128.95	195.95	206.95	9,814.91	1.619
Earthworm biomass (g.m^{-2})	486.95	308.05	216.75	345.95	189.75	269.95	10,966.23	3.031
Relative density (%)	14.03	12.19	11.08	13.10	11.17	12.89	5,971.71	0.044
Frequency (%)	78.48	40.15	56.89	106.13	124.40	186.39	13,753.34	1.34
Richness index	0.24	0.15	0.30	0.19	0.27	0.20	1,024.78	0.005
Diversity index	0.055	0.035	0.115	0.695	0.707	0.735	25,281.27	0.007
Dominance index	0.0019	0.0033	0.4035	0.6095	0.6117	0.6995	12,567.10	0.008
Evenness index	0.0040	0.0049	0.0046	0.0699	0.0790	0.0887	2,106.56	0.003
Lm/O ratio[a]	0.30	0.18	0.23	0.52	0.69	0.99	7,947.68	0.01
Pe/O ratio[b]	0.16	0.09	0.10	1.02	1.10	1.19	13,633.91	0.014

SAS (Statistical Analysis System) version 9.4, One-way ANOVA, Two-way ANOVA was used to examine the occurrence of relationship between soil ecological parameters of on earthworm's experimental study (Table 3). Thus, soil quantities in six types of cultivated land were calculated.

Discussion

The current investigation unveiled the presence of six earthworm species belonging to three families and five genera within the Cuddalore district of Tamil Nadu, India. In a recent survey, a total of eight earthworm species were identified from a collection of 537 specimens, and their abundance was graphically represented in a rank-ordered plot. *Metaphire posthuma* exhibited the highest relative abundance along the banks of water bodies, while both *Metaphire peguana* and *Metaphire posthuma* were prominent in residential areas, and *Metaphire peguana* prevailed in grassland habitats. Conversely, *Metaphire houlleti* exhibited the lowest relative abundance across all these various habitats (Goswami, 2018). In accordance with the research findings, a total of 17 earthworm species were identified, classified into four distinct families. The study provides comprehensive data for each species, including their scientific names, family categorization, numerical representation, geographic locality, and typical habitat characteristics. Among these 17 species, there are six indigenous species and 11 non-native species that have been documented. Notably, three of these species, namely *Eisenia fetida*, *Argilophilus sp*., and *Amynthas morrisi*, were documented in the study area for the first time (Sharma et al., 2022).

The present study was, among the 6 species in different cultivable lands of 5genera and 3 families and 2 orders earthworms were found. They, *Megascolecidae* family - (*Perionyx excavates* and *Perionyx ceylanensis*) were epigeic, *Glossoscolecidae* family - (*Pondoscolex corethrurus*) were endogeic, *Megascolecidae* - (*Lambito mauritti*) were anecic, *Megascolecidae* - (*Amynthas gracilis*) were epiendogeic, and *Moniligastridae* - (*Drawida willsi*) were epianecic. Parthasarathi et al., (2015) have reported that, a total of 9 species belonging to 7 genera, 4 families and 2 order of the class *Oligochaeta* was collected, out of 23 taluks, 3 different districts of Cauvery delta area, Tamil Nadu, India. Among them, five species were from *Megascolecidae* family – *Perionyx excavates* (Perrier, 1872),*P.ceylanensis*, (Michaelsen, 1904), *P. sansibaricus* (Michaelsen, 1903), *Lampito mauritti* (Kinberg, 1867) and *Polypheretima elongata* (Perrier, 1872); two species from *Moniligastridae* – *Drawida willsi* (Michaelsen, 1907) and *Metaphire houlleti* (Perrier, 1872); one species from *Octochaetidae*-*Dichogaster bolaui* (Michaelsen, 1891) and one species from *Glossocolecidae*– *Pontoscolex corethrurus* (Müller, 1856). If we compare the found incidence of 19 epigeic groups within the monitored integrated andecological farming with the number of occurring groupsin nature reserves, where Porhajašová et al. (2015) six cultivable lands were largely epigeic earthworm species spotted (total 6 species out of 2 epigeic earthworm species). Thus, epigeic species are more abundant in Tamil Nadu as compared to other species earthworms.

The composition of soil can impact earthworm populations by influencing various soil properties, including moisture levels, nutrient content, and cation exchange capacity. These factors, in turn, can exert significant effects on the population dynamics of earthworms (Athira et al., 2016). Two types of soils were observed in the study viz, sandy loam, clay loam. A similar experiment was conducted on six types of cultivated lands. In a similar vein, noteworthy correlations were detected between the presence of earthworms and the clay and silt content of the soil in a temperate grass-covered field. Additionally, there was a significant association between earthworm density and the clay content of soil in both rainforest environments and areas designated for forestry purposes (Huerta et al., 2007). Rajwar et al., (2022), have reported that, with the ascent from cultivated areas to forested regions, there was a noticeable decline in soil temperature, accompanied by a greater prevalence of soil moisture. The number of earthworms in agroforestry is increasing more than in agricultural lands. Recently, the agro-forest system supports the population density of earthworms as compared to cultivated land (Cardinael et al., 2019).

Soil tests were conducted on six selected cultivars and their differences were also given (Table 3), and only moisture content was found to be largely equal. Soil environmental measurements were also conducted for all six cultivable lands. A recent examination of the physical and chemical attributes of the soil, along with the climatic conditions in the research area, indicated that the soil's pH neutrality, the presence of organic carbon, nitrogen, and soil moisture, all directly affect the presence and dispersion of earthworm species. Furthermore, the physicochemical characteristics of casts, such as pH, electrical conductivity (EC), organic carbon, total nitrogen, available phosphorus, potassium, sodium, calcium, and magnesium, exhibited no disparities in zero tillage plots treated with mulch derived from either annual or perennial residue sources (Jeyaprakasam et al., 2021). All environmental parameters of the soil were statistically determined (ANOVA). Compared to earlier times, the number of earthworms is slightly lower now, this is because farmers use artificial fertilizers and degrade the quality of the soil. Hence this earthworm survey was conducted by January 2022 to December 2022, in four taluks Cuddalore district, Tamil Nadu, India.

4. **Conclusion**

In the present study, epigeic species of earthworms (*Perionyx excavates, Perionyx ceylanensis*) were found in six types of cultivable lands in Cuddalore district, Tamil Nadu, India. As a result of this survey, six different species of earthworms belonging to three different families and five genera were identified. The species obtained include: *Perionyx excavates, Perionyx ceylanensis, Pondoscolex corethrurus, Lambito mauritti, Amynthas gracilis, Drawida willsi.* Among those collected, five species of earthworms were detected during the survey, *viz* (epigeic, endogeic, anecic, epiendigeic, epianecic). Our study revealed that the number of earthworms on the surface of cultivated lands is low. This is due to the use of artificial fertilizers by farmers. Therefore, to maintain these farmers should use natural fertilizers to increase the number of earthworms.

Acknowledgement

The thankful to Professor and Head, Department of Zoology, Annamalai university for the laboratory facilities provided.

References

[1] Ahmed S, Julka JM (2017) First record of exotic earthworm, *Amynthas hupiensis* (Michaelsen, 1895) (Oligochaeta: Megascolecidae), from India. Megadrilogica 22 (7): 151–154.

[2] Athira CS, Athira BC, James J, Sivaraman K, Kavya KS, Midhuna BV, Reynolds JW (2016) Studies on the Biology and Ecology of Earthworms Collected from Urban and Suburban Areas of Thrissur District, Kerala, India. Studies 21(1).

[3] Bhadauria T, Kumar P, Kumar R, Maikhuri RK, Rao KS, Saxena KG (2012) Earthworm populations in a traditional village landscape in central Himalaya, India, Applied Soil Ecology. 53: 83-93.

[4] Cardinael R, Hoefner K, Chenu C, Chevallier T, Beral C, Dewisme A, Cluzeau D (2019) Spatial variation of earthworm communities and soil organic carbon in temperate agroforestry. Biol Fertil Soils 55(2):171–183.

[5] Chaudhuri P, Singh SM (2014) Biology and Ecology of Tropical Earthworms, DPH Pvt Ltd. New Delhi.

[6] Decaens T (2010) Macroecological patterns in soil communities. Global EcolBiogeogr 19:287–302.

[7] Fragoso C, Lavelle P (1992) Earthworm communities of tropical rain forests. Soil Biol Biochem 24(12): 1397-1408.

[8] Goswami R (2018) Earthworm diversity and abundance in different habitats at Satyajit Ray Film and Television Institute, Kolkata. Records of the Zoological Survey of India 118(2): 133-140.

[9] Huerta E, Rodriguez-Olan J, Evia-Castillo I, Montejo-Meneses E, de la Cruz Mondragon M, Garcia-Hernandez R, Uribe S (2007) Earthworms and soil properties in Tabasco, Mexico. European Journal of Soil Biology 43: S190- S195.

[10] Jackson ML (1962) Soil Chemical Analysis. Asia Publishing House Bombay.

[11] Jackson ML (1973) Soil chemical analysis, pentice hall of India Pvt. Ltd. New Delhi India 49(8): 151-154.

[12] Porhajašová J, Noskovič J, Rakovská, Babošová, M,Čeryová T (2015) Biodiversity and dynamics of occurrence of epigeic groups in different types of farming. Acta Horticulturae et Regiotecturae 18(1): 5-10.

[13] Jeyaprakasam A, Muniyandi B, James AJP, Karmegam N, Ponnuchamy K (2021) Assessment of earthworm diversity and pesticide toxicity in *Eudriluseugeniae*. Environmental Chemistry and Ecotoxicology 3: 23-30.

[14] Julka JM (2014) Diversity and distribution of exotic earthworms (Annelida, Oligochaeta) in India a review. Biology and ecology of tropical earthworms. Discovery Publishing House New Delhi 73-83.

[15] Khan MU, Andleeb S, Khan MF, Mustafa RG, (2021) Biodiversity and ecological interactions of earthworm species from Poonch division Pakistan. Tropical Ecology 1-12.

[16] Lavelle P, Decaens T, Aubert M, Barot S, Blouin M, Bureau F, Margerie P, Mora P, Rossi J (2006) Soil invertebrates and ecosystem services. Eur J Soil Biol 42: S3 S15.

[17] Mohan M, Chandran MSS, Ramasamy EV 2011 Vulnerable earthworm species identified from Nilgiri biosphere reserve. International Journal of Zoological Research 7(6): 410-413.

[18] Olsen SR, Cole CV, Watanabe FS, Dean LA (1954) Estimation of available phosphorus in soil by extraction with sodium bicarbonate. USDA Circ No 939.

[19] Parthasarathi K, Balamurugan M, Prashija KV, Basha SA (2015) Earthworms' population and community structure from agroecosystems of Cauvery delta areas of Tamilnadu State, India. Blaze J Biodivers Conserv 1(1): 1-13.

[20] Parthasarathi K, Jayanthi L, Ameer Basha S (2013) Population dynamics of earthworms in Cauvery delta areas in relation to soil properties. Indian Stream Research Journal 3(10): 1-8.

[21] Ponge JF, Pérès G, Guernion M, Ruiz-Camacho N, Cortet J, Pernin C, Cluzeau, D (2013) The impact of agricultural practices on soil biota: a regional study. Soil Biology and Biochemistry 67: 271-284.

[22] Rajwar N, Singh V, Bhatt S, Bisht SS (2022) Earthworm population dynamics in three different land use systems along an altitudinal gradient (208–2609 m asl) in Kumaun Himalayas, India. Tropical Ecology 1-7.

[23] Reynolds JW, Wetzel MJ (2016) Nomenclatura Oligochaetologica – A catalogue of names, descriptions and type specimens. Editio Secunda. URL: http://wwx.inhs.illinois.edu/people/mjwetzel/nomenoligo (accessed:25 September 2016).

[24] Reynolds JW, Wetzel MJ (2023) Nomenclatura Oligochaetologica-A catalogue of names, descriptions, and type specimens of the Oligochaeta. Editio Secunda Zoo symposia 23: 098–100.

[25] Saikia A, Chutia P, Sarmah SR (2021) The diversity and distribution of indigenous earthworm species of Golaghat district of Assam, Northeast India. Asian Journal of Conservation Biology 10(2).

[26] Senthil V, Sivakami R (2018) An analysis of the biodiversity of earthworms in three locations around Tiruchirappalli, Tamil Nadu, India. Int J Curr Microbiol App Sci 7(9): 3195-3199.

[27] Sharma A, Julka JM, Ahmed S (2022) Earthworm diversity and distribution in district Mandi, Himachal Pradesh of Northwest Himalaya, India. Journal of Entomology and Zoology Studies 10(5): 127-132.

[28] Stanford D, English L (1949) Use of flame photometer in rapid soil tests of K and Ca. Agron J 4: 446-447.

[29] Stevenson IL (1959) Dehydrogenase activity in soils. Canadian J Microbiol 5: 229 235.

[30] Walkley A, Black IA (1934) An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil science 37(1): 29-38.