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Research Article

THE STUDY OF EARTHWORM DISTRIBUTION IN THREE STUDY SITES OF PHEK AND KOHIMA DISTRICT, NAGALAND

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ABSTRACT

This study aims to examine earthworm distribution and its correlation with soil physicochemical properties across different habitats. Sampling was conducted monthly for six months (September 15, 2023 – February 17, 2024) in Zhavame (Phek) and Puliebadze (Kohima), covering forest, vegetable garden, and grassland sites. The collection of earthworms was done by hand sorting and preserved in 4% formalin for further species identification. Analyzation of soil parameters like organic carbon (OC), phosphorous (P), potassium (K), soil moisture, pH, and temperature were done. Ten earthworm species from four families (Megascolecidae, Moniligastridae, Octochaetidae, Lumbricidae) were recorded. Earthworm population was higher in Zhavame (125) as compared to Puliebadze (103). Relationship between earthworm abundance and soil parameters were indicated/showed using ANOVA. Earthworm population showed a strong positive correlation with OC and P from all the sites, while in Puliebadze, potassium and soil moisture showed no significance. Soil pH has a negative correlation with earthworm abundance in forest sites while other parameter has a positive correlation. These findings showed the importance of OC and P in earthworm distribution, with variation across habitats.

Keywords: Earthworm, Population, Soil, Correlation, Zhavame, Puliebadze.

INTRODUCTION

Earthworms are hermaphroditic terrestrial oligochaetes belonging to Phylum Annelida, Class Oligochaeta. They thrive well in moist soil rich in organic matter (Edward & Bohlen, 1996). As compared to other soil organisms, earthworm consume more organic matter, thereby influencing soil structure, fertility, and nutrient cycling (Ismail, 2005). Soil physicochemical properties, including moisture, nitrogen (N), phosphorus (P), potassium (K), organic matter, and pH were directly effected by their feeding activities, casting and burrowing (Singh, 1997). Earthworms were considered a vital component of soil biota due to their role in soil formation and maintenance (Curry, 2004). Alteration in soil properties impact earthworm populations and their ecological functions (Singh *et al*, 2016).

Earthworms are classified into three ecological categories Epigeic, Anecic, and Endogeic (Bouché, 1977: Kumar *et al*, 2018). Global earthworm distribution, despite their significance remains poorly documented (Edwards & Lofty, 1972). In tropical, subtropical, and temperate regions, earthworms account for over 80% of total soil invertebrate biomass (Nainawat & Nagendra, 2001). Recognized as “ecosystem engineers,” earthworms enhance soil quality, aeration, and fertility through burrowing and casting (Baskin, 2005). Their activities facilitate nutrient mineralization, decomposition, and organic matter mixing (Brown *et al*., 2004), improving soil structure (Ramsay & Hill, 1978). Globally, approximately 3,627 earthworm species have been recorded (Kooch & Jalilvand, 2008). In Northeast India, 125 species under 10 families and 28 genera are documented, with Meghalaya reporting the highest diversity (54 species, 7 families, 15 genera) and Nagaland the least (9 species, 3 families, 4 genera) (Chakraborty *et al*., 2023). This study aims to assess earthworm distribution and its correlation with soil physicochemical properties in Zhavame (Phek) and Puliebadze (Kohima) across forest, vegetable garden, and grassland habitats.

MATERIALS AND METHOD

The study was conducted at Zhavame village (Phek district) and Pulie Badze (Kohima district) in Nagaland, India, to

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investigate earthworm diversity across three habitats: forest, vegetable Garden, and Grassland Zhavame village is situated at an altitude of 1,891 m (25°30′53″ N, 94°10′18″E) while Puliebadze is located at 2,300m (25°38′53″N, 94°4′ 21′ E) with an area of 9.23 sq. km. Sampling was carried out monthly for six months, with three random quadrates (25×25×30cm) dug from a 10×10m plot at each site. Adult earthworms collected through hand sorting, cleansed with water, narcotized in 70% ethyl alcohol, and preserved in 4% formalin for identification using a monocular microscope and taxonomic keys. Materials used included a spade, digging bar, soil thermometer, plastic containers, black polyethene bag, 4mm plastic sieve, and an Olympus Tough TG-6 camera.

Data Analysis

For data analysis, Microsoft Excel 2007 was used for computing the data for calculations, graphs and charts. Statistical analysis like correlation and ANOVA was performed.

Table 1. Pearson correlation coefficient value(r) interpretation reference table.

Correlation coefficient value (r)	Strength of correlation (Interpretation)
0 - 0.1	Markedly low
0.1 – 0.3	Weak
0.4 - 0.6	Moderate
0.7 - 1	High

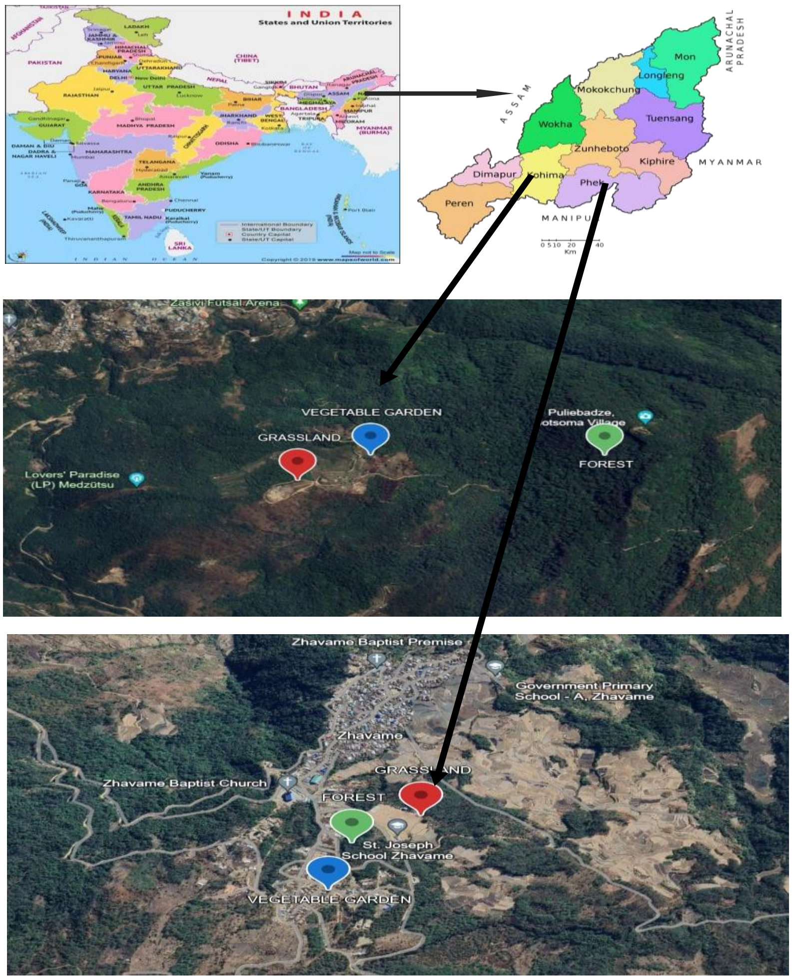

Figure 1. Map of India, Nagaland, and satellite view of Puliebadze (Kohima) and Zhavame village (Phek).

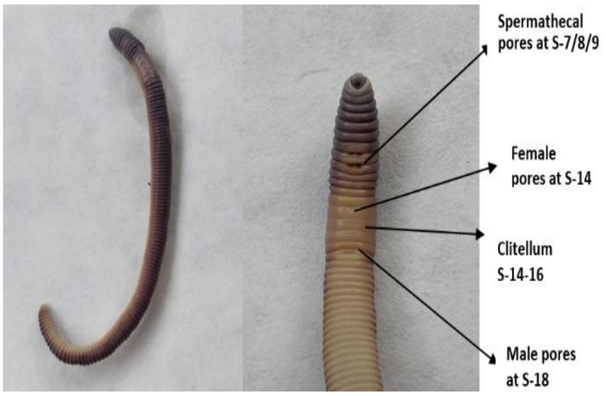

Plate 1. *Perionyx excavatus* (dorsal and ventral view).

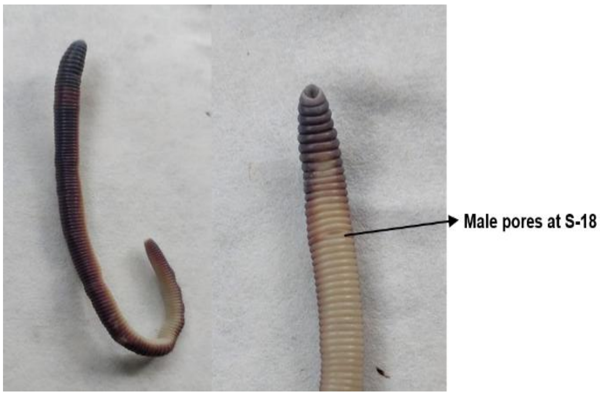

Plate 2. Perionyx sp. 1 (dorsal and ventral view).

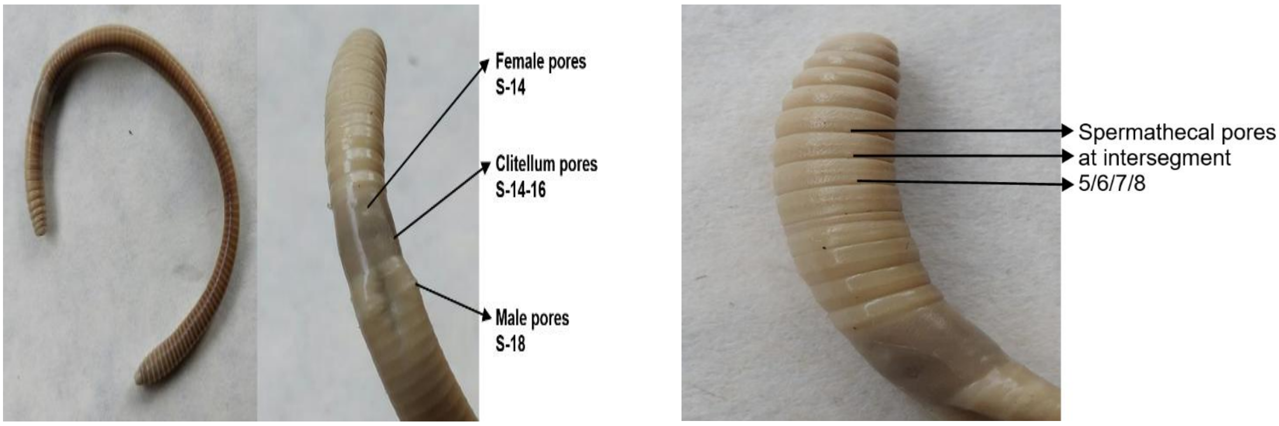

Plate 3. *Amynthas gracilis* (Dorsal, ventral and side view).

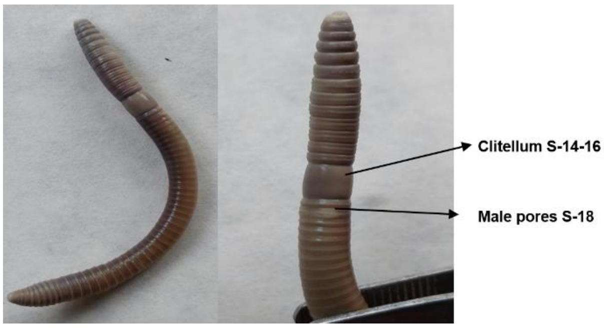

Plate 4. *Metaphire* sp. (Dorsal and ventral view).

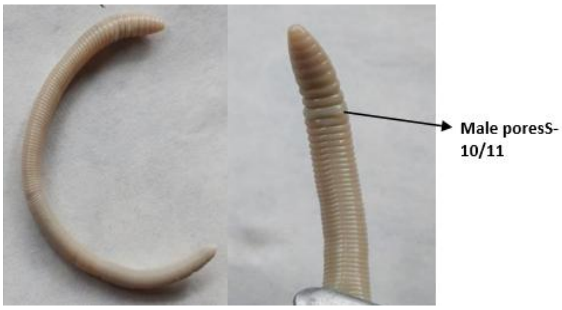

Plate 5. Drawida sp. (Dorsal and Ventral view).

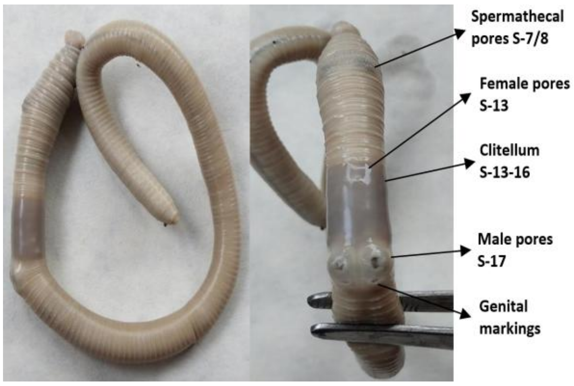

Plate 6. *Eutyphoeus* sp. 1 (Dorsal and ventral view).

Plate 7. *Eutyphoeus* sp. 2 (Dorsal and ventral view).

Plate 8. *Eutyphoeus* sp. 3 (Dorsal and ventral view).

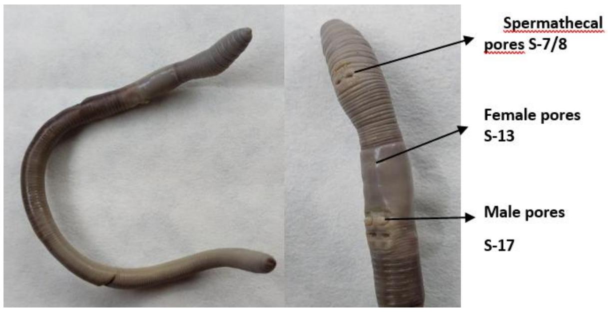

Plate 9. *Eutophoeus* sp. 4 (Dorsal and ventral view).

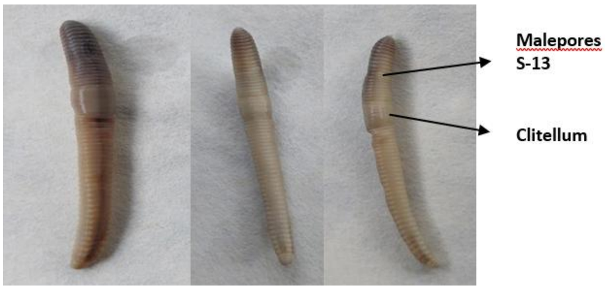

Plate 10. *Eiseniella* sp. (Dorsal and ventral view).

A total of 390 earthworms was recorded in various study habitat with 162 juveniles and 228 matured earthworms. In the present study 10 species of earthworm belonging to four families and six genera have been identified viz, *Perionyx excavatus* (Perrier, 1872), *Perionyx* sp.1 (Perrier,1872), *Amynthas gracilis* (Kinberg, 1867), *Metaphire* sp. (Sims & Easton 1972), *Drawida sp.* (Michaelsen,1900), *Eutyphoeus* sp.1 (Michaelson,1900), *Eutyphoeus* sp.2 (Michaelson,1900), *Eutyphoeus* sp.3 (Michaelson,1900), *Eutyphoeus* sp.4 (Michaelson,1900) *and Eiseniella* sp. (Savigny, 1826). Out of these, four species belong to family Megascolecidae, another four species belong to family Octochaetidae, one species each from family Moniligastridae and Lumbricidae respectively were recorded (Table 2). The earthworm fauna was collected from six sampling sites, three from Zhavame village and three from Puliebadze and its vicinity of similar habitat condition viz, Forest, Vegetable Garden and Grassland.

Table 2. The earthworms identified includes the following.

FAMILY 1: MEGASCOLECIDAE		
Species	**Ecological habitat**	**Diagnosis**
Perionyx excavates (Perrier,1872) (Plate-1)	It is an epigeic earthworm found mostly on the surface on moist habitats. This species was found in all the three sampling sites in both Zhavame and Puliebadze.	They are highly pigmented active worms, usually small to medium in size, body length 8.2cm, spermathecal pores paired at intersegment 7/8/9, single female pores at middle of 14 segment, clitellum in 13-14 segments, male pores in 18 segment, genital markings absent, prostomium epilobic.
Perionyx sp.1 (Perrier, 1872) (Plate-2)	The genus is an epigeic earthworm found mostly on moist habitats. This species was found in all the sampling sites Zhavame and in Forest and Vegetable Garden Puliebadze.	They are highly pigmented on the dorsal side and lighter on the ventral side, prostomium epilobic, body length 6.5 cm, male pores on 18^{th} segment.
Amynthas gracilis (Kinberg, 1867) (Plate-3)	It is an epigeic earthworm found in moist habitats. This was found in all the sampling sites in Puliebadze and in Forest and Grassland in Zhavame.	Body brownish in colour, body length 9.2 cm, setae present, spermathecal pores at intersegment 5/6-7/8, clitellum in 14-16 segments, female pore single at middle of 14 male pores paired at 18 segment, prostomium epilobic.
Metaphire sp. (Sims & Easton 1972) (Plate-4)	It is anepigeic earthworm. This was found in all the sampling sites in Zhavame and occurred only in Vegetable Garden in Puliebadze.	Body length 10cm, setae present, annular clitellum in 14-16 segments, female pore single in 14 segment, male pores (combined with prostatic pores paired) on18 segment, prostomium epilobic.
FAMILY 2: MONILIGASTRIDAE		
Drawida sp. (Michaelsen,1900) (Plate -5)	The genus is an anecic type of earthworm. This was found in all the sampling sites in Puliebadze and was found only in Grassland in Zhavame.	They are unpigmented, body length 9cm, spermathecal pores large present at intersegment7/8/, male pores paired at intersegment 10/11.
FAMILY 3: OCTOCHAETIDAE		
Eutyphoeus sp.1 (Michaelson,1900) (Plate-6)	The genus is anendogeic type of earthworm. This was found in all the sampling sites in Zhavame and in Forest and Vegetable Garden in Puliebadze.	Body is unpigmented, body length 13.2cm, spermathecal pores present at intersegment 7/8, clitellum covers 13-16 segments, female pores paired at segment 13, male pores paired in segment 17, genital markings present in pair at segment 18.
Eutyphoeus sp.2 (Michaelson,1900) (Plate-7)	The genus is anendogeic type of earthworm. This was found in Forest and Vegetable Garden but absent in Grassland in both Zhavame and Puliebadze.	Body is colourless, body length 15cm, spermathecal pores present at intersegment 7/8, clitellum covers 13-16 segments, female pores paired at segment 13, male pores paired in segment 17, genital markings absent.

*Eutyphoeus*sp.3 (Michaelson,1900) (Plate-8)	The genus is an endogeic type of earthworm. This was found in all the sampling sites in Puliebadze.	Body is greyish on the posterior part, body length 15cm, spermathecal pores present at intersegment 7/8, clitellum covers 13-16 segments, female pores paired at segment 13, male pores paired in segment 17, genital markings present on segment 17 (paired) and 18 (single), 16 (paired) and 15 (single).
*Eutyphoeus*sp.4 (Michaelson,1900) (Plate-9)	The genus is an endogeic type of earthworm. This was found only in Forest in Zhavame.	Body length 12.9cm, body darkly pigmented, spermathecal pores present at intersegment 7/8, clitellum covers from 13-16 segments, female pores paired at 13 segment, male pores paired at 17 segment, genital markings present onsegment17(paired) and 18 and 19 (paired).
FAMILY 4: LUMBRICIDAE		
Eiseniella sp. (Savigny, 1826) (Plate -10)	Body length 4cm, male pores paired at segment 13, clitellum saddle-shaped.	Body length 4cm, male pores paired at segment 13, clitellum saddle-shaped.

Table 3. Distribution of earthworms in three different sites (Zhavame).

Sl. No	Name of the Species	Site-I (Forest)	Site-II (Vegetable Garden)	Site-III (Grassland)
1.	*Perionyx excavatus*	+	+	+
2.	*Perionyx* sp.1	+	+	+
3.	*Amynthas gracilis*	+	-	+
4.	*Metaphire* sp.	+	+	+
5.	*Drawida* sp.	-	-	+
6.	*Eutyphoeus* sp.1	+	+	+
7.	*Eutyphoeus* sp.2	+	+	-
8.	*Eutyphoeus* sp.3	-	-	-
9.	*Eutyphoeus* sp.4	+	-	-
10.	*Eiseniella* sp.	-	+	+

Table 4. Distribution of earthworms in three different sites (Puliebadze).

Sl. No.	Name of the Species	Site-I (Forest)	Site-II (Vegetable Garden)	Site-III (Grassland)
1.	*Perionyx excavatus*	+	+	+
2.	*Perionyx* sp.1	+	+	-
3.	*Amynthas gracilis*	+	+	+
4.	*Metaphire* sp.	-	+	-
5.	*Drawida* sp.	+	+	+
6.	*Eutyphoeus* sp. 1	+	+	-
7.	*Eutyphoeus* sp. 2	+	+	-
8.	*Eutyphoeus* sp. 3	+	+	+
9.	*Eutyphoeus* sp. 4	-	-	-
10.	*Eiseniella* sp.	-	-	-

Table 5. ANOVA (Analysis of variance) between earthworm population and physico-chemical parameters.

Study Sites	Physicochemical Parameters	ANOVA (P value) Site I	Site II	Site III
Phek (Zhavame)	Air temperature	0.023*	0.025*	0.012**
	Soil temperature	0.415	0.466	0.168
	Soil moisture	0.001**	0.009**	0.0008**
	pH	0.258	0.008**	0.565
	OC	0.002**	0.0002**	0.003**
	P	0.008**	0.006**	0.014**
	K	0.0007**	0.0001**	0.0002**
Kohima (Puliebadze)	Air temperature	0.066	0.045*	1.46
	Soil temperature	0.452	0.689	0.0002**
	Soil moisture	1.74	8.67	1.01
	pH	0.249	0.003**	0.401
	OC	0.001**	0.002**	0.0004**
	P	0.003**	0.003**	0.004**
	K	5.74	6.5	1.52

Table 6. Atmospheric parameters.

Months	Phek			Zhavame		
	Avg. Mean Temp.(°C)	Avg. R/H%	Rainfall (mm)	Avg. Mean Temp. (˚C)	Avg. R/H%	Rainfall (mm)
SEPT/23	23.8	83.2	139.6	17.3	80.6	207.1
OCT/23	20.7	83.4	56.4	14	82.3	36.6
NOV/23	16.1	83.9	61	10	75.9	51.4
DEC/23	12.7	84.7	26.2	6.6	72.7	49.6
JAN/24	10.9	77.5	0	10.9	72	0
FEB/24	13.2	75.7	35	11.6	75.5	48.4

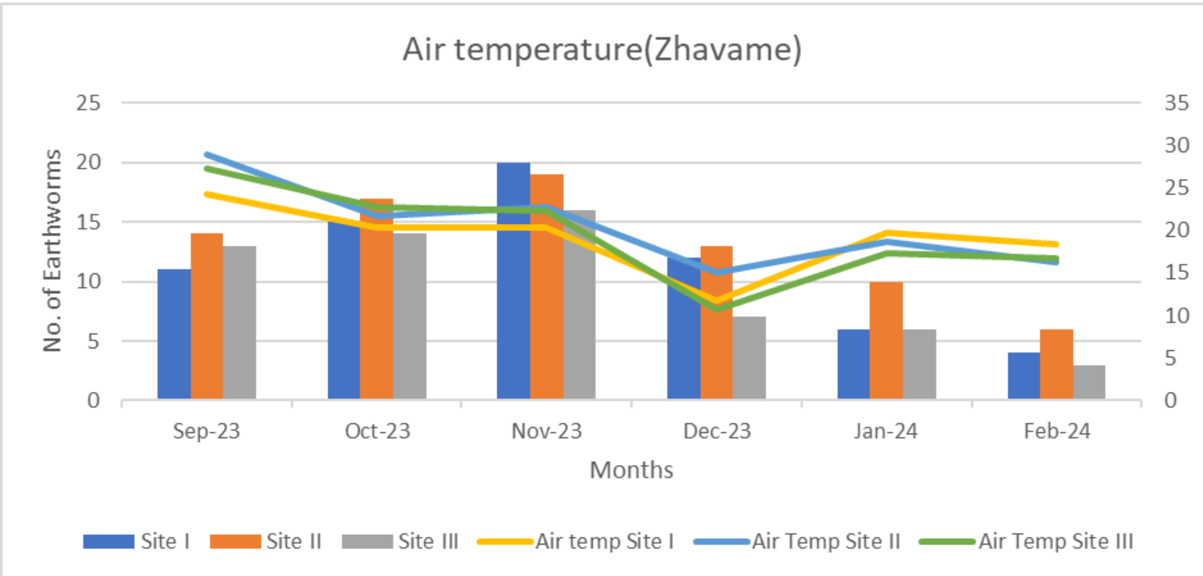

Figure 2.1. Earthworm population in relation to air temperature in three study sites under Zhavame.

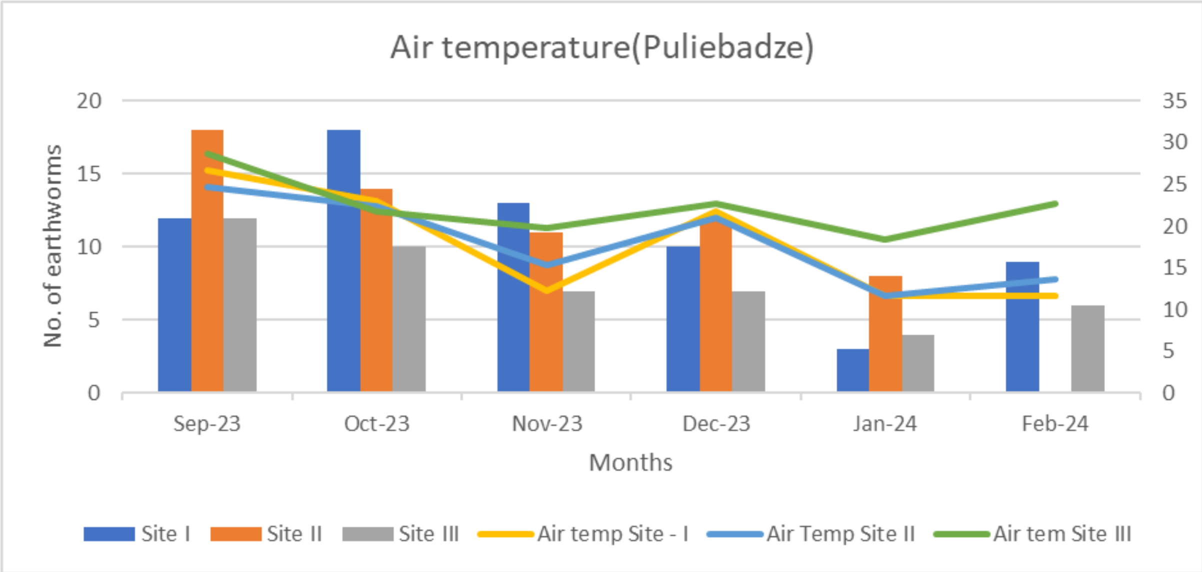

Figure 2.2. Earthworm population in relation to air temperature in three study sites under Puliebadze.

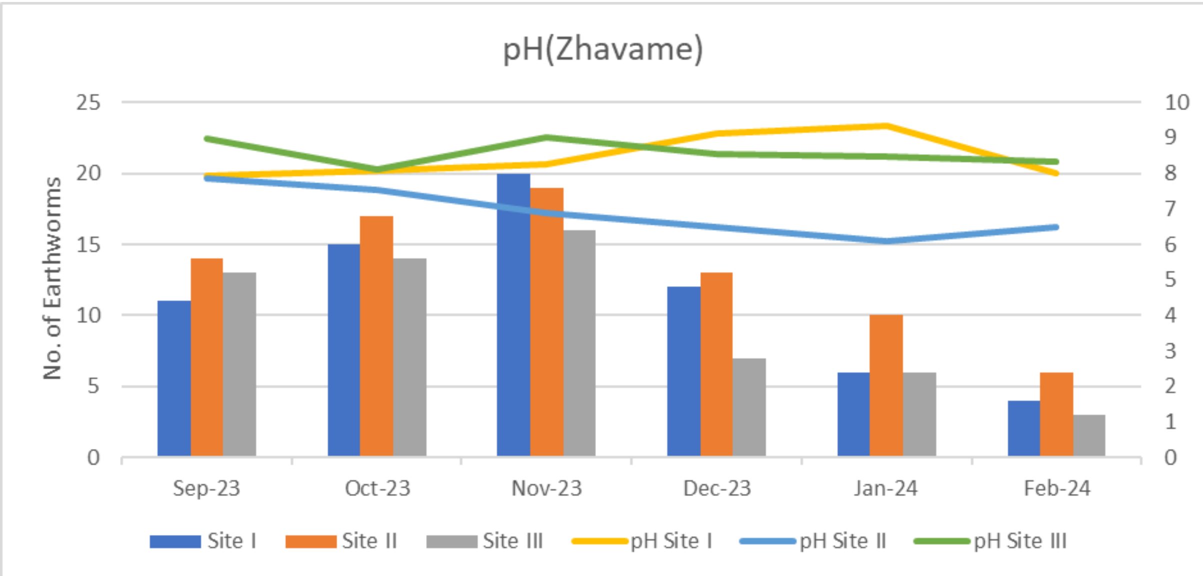

Figure 3.1. Earthworm population in relation to soil pH in three study sites under Zhavame.

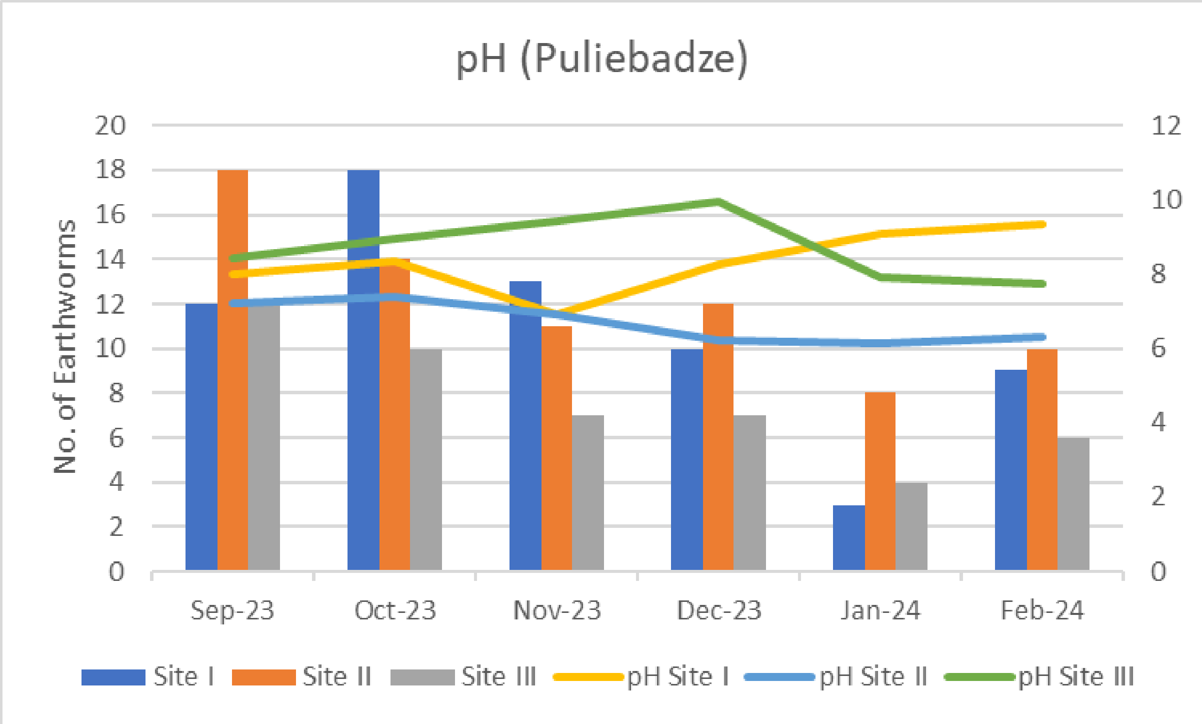

Figure 3.2. Earthworm population in relation to soil pH in three study sites under Puliebadze.

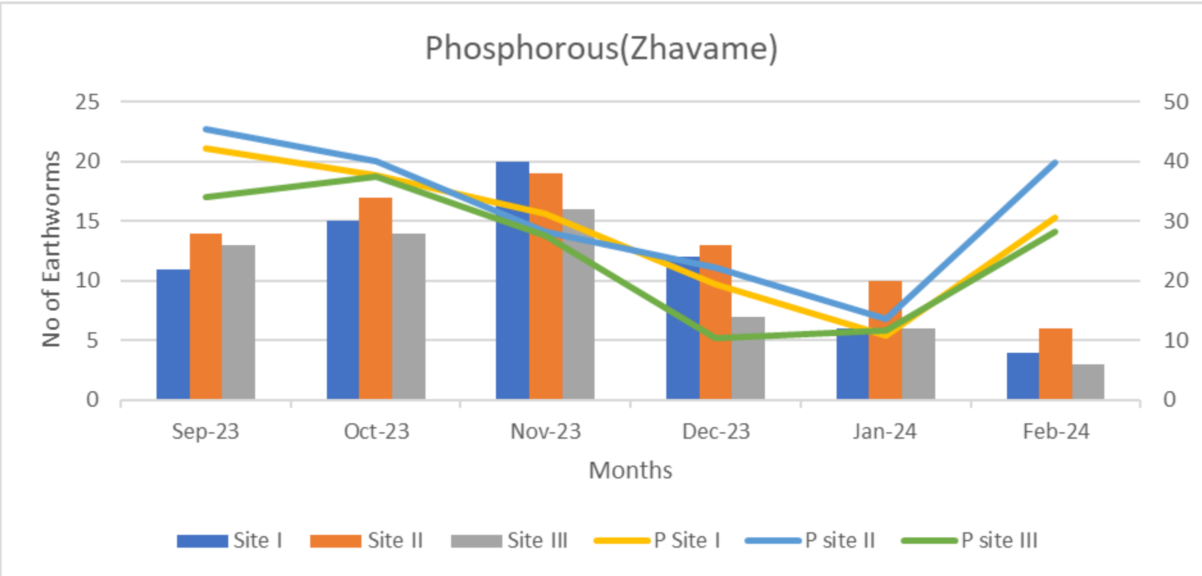

Figure 4.1. Earthworm population in relation to soil Phosphorus content in three study sites under Zhavame.

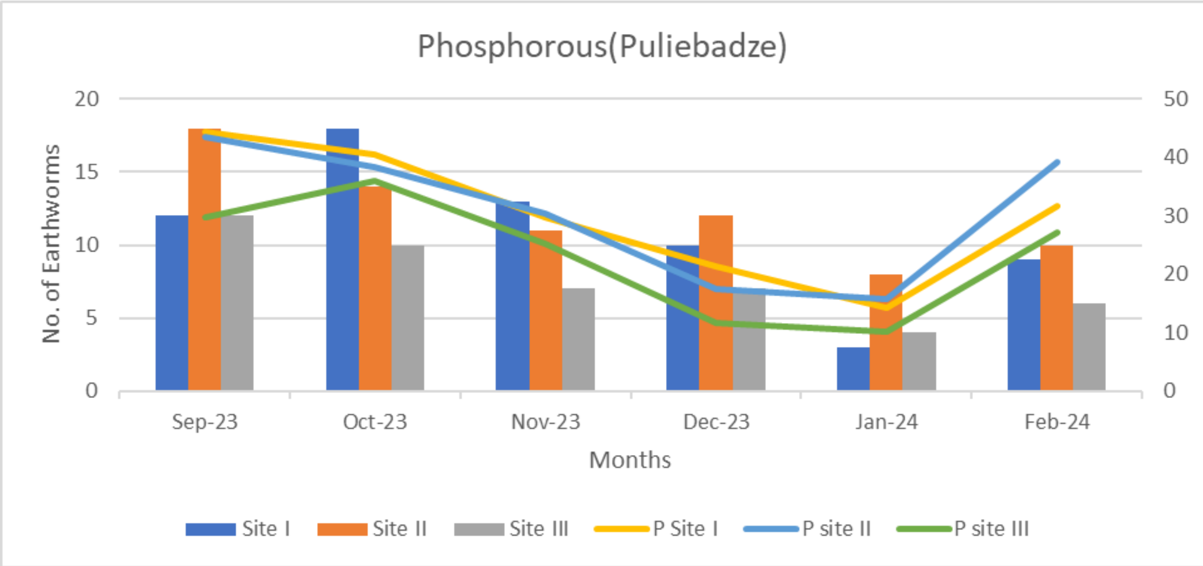

Figure 4.2: Earthworm population in relation to soil Phosphorus content in three study sites under Puliebadze.

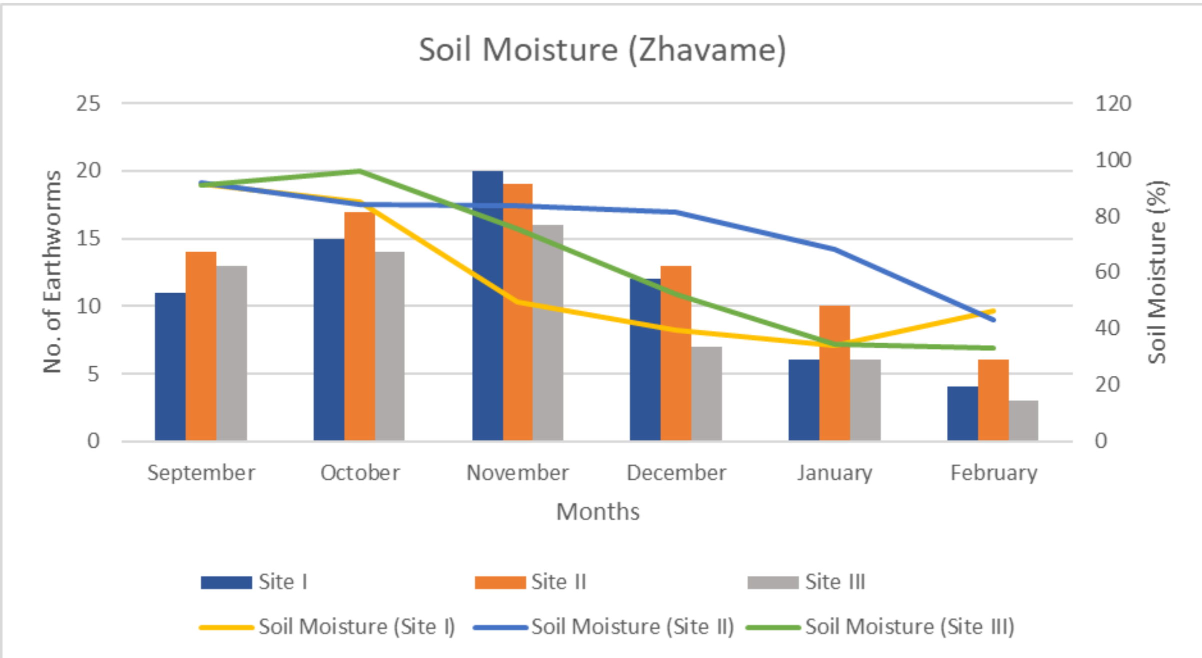

Figure 5.1. Earthworm population in relation to soil temperature in three study sites under Zhavame.

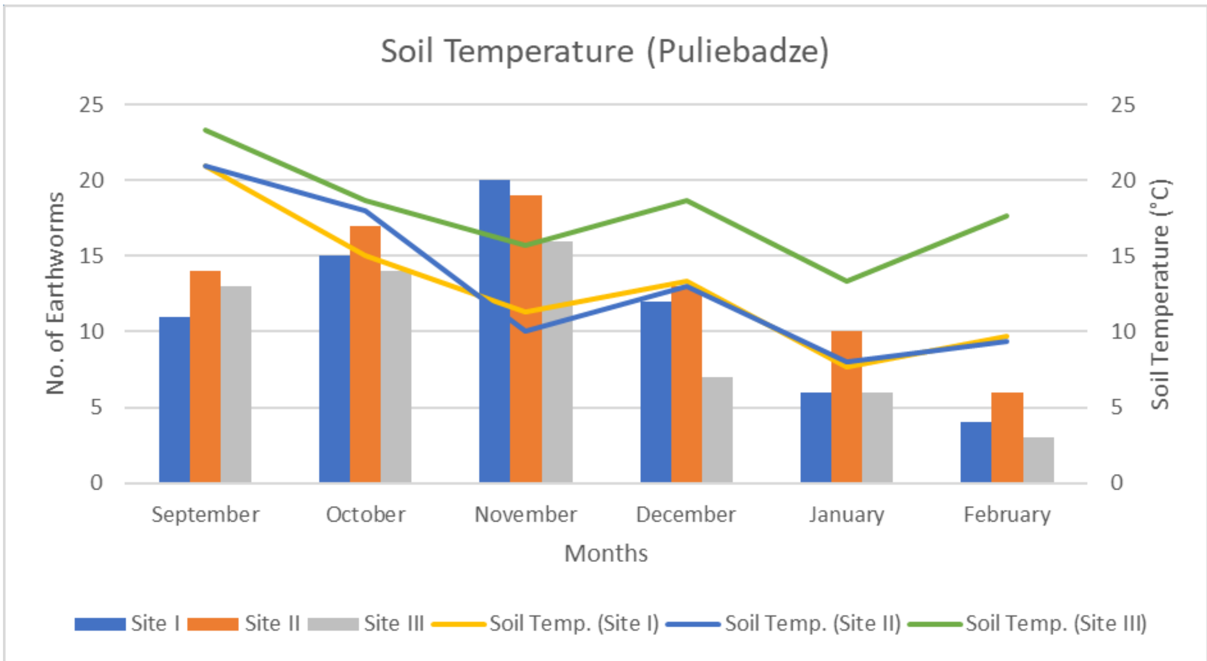

Figure 5.2. Earthworm population in relation to soil temperature in three study sites under Puliebadze.

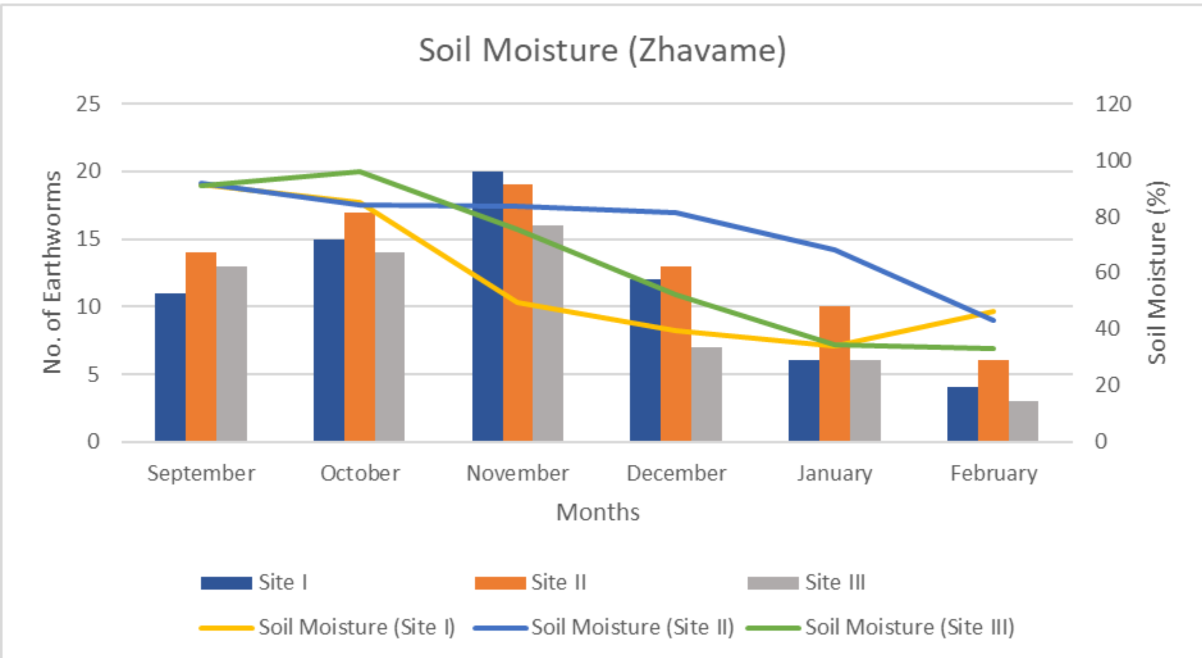

Figure 6.1. Earthworm population in relation to soil moisture in three study sites under Zhavame.

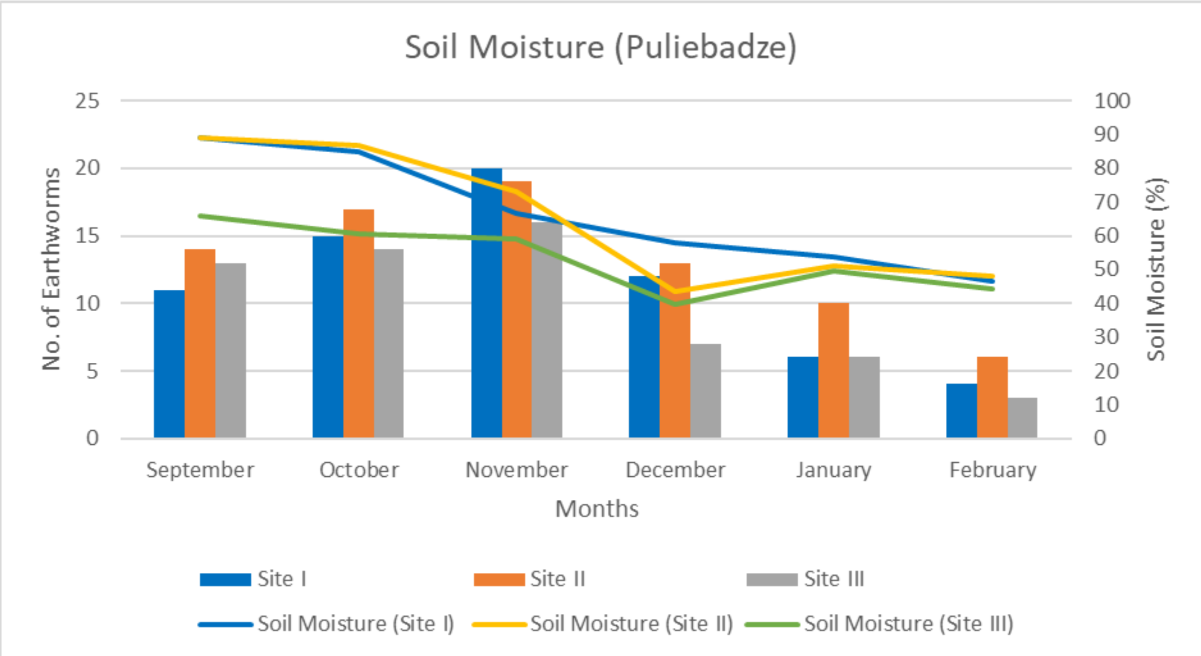

Figure 6.2. Earthworm population in relation to soil moisture content in three study sites under Puliebadze.

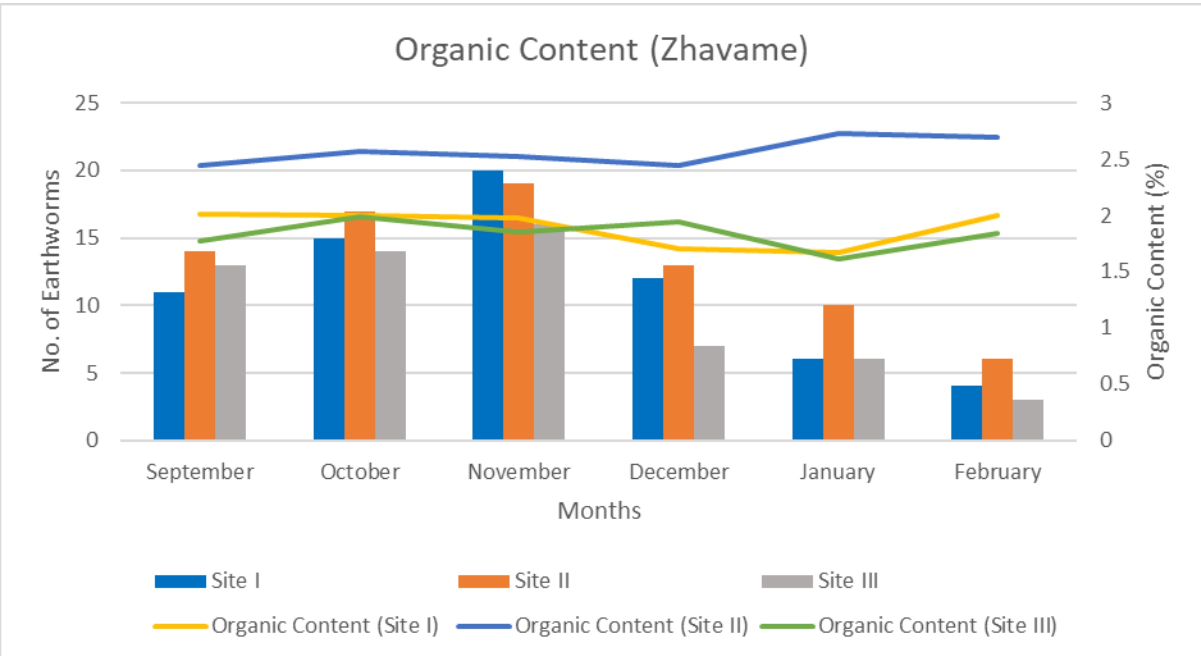

Figure 7.1. Earthworm population in relation to the organic content of soil in three study sites under Zhavame.

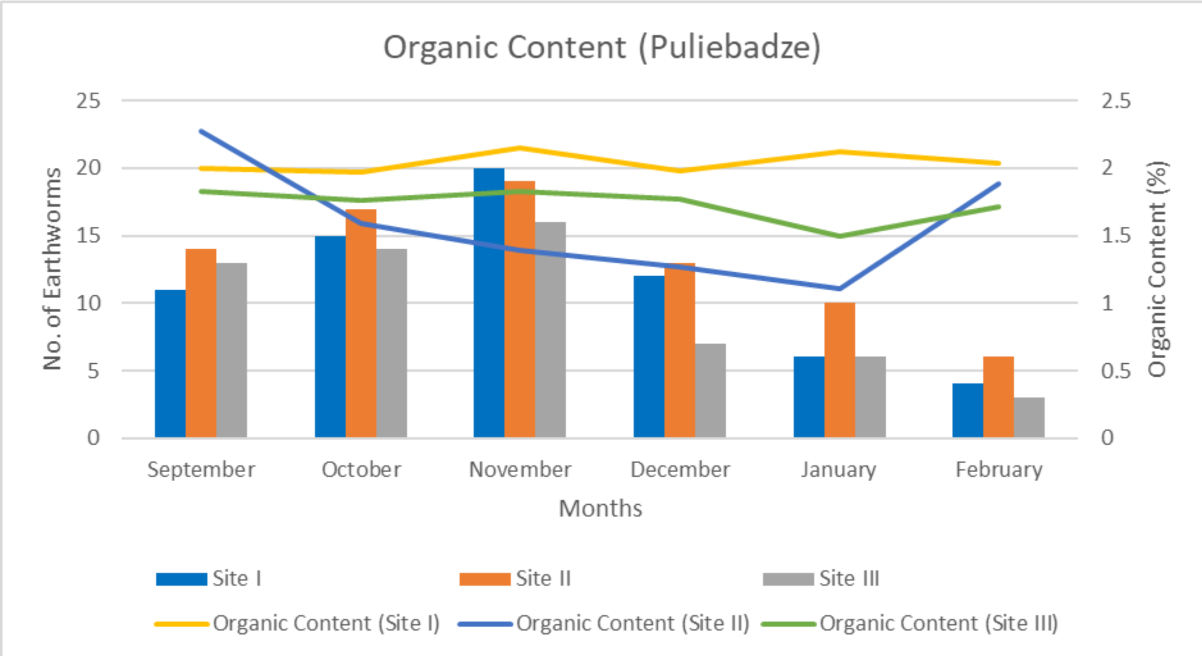

Figure 7.2. Earthworm population in relation to the organic content of soil in three study sites under Puliebadze.

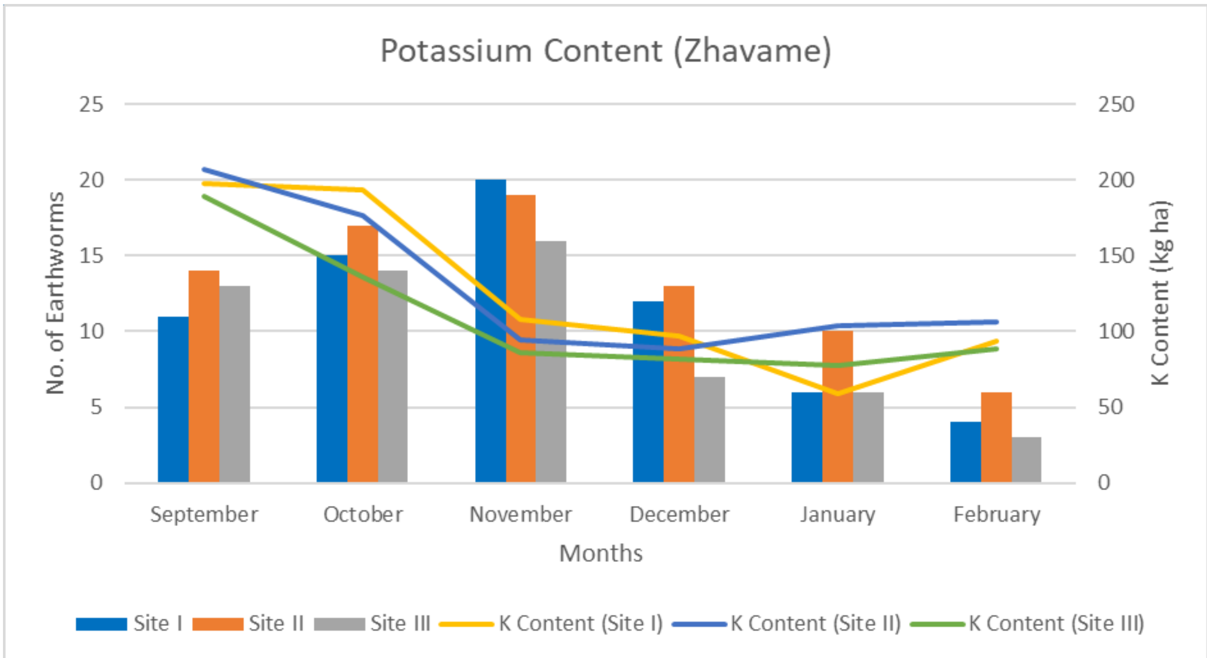

Figure 8.1. Earthworm population in relation to soil Potassium content in three study sites under Zhavame.

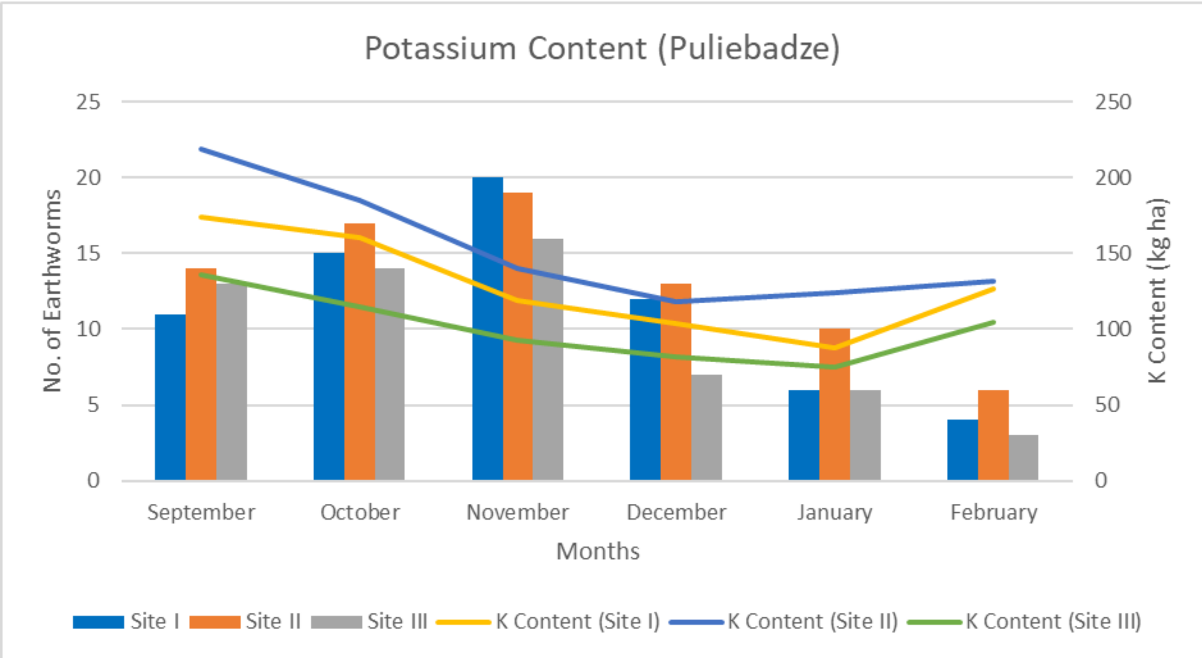

Figure 8.2. Earthworm population in relation to soil Potassium content in three study sites under Puliebadze.

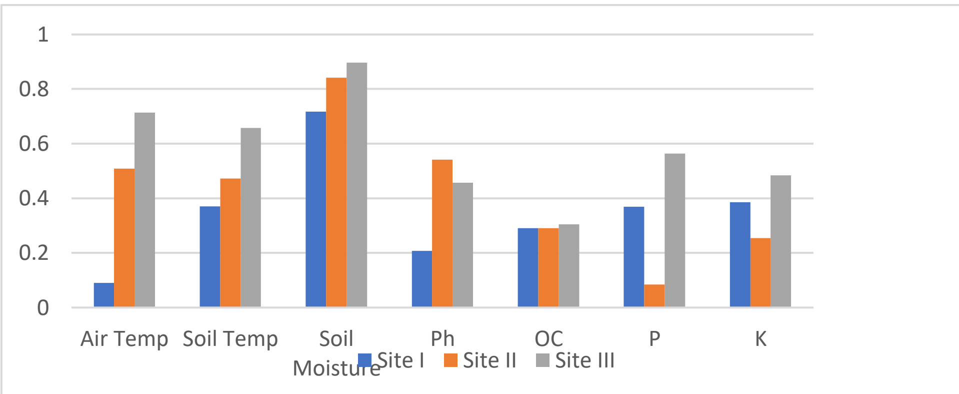

Figure 9.1. Correlation between physico-chemical parameters and Earthworm Population in Zhavame.

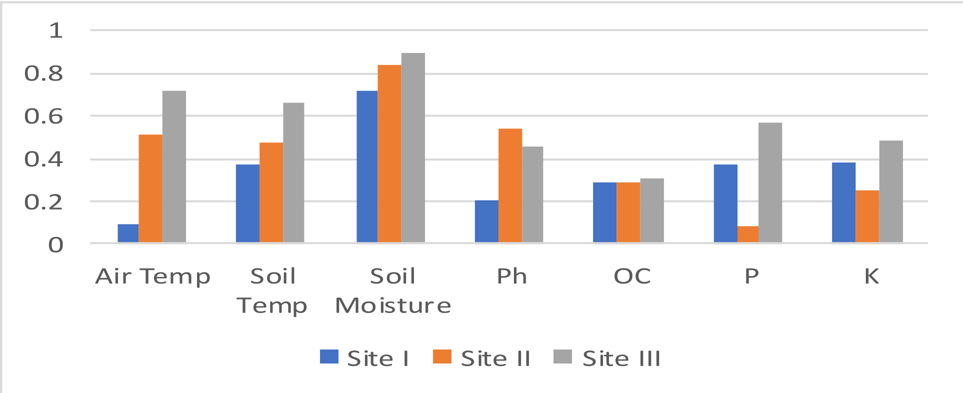

Figure 9.2. Correlation between physico-chemical Parameters and Earthworm Population in Puliebadze.

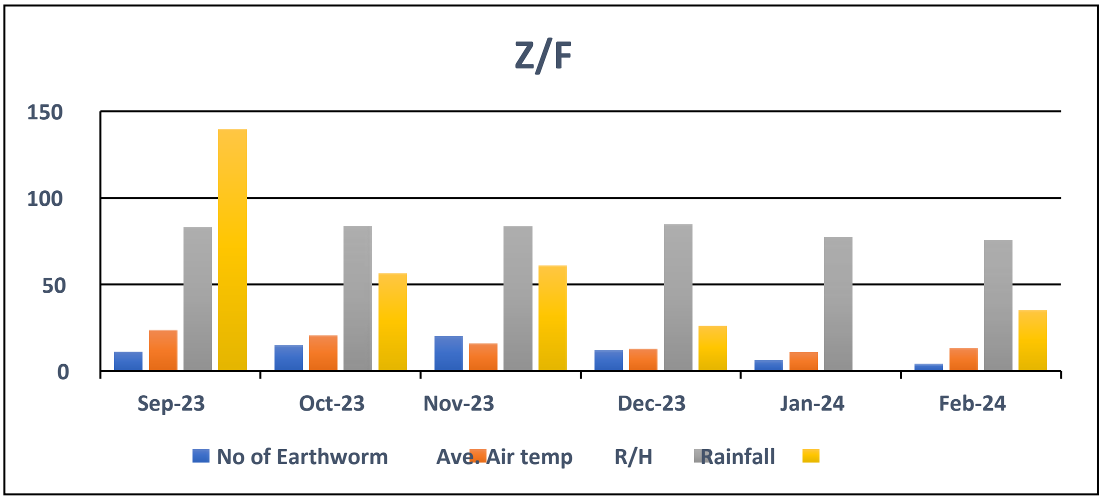

Figure 10.1. Earthworm population in relation with Air temp, R/H, & Rainfall under Phek District (Zhavame) in Forest.

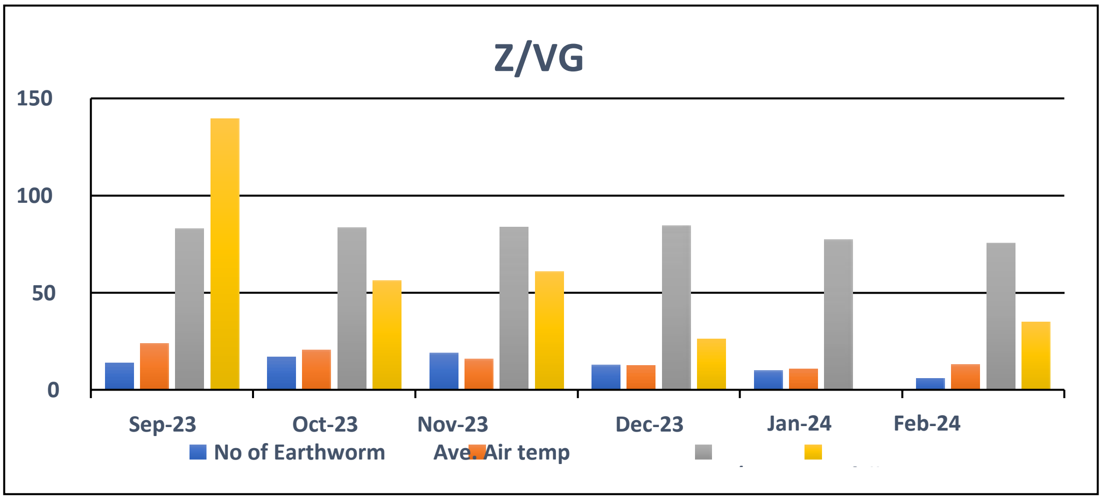

Figure 10.2. Earthworm population in relation with Air temp, R/H, & Rainfall under Phek District (Zhavame) in Vegetable Garden.

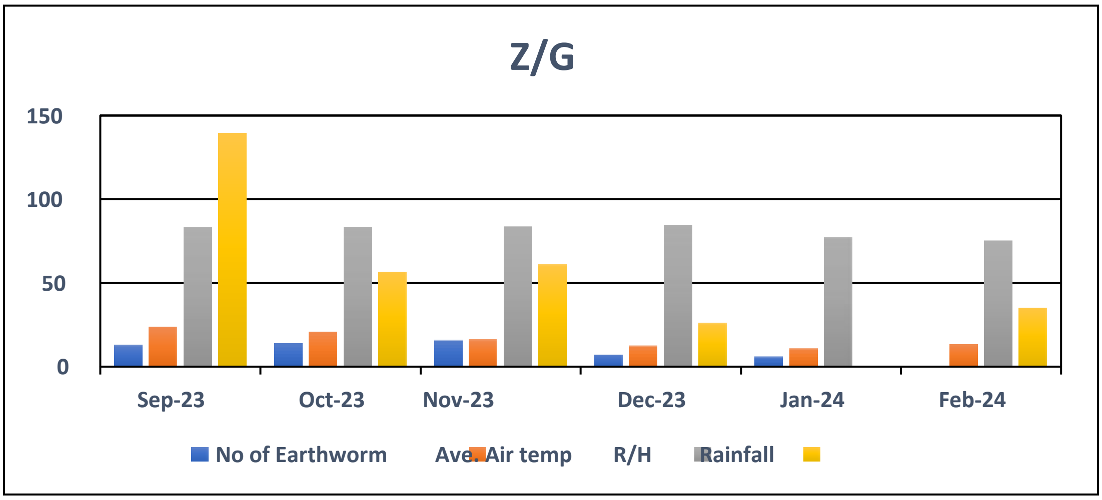

Figure 11.1. Earthworm population in relation with Air temp, R/H, & Rainfall under Phek District (Zhavame) in Grassland.

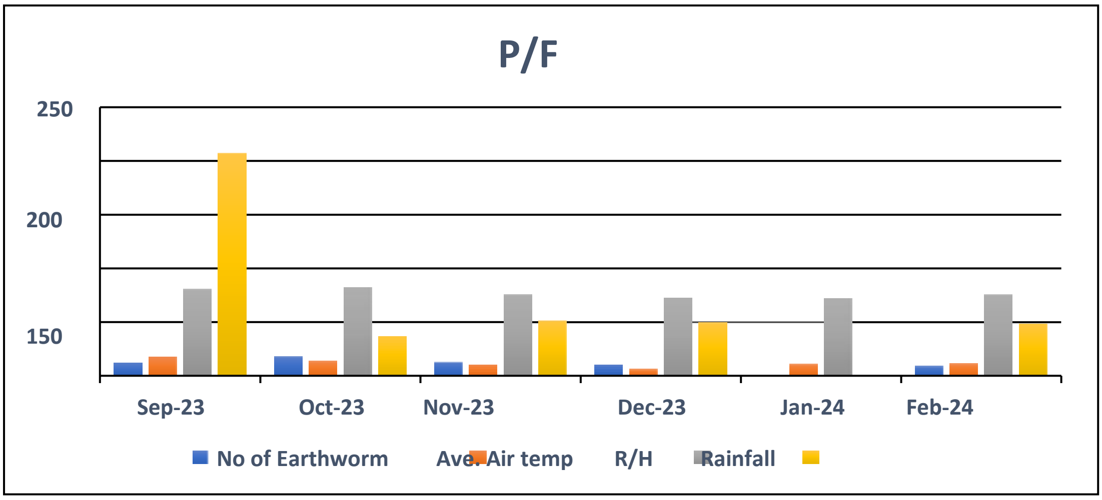

Figure 11.2. Earthworm population in relation with Air temp, R/H, & Rainfall under Kohima District (Puliebadze) in Forest**.**

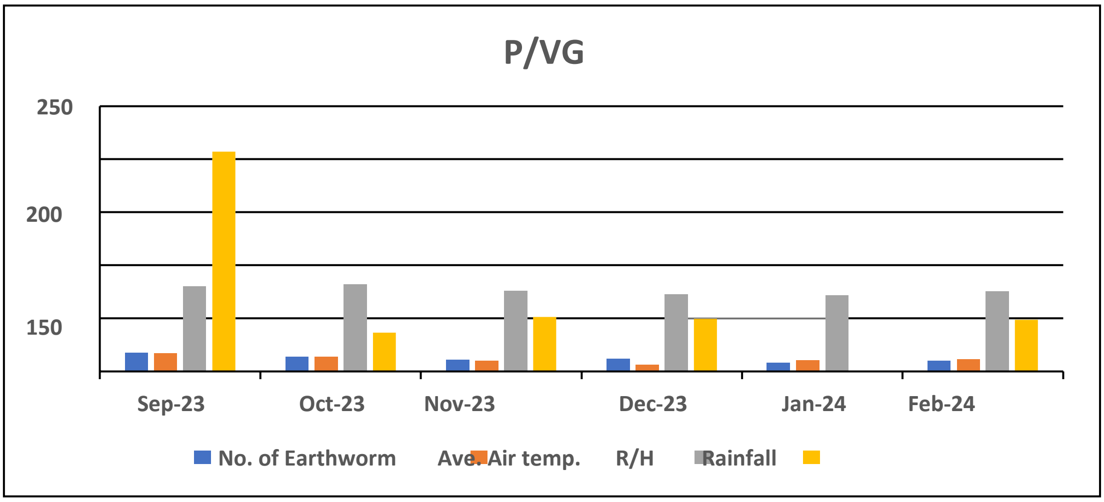

Figure 12.1. Earthworm population in relation with Air temp, R/H, & Rainfall under Kohima District (Puliebadze) in Vegetable.

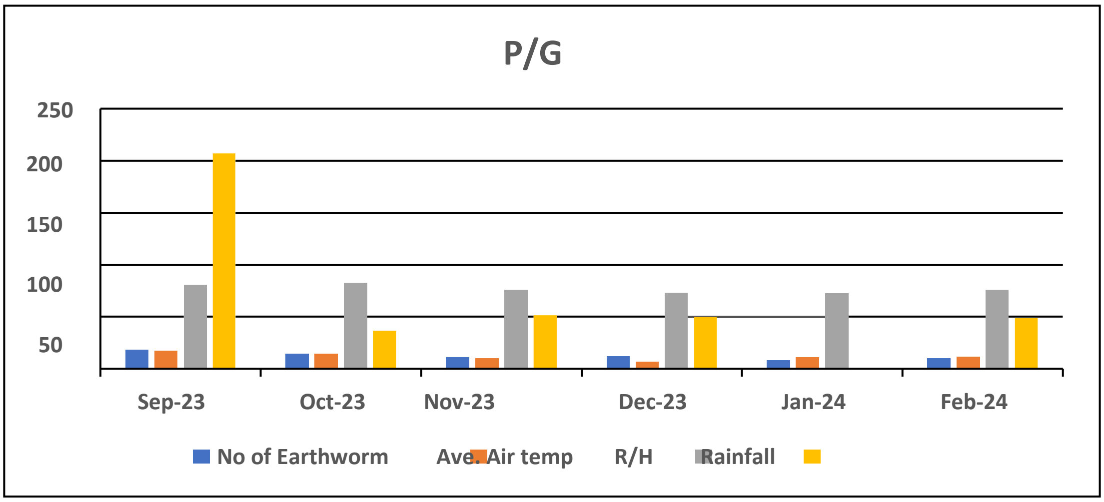

Figure 12.2. Earthworm population in relation with Air temp, R/H, & Rainfall under Kohima District (Puliebadze) in Grassland.

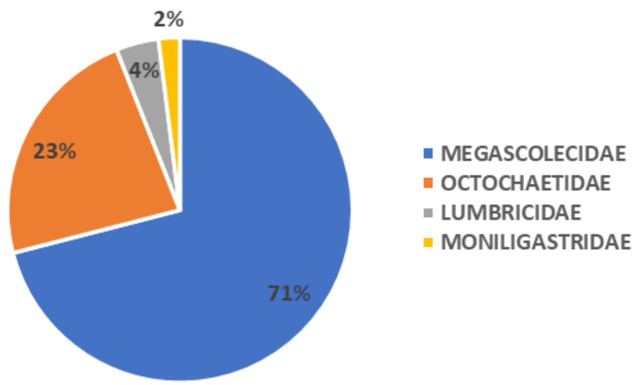

Figure 13.1. Observed percentage of earthworms under different families in Zhavame village.

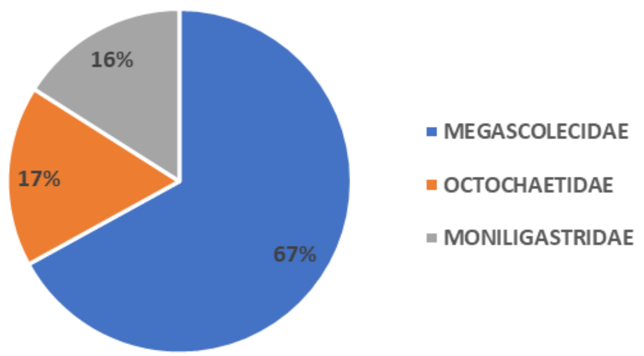

Figure 13.2. Observed percentage of earthworms under different families in Puliebadze.

The total number of earthworm species collected in Zhavame is 125 and in Puliebadze is 102. Under Zhavame village, Site I (Forest), *Eutyphoeus* sp.1 shows maximum number of species count. In both Site II (Vegetable Garden) and Site III (Grassland), *Metaphire* sp. shows maximum numbers count. Under Puliebadze, Site I, *Perionyxex cavatus* shows maximum number of species count. In Site II *Perionyx* sp. 1 and in Site III, *Drawida* sp. showed maximum number of species count. Highest species count was observed in both Site I and II from Zhavame village, while from Puliebadze, it was observed in Site II. The distribution of earthworms from Zhavame village (Table 3) shows that from the family Megascolecidae, *Perionyx excavatus*, *Perionyx* sp. 1, and *Metaphire* sp. was recorded in all the three sites. *Amynthas gracilis* was recorded in Site I and Site II. From family Moniligastridae, *Drawida* sp. was recorded only in Site III. Under family Octochaetidae, *Eutyphoeus* sp. 1 was recorded in all the three sites, *Eutyphoeus* sp. 2 in Site I and Site II and *Eutyphoeus* sp. 4 was recorded only in Site I. From family Lumbricidae, *Eiseniella* sp. Was recorded in Site II and Site III. Megascolecidae was found to be the dominant family with 4 different species (71%), followed by family Octochaetidae with 3 different species (23%), Lumbricidae (45%) and Moniligastridae (2%) with 1 species each (Figure 13.1). The distribution of earthworms from Puliebadze (Table 4) shows that from the family Megascolecidae, *Perionyx excavatus* and

Amynthas gracilis was recorded in all the three study sites, *Perionyx* sp. 1 was recorded in Site I and Site II, while *Metaphire* sp. Was recorded only in Site II. *Drawida* sp. From family Moniligastridae was recorded in all the three sites. From family Octochaetidae, *Eutyphoeus* sp.1 and *Eutyphoeus* sp.2 was recorded in Site I and Site II, while *Eutyphoeus* sp.3 was recorded in all the three sites. Megascolecidae was found to be the dominant family with 4 different species (67%), followed by Octochaetidae with 3 different species (17%) and Moniligastridae with 1 species (16%) (Figure 13.2**).**

Air temperature

Under Zhavame, the air temperature in Forest area (Site I) ranged from 11.7 ˚C (Dec) to 24.33˚c (Sept) (Figure 2.1). In Vegetable Garden (Site II), it ranged from 15˚c (Dec) to 29˚c (Sept) (Figure 2.1) and in Grassland (Site III), it ranged from 10.7˚c (Dec) to 27.33˚c (Sept) (Figure 2.1). Under Puliebadze, the air temperature in Forest area ranged from 11.7 ˚c (Jan & Feb) to 26.7˚c (Sept) (Figure 2.2). In Vegetable Garden it ranged from 11.7˚c (Jan) to 24.7˚c (Sept) (Figure 2.2) and in Grassland, it ranged from 18.33˚c (Jan) to 28.7˚c (Sept) (Figure 2.2).

Soil temperature

Under Zhavame, the soil temperature in Forest area ranged from 7.7˚c (Jan) to 21˚c (Sept) (Figure 5.1). In Vegetable Garden, it ranged from 8˚c (Jan) to 21˚c (Sept) (Figure 5.1) and 13.33˚c (Jan) to 23.33˚c (Sept) in Grassland area (Figure 5.1). Under Puliebadze, the soil temperature in Forest area ranged from 10˚c (Feb) to 21.33˚c (Sept) (Figure 5.2). In Vegetable Garden, it ranged from 10˚c (Jan) to 23.33˚c (Sept) (Figure 5.2) and 9˚c (Dec) to 21.33˚c (Sept) in Grassland area (Figure 5.2).

Soil pH

Under Zhavame, the soil pH in Forest area ranged from 7.93 (Sept) to 9.33 (Jan) (Figure 3.1) indicating slightly alkaline soil type, in Vegetable Garden, it showed slightly acidic soil type ranging between 6.1 (Jan) to 7.87 (Sept) (Figure 3.1) and alkaline soil type in Grassland of range 8.1 (Oct) to 9.03 (Nov) (Figure 3.1). Under Puliebadze, the soil temperature in Forest area ranged from 6.93 (Nov) to 9.33 (Feb) slightly acidic to alkaline soil type (Figure 3.2), pH ranged from 6.13(Jan) to7.38 (Oct) in Vegetable Garden (Figure 3.2) and 7.73 (Feb) to 9.96 (Dec) of alkaline soil types in Grassland area (Figure 3.2).

Soil moisture

Under Zhavame, the soil moisture percentage in Forest area ranged from 33.81% (Jan) to 91.3% (Sept) (Figure 6.1). In Vegetable Garden, it ranged from 43.26% (Feb) to 91.76% (Sept) (Figure 6.1) and 33.2% (Feb) to 95.98% (Oct) in Grassland area (Figure 6.1). Under Puliebadze, the soil moisture percentage in Forest area ranged from 46.72% (Feb) to 88.93% Sept) (Figure 6.2). In Vegetable Garden, it ranged from 43.41% (Dec) to 88.93% (Sept) (Figure 6.2) and 39.81% (Dec) to 65.88% (Sept) in Grassland area (Figure 6.2).

Organic Carbon

Under Zhavame, the organic carbon in Forest area ranged from 1.67% (Jan) to 2.01% (Sep) (Figure 7.1). In Vegetable Garden range from 2.44% (Sept & Dec) to 2.73% (Jan) (Figure 7.1) and 1.61% (Jan) to 1.99 (Oct) in Grassland area (Figure 7.1). The maximum organic carbon content was observed in Vegetable Garden tans minimum in Grassland. Under Puliebadze, the soil organic carbon of Forest area ranged from 1.97% (Oct) to 2.15% (Nov) (Figure 7.2). In Vegetable Garden, ranged from 1.11% (Jan) to 2.27% (Sept) (Figure 7.2) and organic carbon in Grassland area ranged from 1.5% (Jan) to 1.83% (Sept & Nov) (Figure 7.2). The maximum organic carbon content was observed in Vegetable Garden and minimum in Grassland.

Phosphorus

Under Zhavame, the phosphorus content in Forest area ranged from 10.80kg/ha (Jan) to 42.30kg/ha (Sept) (Figure 4.1). In Vegetable Garden, it ranged from 13.60kg/ha (Jan) to 45.34kg/ha (Sept) (Figure 4.1) and 10.34kg/ha (Dec) to 37.40kg/ha (Oct) in Grassland area (Figure 4.1). The maximum phosphorus content was observed in Forest area and minimum in Grassland. Under Puliebadze, the phosphorus contentin Forest are aranged from 14.30kg/ha (Jan) to 44.40kg/ha (Sept) (Figure 4.2). In Vegetable Garden, it ranged from 15.70kg/ha (Jan) to 43.47kg/ha (Sept) (Figure 4.2) and 10.10kg/ha (Jan) to 36ka/ha (Oct) in Grassland area (Figure 4.2). The maximum phosphorus content was observed in Forest and minimum in Grassland.

Potassium

Under Puliebadze, the potassium content in Forest are arranged from 88.1kg/ha (Jan) to 173.98kg/ha (Sept) (Figure 8.1). In Vegetable Garden, it ranged from 117.98kg/ha (Dec) to 218.78kg/ha (Sept) (Figure 8.1) and 75.42kg/ha (Jan) to 135.9ka/ha (Sept) in Grassland area (Figure 8.1). The maximum potassium content was observed in Vegetable Garden and minimum in Grassland area.Under Zhavame, the potassium content in Forest area ranged from 58.76kg/ha (Jan) to 197.86kg/ha (Sept) (Figure 8.2). In Vegetable Garden, it ranged from 88.86kg/ha (Dec) to 206.82kg/ha (Sept) (Figure 8.2) and 77.66kg/ha (Jan) to 189.66kg/ha (Sept) in Grassland area (Figure 8.2). The maximum potassium content was observed in Vegetable Garden and minimum in forest area.

Correlation

Generally weak correlations between soil parameters and earthworm population (EP) were observed in the Forest area of Zhavame, while soil moisture showed the highest positive correlation (r = 0.09). A high positive correlation was observed with soil moisture (0.842) in the Vegetable Garden, whereas soil and air temperatures as well as pH showed moderate positive correlations. Organic carbon

(OC), Potassium (K), and Phosphorus (P) contents exhibited weak or very weak correlations. Air temperature and soil moisture showed high positive correlations (r = 0.714, 0.897) in Grassland area. Simultaneously, moderate positive correlations were observed with pH, P, K, and soil temperature. A high positive correlation of soil moisture, P, and L with EP were observed in the Forest area of Puliebadze, with air and soil showing moderate positive correlations. However, soil pH showed moderate negative correlation. In the Vegatable Garden, air and soil temperatures, soil moisture, pH, K, and OC displayed high positive correlations (r > 0.75) highlighting a strong relationship with EP. In Grassland, air and soil temperatures, soil moisture, P, and K showed high correlations. On the other hand, soil pH had a weak positive correlation. In general, across all areas, soil moisture consistently showed a high positive correlation with EP, making it the most influential factor. Soil and air temperatures also showed generally moderate to high correlations, indicating their importance in earthworm distribution, while soil pH showed mixed results, with some weak to moderate correlations, and in some cases, negative relations with EP. Among all the land-use types, the Vegetable Garden in Puliebadze exhibited the strongest overall correlations, which implies that the area might be the most favourable for earthworm populations

ANOVA (Analysis of Variance)

Table 5 presents the relationship between earthworm populations (EP) and soil physico-chemical parameters. In Zhavame, EP showed no correlation with pH and soil temperature (p>0.05), but soil moisture, organic carbon (OC), phosphorus (P), and potassium (K) were significant (p<0.05). In the Vegetable Garden, soil moisture and temperature had no effect (p>0.05), while pH, OC, P, K, and air temperature were significant (p<0.01). In Grassland, pH and soil temperature showed no significance (p>0.05), but soil moisture, air temperature, OC, P, and K were significant (p<0.01).

Under Puliebadze, EP in the Forest had no correlation with pH, soil moisture, soil temperature, air temperature, and K (p>0.05), while OC and P were significant (p<0.01). In the Vegetable Garden, soil moisture, soil temperature, and K showed no effect (p>0.05), while OC, pH, and P (p<0.01) and air temperature (p<0.05) were significant. In Grassland, pH, soil moisture, air temperature, and P had no significance (p>0.05), but soil temperature, OC, and P were significant (p<0.01). Table 6 shows that rainfall influenced EP, while air temperature and humidity had no significant trend. In Phek, average temperatures ranged from 10.9°C (Jan) to 23.8°C (Sept), humidity from 75.7% (Feb) to 83.9% (Nov), and rainfall from 0mm (Jan) to 139.6mm (Sept) (Figures 10.1-11.1). In Kohima, temperatures ranged from 6.6°C (Dec) to 17.3°C (Sept), humidity from 72% (Jan) to 82.3% (Oct), and rainfall from 0mm (Jan) to 207.1mm (Sept) (Figures 11.2-12.2).

RESULTS AND DISCUSSION

The present study was conducted from 15th September 2023 to 17th February 2024 (6 months) covering six sampling sites and a total of 7 parameters. The study recorded 10 earthworm species across four families—Megascolecidae, Moniligastridae, Octochaetidae, and Lumbricidae—spanning six genera (*Perionyx, Amynthas, Metaphire, Drawida, Eutyphoeus, Eiseniella*). In Zhavame, species richness varied across sites, with 7 species recorded at Site I, 6 species at Site II, and 7 species at Site III (Table 3). Similarly, in Puliebadze, species diversity differed, with 7 species at Site I,8 species at Site II, and 4 species at Site III (Table 4). The family Megascolecidae was the most abundant, particularly epigeic species which aligns with the findings of Padashetty and Jadesh (2014) in Karnataka, Thyug *et al.,* (2024) in Jotsoma village, Kohima, Mohan *et al* (2023) in Amritsar, Punjab. In Zhavame, species like *Perionyx excavatus, Perionyx sp. 1, Metaphire sp.* and *Eutyphoeus sp. 1* were found across all habitats whereas *Drawida sp.* and *Eutyphoeus sp. 4* had the least distribution. In Pulie Badze, *Perionyx excavatus, Amynthas gracilis, Drawida sp.* and *Eutyphoeus sp. 3* were common across habitats, while *Metaphire sp.* was the least distributed. Higher densities of specific earthworm species in particular soil habitats underscore their potential to thrive and exhibits high tolerance to varying soil conditions (Bhadauria *et al.* 2000, Rajkhowa *et al*. 2014).

Soil properties significantly influenced earthworm populations. The population of earthworm showed a seasonal variation, which peaked during monsoon season and declined in winter (Rathour, 2024). Rainfall is a critical factor which indirectly affects the earthworm population by affecting soil moisture (Curry *et al*., 2004; Haokip & Singh, 2009). In Zhavame, key factors were soil moisture, organic carbon (OC), phosphorus (P) and Potassium(K), while in Puliebadze organic carbon and phosphorus were the key factors that has a strong impact. Bhawalkar & Bhawalkar (1993), Bhat & Khambata (1994), Singh (1997) and Padmavathi (2013) also reported that the soil factors that significantly affects the earthworm abundance were nitrogen, phosphorus, and potassium. The earthworm population negatively correlate with high soil pH which supports the prior findings of Edwards & Bohlen, (1996); Edwards & Lofty, (1977), Hassan, (2025) which favour neutral pH. Through ANOVA analysis it confirmed that air temperature impacted earthworm populations in both the study areas, while soil factors varied across habitats (Singh & Singh, 2023). The above findings on earthworm population with reference to soil characteristics supports the previous research by Kalu *et al*. (2015), Tripathi & Bhardwaj (2004), and Sankar & Patnaik (2018).

Zhavame had more earthworm species overall, including *Eutyphoeus* sp.4 and *Eiseniella* sp., which were not found in Puliebadze. While Puliebadze exclusively reported *Drawida* sp. and *Eutyphoeus* sp.3, which was not found in Zhavame. Zhavame showed a more balanced and diverse distribution of earthworm species across all three habitats, while Puliebadze had a slightly lower diversity with some species occurring only in specific habitats. This may be due to the pH of the soils in the study areas. (Kumar & Singh, 2013; Singh & Kaur, 2014; Goswami & Mondal, 2015; Singh & Singh, 2023).

CONCLUSION

The study conducted from 15th September 2023 to 17th February 2024 across six sampling sites (three each in Zhavame and Puliebadze) found that Zhavame had a higher diversity and abundance of earthworms, particularly epigeic species (five species from two families), followed by endogeic (three species from one family), and anecic (one species). Puliebadze also showed greater epigeic diversity (four species, one family), with similar endogeic and anecic patterns. Earthworm numbers were highest in forest and vegetable garden sites, with Zhavame showing stronger positive correlations between soil factors and earthworm population. Due to time constraints, only seven soil parameters were studied; further research could expand on seasonal variation and include more physicochemical factors such as nitrogen, bulk density, and biomass to better understand earthworm distribution. The present study could cover six sampling sites and a total of 7 parameters due to time constraint; more extensive research could be employed to gain in depth knowledge about earthworm distribution and influence of the physicochemical factors; further studies could be carried out by including more physicochemical parameters like N, ECD, bulk density, biomass with various soil nutrients and mineral content; studies on seasonal variations of earthworm with different soil habitats can be surveyed.

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CONFLICT OF INTERESTS

The authors declare no conflict of interest

ETHICS APPROVAL

Not applicable

AI TOOL DECLARATION

The authors declares 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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