Research Article

Diversity and Abundance of Earthworms in Different Landuse Patterns: Relation with Soil Properties

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ABSTRACT

The earthworms are the most important soil species because of their important role in the distribution of soil nutrients. The objective of the study was to know the earthworm diversity and their abundance in different land use pattern of Punjab (India) and how their diversity related to soil physico-chemical properties. The earthworm collections were perfomed in different land use system viz. Garden, Agricultural Field, Forest, Grassland and Leaf litter sites. The physico-chemical properties and heavy metal analysis of the soil were also done by using standard protocols. The statistical anaylsis of the data was also performed by using statistical softwares. Total five species of earthworms viz. *Metaphire posthuma, Lampito mauritii, Amynthas morrisi, Metaphire houlleti* and *Octochaetona beatrix*. The abundance of earthworms was significantly ($p < 0.05$) different with order of their abundance was Garden > Grassland > Forest > Leaf litter > Agricultural field. The *M. posthuma* was reported from all the collection sites while *L. mauritii* was reported at only three collection sites. The distribution of *A. morrisi*, *M. houlleti* and *O. beatrix* were reported from only single collection sites. The physico-chemical properties of the soil samples collected from all the sampling sites were varied significantly ($p < 0.05$). Factor analysis also proved the direct relation of earthworm abundance on soil physico-chemical properties. We recommend that the farmers should be awared regarding the importance of earthworms diversity in their fields and should also be encouraged to shift their agricultural practices from conventional to non-conventional to improve the diversity of earthworms in the agricultural fields.

Key words: Abundance, Diversity indices, Earthworm, Factor analysis, Physico-chemical properties.

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INTRODUCTION

The soil is a valuable bio-resource that inhabits millions of micro and macro-organisms involved in biodegradation and soil building processes which describes the biodiversity in the soil. The soil biodiversity is vital to humans as it supports a wide range of ecosystem processes, functions and services.[1,2] The biodiversity is classified into above-ground biodiversity and below-ground biodiversity (soil biodiversity) which mutually interact with each other.[3] Among the below soil biodiversity, Earthworms are the most important soil species due to their crucial roles in the soil sustainability.[4]

Earthworms, the members of the Oligochaeta class under the phylum Annelida, are very important soil organisms and also constitute a large part of the invertebrates existing in the soil.[5] They are also regarded as environmental engineers, as they play a major role in the conservation of soil structure and composition.[6,7] They also play a major role in soil nutrient dynamics by altering the soil physical, chemical and biological properties. According to Bouche,[8] earthworms are classified into three different ecological categories i.e. epigeic, anecic and endogeic; on the basis their feeding

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habits on different food resources. Epigeic lives on the upper surface of soil without making burrows and prefers the food having high organic matter content. Anecic are mostly phytophagus and feed on the surface residue along with the soil by pulling the feed material through its vertical burrows. Endogeic earthworms are geophagus and are mostly found in the soil layer after creating the horizontal burrows by consuming the soil.

There are about more than 7000 species of earthworm widely dispersed all over the world[9] which constitute about 80% of the total soil invertebrates biomass.[10] The India is also one of the major mega biodiversity country w.r.t to earthworm diversity[11,12] and around 426 earthworm species in 10 different families 69 genra were reported from India[13-15] but the expected number of species were much higher. But the diversity of earthworms in india is usually varies with variation in climate[16] and physico-chemical properties of soil.[17] The use of conventional agricultural practices such as application of chemical fertilizers and pesticides from last three decades also causes a huge loss for the earthworm biodiversity.[4,18] While on the other hand, studies also repored that non-conventional agricultural practices favorus earthwor diversity in the soil.[19]

So, the present study was carried out to know how the earthworm diversity changed from cultivated to non-cultivated soil under different land use pattern. The main objective of the study was (a) to know the diversity and abundance of earthworms in different land use paterns; b) to find the abundance of earthworm with respect to ecological categories; c) to find the relationship of earthworm diversity and abundance as affected by the different physico-chemical properties of the soil.

MATERIALS AND METHODS

Site Study and Earthworm sampling

The five different land use pattern of District Amritsar, Punjab, India (Table 1) were used for study. Earthworms were sampled at each land use pattern by the hand-sorting method using quadrates (1 × 1 m^2 area) for each sampling site. The GPS coordinates and moisture content at each sampling sites were also recorded. Earthworms were washed in fresh water and sorted as juvenile or adult on the basis of absence or presence of clitellum respectively. The clitellated earthworms were killed with 70% ethyl alcohol and preserved in 5% formalin. The preserved samples of earthworms identified on the basis of keys of Julka.[20]

Physico-chemical Analysis

Soil was analyzed for texture, pH, electrical conductivity (EC), total dissolved salts (TDS), nitrogen (N), phosphorus (P), potassium (K), organic carbon (OC), sodium (Na), calcium (Ca), lithium (Li) and heavy metals. Soil texture was measured by using method of Bouyoucos.[21] The EC, pH and TDS were measured by using a digital meter (Eutech Instruments, PCSTestr 35 series). The Total Kjeldhal Nitrogen was measured by the method of Bremner and Mulvaney[22] by using Kjeldhal assembly. The Nelson and Sommers[23] method was used to measure OC using muffale furnance. The method John[24] was used to measure the content of Phosphorus. The content of Na, K, Ca and Li were analyzed by Systronics Flame Photometer-128. The content of heavy metals (Cr, Cu, Cd, Pb, Ni, Zn, Fe) were analyzed by Microplasma Atomic Emission Spectrophotometer-4200 series (Agilent technolohies).

Statistical Analysis

Before the statistical analysis, the data for normality and homogeneity of variances were tested by using the Shapiro-Wilk test and Anderson-darling test. A Tukey post hoc test was applied to the compare the earthworm abundance and physico-chemical properties of soil from the study sites. The diversity indices such as Shannon-Weiner diversity index;[25] species richness[26] and species evenness[27] were also calculated for each collection site. The factor analysis (FA) was used to examine the major factors in the soil which affects the diversity and abundance of earthworms by using Varimax rotation with Kaiser Normalization. The eigenvalues greater than 1 was considered as standard for extraction of the principal factors. PERMANOVA were also applied to test the relationship between soil variables and earthworm abundance by using similarity matrices by using Bray–Curtis similarity measures with 9999 random permutations. The data were represented as mean ± S.E. of triplicate values. All the statistical analysis were done with the help of SPSS (Version 21) and Past (version 4.02) software programme.

Table 1: Different land use system along with sampling site and GPS coordinates.

S. No.	Land use system	Sampling Site	GPS Coordinates
1	Garden	Guru Nanak Dev University Amritsar	N 31° 63’ 18.7” E 74° 82’ 35.5”
2	Grassland	Village Lopoke	N 31° 71’ 95.1” E 74° 62’ 34.6”
3	Agricultural field	Village Neshta	N 31° 58’ 55.7” E 74° 60’ 79.2”
4	Forest	Village Kohali	N 31° 75’ 56.6” E 74° 68’ 33.4”
5	Leaf litter	Ajnala	N 31° 84’ 38.9” E 74° 72’ 79.8”

RESULTS

Earthworm community structure and their diversity indices

Total five earthworm species i.e. *Amynthas morrisi, Lampito mauritii, Metaphire houlleti, Metaphire posthuma* and *Octochaetona beatrix* belongs to two different families were reported from all collection sites (Table 2). The *A. morrisi, L. mauritii, M. houlleti* and *M. posthuma* belongs to family Megascolecidae while *O. beatrix* belongs to family Octochaetidae. The garden has high earthworm diversity with four earthworm species, followed by grassland, forest and leaf litter sites having two earthworm species at each site. While on the other hand, agricultural field has only single earthworm species i.e. *M. posthuma.* The *M. posthuma* was reported from all the collection sites while *L. mauritii* was reported at only three collection sites i.e garden, grassland and leaf litter sites. The distribution of *A. morrisi, M. houlleti* and *O. beatrix* were reported from only single collection sites. On comparing earthworm individiuals from the five different land use, the abundance of earthworms was significantly ($p < 0.05$) different in all the collection sites with high and lowest abundance of earthworms were reported from garden and agriculture field respectively (Figure 1A). On the other hand, the endogeic earthworm showed their high abundance at all the sampling sites while anecic species were reported only from garden, grassland and leaf litter sampling sites (Figure 1B). The both agicultural field and forest have only endogeic species but the abundance of endogeic species was less in agricultural fields as compared to forest. Among the total collected earthworm individuals from all the collection sites, the occurrence rate of earthworm individuals at the garden, grassland, forest and leaf litter site has 27.36%, 22.89%, 20.89% and 16.92% respectively while agricultural field has lowest earthworm individuals (11.94%) (Figure 2A). On the other hand, ocuurence rate of *M. posthuma, L. mauritii, A. morrisi, O. beatrix* and *M. houlleti* was 67.66%, 19.41%, 6.97%, 3.98% and 1.98% respectively

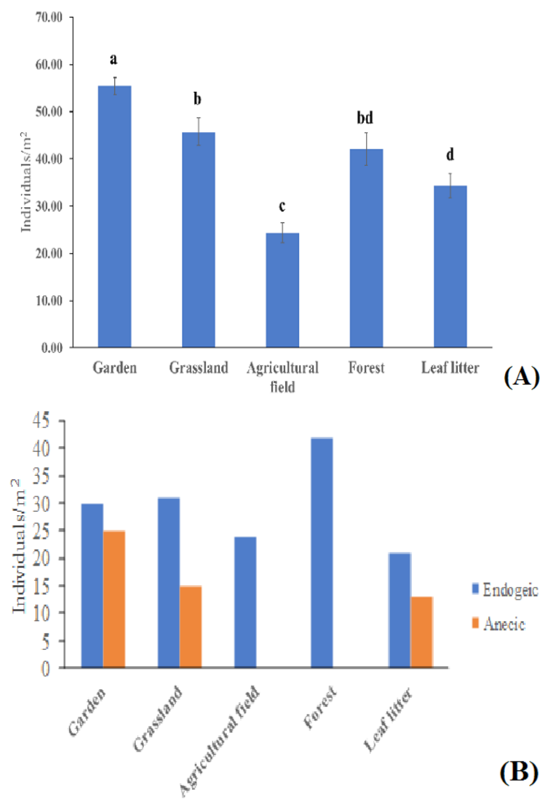

Figure 1: Total abundance (A) and ecological category wise abundance (B) of earthworm species at all sampling sites.

Table 2: Distribution of earthworms species along with their diversity indices in different land use patterns.

S. No.	Land Use Systems	Family	Ecological category	Garden	Grass land	Agricultural field	Forest	Leaf litter
1.	*Metaphire posthuma*	Megascolecidae	Endogeic	+	+	+	+	+
2.	*Lampito mauritii*	Megascolecidae	Anecic	+	+	-	-	+
3.	*Amynthas morrisi*	Megascolecidae	Anecic	+	-	-	-	-
4.	*Metaphire houlleti*	Megascolecidae	Endogeic	+	-	-	-	-
5.	*Octochaetona beatrix*	Octochaetidae	Endogeic	-	-	-	+	-
6.	Shannon-Weiner diversity index	-	-	1.05	0.62	0	0.64	0.65
7.	Species Evenness	-	-	0.96	0.92	1	0.95	0.96
8.	Species richness	-	-	0.41	0.21	0	0.2	0.22

+= Present; - = Absent

at all the collection sites (Figure 2B). Thus the order of distribution of earthworms was Garden > Grassland > Forest > Leaf litter > Agricultural field.

The Shannon-Weiner diversity index, species evenenss and species richness were ranged from 0 to 1.05, 0.92 to 1 and 0 to 0.41 respectively (Table 2). The high value of Shannon-Weiner diversity index and species richness were reported at garden which was due to presence of high earthworm species while Shannon-Weiner diversity index and species richness at agricultural field was 0 which was due to single species of earthworm.

Relationship of soil properties with distribution of earthworm

The physico-chemical properties of the soil samples collected from all the sampling sites were varied significantly (Table 3). The soil texture of garden was sandy clay loam while grassland, leaf litter has loam and agricultural field, forest has sandy loam. The pH content of soil from all sampling sites ranged from slightly acidic to slightly alkaline. On the other hand, the EC and TDS content were statistically ($p < 0.05$) different with highest and lowest content at agricultural field and garden respectively. The N, P and K content were also varied significantly with highest content at agricultural field. The Ca and Li content were also found to be significantly ($p < 0.05$) different. The OC content was differ significanlty at all the sampling sites with high content at garden site. On the other hand, high moisture content was observed in agricultural field. The heavy metals content (Cr, Cu, Cd, Pb, Ni, Zn and Fe) of soil samples also varied significantly (Table 3). The content of Cr, Cu, Cd, Pb, Ni, Zn and Fe were found to be significantly different ($p < 0.05$) with the highest content was found at agricultural sampling site while the lowest content of the same were reported at garden site. This high content of heavy metals in agricultural fields might be due to application of chemical fertilizers. The all physico-chemical variables in the soil of agricultural field was different from the other sampling sites.

Table 3: Physico-chemical analysis of soil of different land use systems.

S. No.	Soil variables	Garden	Grassland	Agricultural field	Forest	Leaf litter
1.	Soil Texture	Sandy Clay Loam (Clay=21%; Silt=26%; Sand=53%)	Loam (Clay=13%; Silt=38%; Sand=49%)	Sandy Loam (Clay=15%; Silt=22%; Sand=63%)	Sandy Loam (Clay=7%; Silt=24%; Sand=69%)	Loam (Clay=15%; Silt=36%; Sand=49%)
2.	pH	6.91±0.06 a	8.41±0.24 b	5.73±0.19 c	8.81±0.42 b	8.77±0.51 b
3.	EC (µS/cm)	43.24±2.26 a	92.65±0.05 b	214.32±0.95 c	69.65±0.05 d	82.35±1.75 e
4.	TDS (mg/L)	65.28±1.5 a	37.17±0.18 b	151.47±1.19 c	42.2±0.29 b	58.25±1.25 d
5.	N (g/Kg)	0.17±0.01 a	0.21±0.03 b	0.39±0.01 c	0.08±0.02d	0.03±0.01d
6.	P (g/Kg)	0.31±0.01 a	0.32±0.03 a	4.71±0.03 b	0.62±0.07 c	0.24±0.03 a
7.	Na (g/Kg)	1.81±0.05 a	0.84±0.11 b	5.53±0.9 c	0.67±0.05 bd	0.58±0.01 d
8.	K (g/Kg)	3.43±0.15 a	1.47±0.06 b	4.01±0.08 c	1.59±0.39 b	1.81±0.18 b
9.	Li (g/Kg)	0.54±0.04 a	1.31±0.04 b	2.39±0.08 c	1.39±0.02 b	1.04±0.01 d
10.	Ca (g/Kg)	20.66±1.99 a	18.66±0.05 b	8.36±0.21 c	9.24±0.29 c	1.12±0.05 d
11.	OC (%)	4.99±0.25 a	4.41±0.36 b	1.89±0.25 c	3.61±0.35 d	3.83±0.25 d
12.	Moisture (%)	59.18±0.21 a	42.5±0.34 b	80.5±0.52 c	48.23±0.54 d	67.14±0.89 e
13.	Cr (ppm)	19.84±0.05 a	24.96±0.52 b	28.09±0.34 c	24.45±1.51 d	25.67±0.35 d
14.	Cu (ppm)	26.36±0.25 a	31.44±0.25 b	41.46±0.31 c	31.77±0.45 c	30.64±0.41 c
15.	Cd (ppm)	0.04±0.01 a	0.06±0.01 b	0.12±0.01 c	0.05±0.01 b	0.05±0.02 b
16.	Pb (ppm)	0.29±0.05 a	0.28±0.05 a	2.01±0.3 b	0.56±0.35 c	0.02±0.01 d
17.	Ni (ppm)	1.95±0.01 a	4.71±0.28 b	8.76±0.35 c	2.12±0.28 a	<BDL*
18.	Zn (ppm)	9.56±0.15 a	13.66±0.16 b	41.12±0.38 c	18.86±0.19 d	9.64±0.17 a
19.	Fe (ppm)	323.71±0.85 a	338.24±2.81 b	534.78±0.65 c	280.71±0.95 d	297.41±1.25 e

The tukey test at 5% significance level was applied. The mean of each variable (row wise) followed by the different letters in each row are statistically different from each other at 5% level of significance.
* BDL= Below detectable limit

In the present study, the factor analysis was used to find the correlation matrix of different variables of soil followed by varimax rotation. The factor analysis was applied to 21 different physico-chemical variables which resulted in four major factors i.e. F_1, F_2, F_3 and F_4 with a total variance of 45.18%, 24.48%, 13.79% and 9.01% respectively. The different factors, their loading values, respective eigenvalues and total variance (%) for the each factor are given in Table 4. The method of Liu *et al.*[28] was used to classify the factor loadings as strong, moderate and weak having absolute loading values >0.75, 0.75–0.50 and 0.50–0.30 respectively. The F_1 contibutes 45.18% of the total variance with strong negative loading of pH and Li while strong positive laoding of EC and TDS. The F_2 contributes 24.48% of the total variance with strong positive loading of clay, silt, OC and moisture while moderate negative loading of sand. The F_3 contibutes 13.79% of the total variance with strong positive loading of K, moderate loading of N, Na, Ca while a strong negative loading of P. The F_4 contributes 9.01% of the total variance with strong negative loading of Cr, Cu, Cd, Pb, Ni, Zn and Fe. The loading plot for the factor loading of FA is given in Figure 3. The loading plot clearly showed that the laoding values of agriculture field is very much different from the other sampling sites. The earthworm abundance and soil properties also have significant direct relation (PERMANOVA, F= 18.2, $p < 0.05$) and soil properties also favours the earthworm abundance at a particular site and vice versa.

Table 4: The laoding values for each variables in four different factors along with variance in each factor.

S. No.	Soil Factors	Components			
		F_1	F_2	F_3	F_4
1.	pH	-0.936	0.200	0.087	0.576
2.	EC	0.982	-0.029	-0.111	-0.130
3.	TDS	0.796	0.012	-0.442	-0.403
4.	N	-0.246	0.587	0.711	-0.156
5.	Clay	-0.066	0.836	0.140	-0.956
6.	Silt	-0.231	0.810	-0.503	-0.012
7.	Sand	0.235	-0.623	0.330	0.625
8.	P	-0.237	0.103	-0.942	-0.142
9.	Na	-0.183	0.302	0.638	0.431
10.	K	0.162	0.017	0.954	0.212
11.	Li	-0.862	0.376	-0.107	-0.295
12.	Ca	0.259	0.651	0.696	0.073
13.	OC	0.139	0.823	0.594	-0.019
14.	Moisture	-0.372	0.756	-0.508	-0.535
15.	Cr	0.180	0.128	0.900	-0.901
16.	Cu	0.129	0.243	0.457	-0.831
17.	Cd	-0.050	0.115	-0.027	-0.841
18.	Pb	-0.088	0.238	-0.386	-0.886
19.	Ni	-0.057	0.443	-0.013	-0.887
20.	Zn	0.027	0.145	-0.339	-0.919
21.	Fe	-0.343	0.180	-0.183	-0.895
22.	Eigenvalue	9.488	5.141	2.897	1.893
23.	Variance (%)	45.182	24.482	13.797	9.016

DISCUSSION

Total five earthworm species i.e. *Amynthas morrisi, Lampito mauritii, Metaphire houlleti, Metaphire posthuma* and *Octochaetona beatrix* belonging to two ecological categories i.e endogeic and anecic were reported in the present study from five different landuse patterns. The high and low abundance of earthworms was observed at garden site and agricultural site respectively. On the

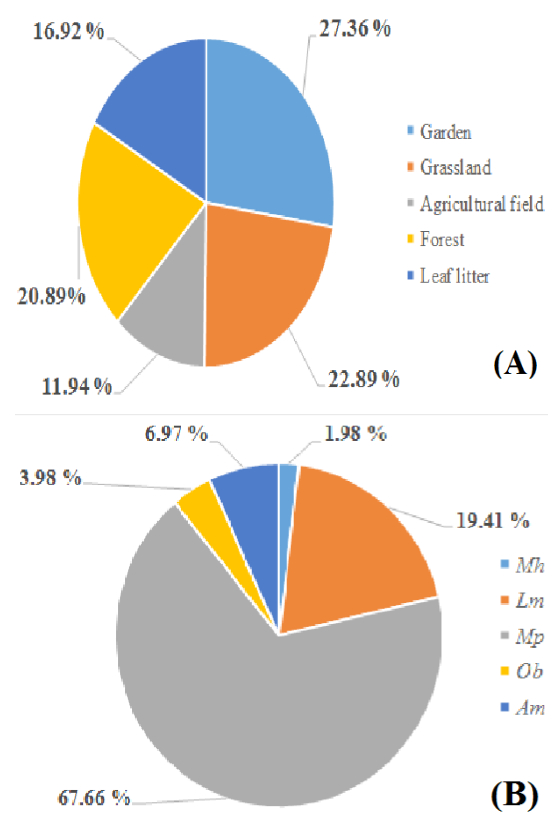

Figure 2: The percentage of (A) earthworm individuals at each sampling site; (B) earthworm individuals species wise at different land use pattern.
(Mh: Metaphire houlleti; Lm: Lampito mauritii; Mp: Metaphire posthuma; Ob: Octochaetona beatrix; Am: Amynthas morrisi)

basis of ecological category, the endogeic earthworms were reported at all the sampling sites while anecic earthworms were reported at garden, grassland and leaf litter. The less abundance of earthworms in agricultural field might be due to use of pesticides and chemical fertilizers or agricultural management practices which disturb the epigeic and anecic earthworm communities within the soil.[17,29] Despite three endogeic earthworm species were reported in the present study but agricultural field has abundance of only *M. posthuma*, while *M. houlleti* and *O. beatrix* were reported from garden and forest sampling sites respectively. Thus, *M. posthuma* was found to be the most stable and adapted earthworm species in all the agro-ecosystem which supported with the findings of Singh *et al.*[17] Jouquet *et al.*[30] also stated that the most resistant earthworm found in disturbed soil were endogeic in nature. *Metaphire posthuma* deep burrowing nature protects it from mechanical disturbance caused during agricultural practices. Our results are corroborated by the conclusion of Ernst and Emmerling,[31] who concluded that cultivated fields contain less anecic earthworms but more endogeic earthworm abundance. The ploughing disturbs the anecic species as it destroys the burrows formed by the earthworm, which may be the explanation for the absence of anecic species in agricultural fields.[17] While on the other hand, garden has minimum ploughing with application of cattle dung and organic manure like vermicompost as compared to agricultural fields which favours earthworm diversity. This input of organic manures improves soil quality which promotes earthworm presence within the soil.[4,32] Bacher *et al.*[33] and Singh *et al.*[34] also reported that the use of cattle dung in the fields increase the earthworm species and their abundance upto four times which directly affected the earthworm diversity. The forest, grassland and leaf litter sites have also without use of chemical pesticides but these sites were surrounded by agricultural fields having paddy plantation which requires a huge amount of chemical pesticides. The less abundance of earthworms at forest, grassland and leaf litter sites as compared to garden sites might be due to impact of agricultural practices on their surrounding sites.

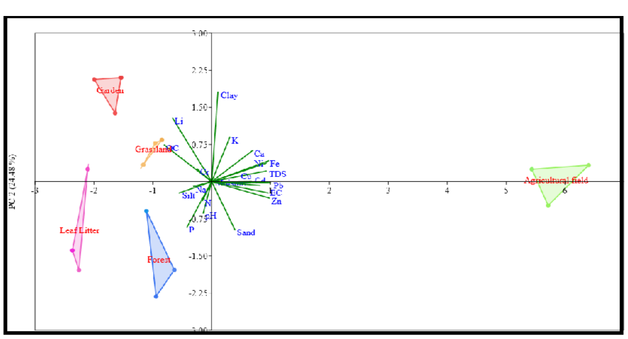

Figure 3: Loading plots for factor analysis showing different abiotic factors in five sampling sites.

Factor analysis analysed total four factors i.e F_1, F_2, F_3 and F_4 with a total variance of 45.18%, 24.48%, 13.79% and 9.01% respectively in each factor. The factor F_1 causes 45.18% of the total variance which was resulted due to pH, EC, TDS and Li. The EC, TDS and Li maintain the salt concentration while pH maintains the acidity or alkalinity in the soil. This pH and salt concentration at a particular site is an important factor for earthworm distribution as earthworms can survive only in moderate salt concentration with neutral pH.[35] McCallum *et al.*[36] reported that earthworms are very sensitive for pH and their abundance decreases as the pH in the soil shifts to acidic range or basic range. But most of the studies reported high abundance of earthworms near neutral pH i.e. 7.[37] In our study low salt concentration with neutral pH was observed at garden sites which showed high earthworm diversity. Thus factor F_1 explain pH with level of salt concentration in the soil. The factor F_2 causes 24.48% of the total variance which was due to clay, silt, sand, OC and moisture which are the critical factors for the earthworm survival. The clay, silt and sand determines the texture of soil and variation in texture of soil also affect earthworm abundance.[17,38] Siddiqui[39] also stated that soil bulk density and soil texture directly influence the growth and development of the earthworms. While on the other hand, OC is act as a kind of food for the earthworm and various studies also reported that soil having high OC content usually have higher earthworm abundance[34,40] which is clearly observed in our findings also. The moisture is also an significant factors for earthworm survival as earthworm usually respire through their skin due to cutaneous respiration mode and thus they always prefer moist soil.[41] Thus F_2 represents the soil texture and growth factor for the earthworm abundance. The factor F_3 causes 13.79% of the total variance which was due to K, N, Na, Ca and P which are the edaphic factors for the earthworm abundance.[17] The factor F_4 causes 9.01% of the total variance which was due to heavy metals (Cr, Cu, Cd, Pb, Ni, Zn, and Fe). These heavy metals have very toxic affect on the earthworm. The Zn, Pb, and Cd in the soil directly affect earthworm biomass and species richness.[42] But the affects of the heavy metal in the soil is also dependent on their concentration i.e. earthworms can survive in less concentration of heavy metals.[43] The survival of earthworms in less heavy metals concentration might be due to their capability to bioaccumulate and storage of heavy metals in their yellow tissues.[44,45] But as the concentration of heavy metals in the soil increases, more bioaccumlation of heavy metals done by the earthworm which causes toxicity and hence mortality in the earthworm.[46] Hence the factor F_4 represents heavy metals affect on earthworm abundance.

CONCLUSION

The present study has provided information regarding distribution of earthworm in different land use system and the effects of soil variables on the same. In this study, 5 species of earthworm have been reported i.e. *Metaphire posthuma, Lampito mauritii, Amynthas morrisi, Metaphire houlleti* and *Octochaetona beatrix*. The gardens site has high earthworm abundance with 4 earthworm species while agricutltural field has lowest earthworm abundance (only one earthworm species). Factor analysis has also shown that the soil variables have significant positive effects on earthworm diversity and abundance. The vermicast egested by the earthworms have high nutritive content which is helpful for the soil and plants. The farmers should also be awared regarding the importance of earthworms in crop improvement and shift their agricultural practices from conventional to non-conventional to improve the diversity of earthworms in the agricultural fields. This will not only reduces the cost of farmers but crop produced is also of good quality which is a good step for sustainable agriculture.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

ABBREVIATIONS

Am*:** *Amynthas morrisi*; **Ca:** Calcium; **Cr:** Chromium; **Cu:** Copper; **Cd:** Cadmium; **EC:** Electrical conductivity; **FA:** Factor Analysis; **Fe:** Iron; **g/Kg:** gram per kilogram; **GPS:** Global positioning system; **K:** Potassium; ***Lm*:** *Lampito mauritii*; **Li:** Lithium; **mg/L:** milligram per liter; ***Mp: *Metaphire posthuma*; ***Mh*:** *Metaphire houlleti*; **Na:** Sodium; **N:** Nitrogen; **Ob:** *Octochaetona beatrix*; **OC:** Organic carbon; **Pb:** Lead; **P:** Phosphorus; **PERMANOVA:** Permutational multivariate analysis of variance; **ppm:** parts per millions; **S.E:** Standard error; **SPSS:** Statistical Package for the Social Sciences; **TDS:** Total dissolved solids; **Zn:** Zinc; **µS/cm:** micro siemens per centimeter.

SUMMARY

The diversity and abundance of earthworm species varies in different land use patterns of the soil. The less disturb soil has higher earthworm diversity and abundance as compared to disturbed soil system. Apart from land use pattern, the earthworm communities were also affected by physico-chemical properties of the soil.

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