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Original Research Article

Population Dynamics of Earthworm Species *Amynthas alexandri* (Annelida: Megascolecidae) in Two Different Land-Use Systems of Kumaun Himalayas

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ABSTRACT:
Comparative study on population dynamics of earthworm Amynthas alexandri carried out in two different land-use systems, i.e., grassland soil at Governor's Golf field Nainital and croplands at Khurpatal and Chanfi, Nainital. Earthworms from different soil systems were collected by hand sorting and preserved in formalin for further investigations. Soil analysis revealed that the C: N ratio decreased with increasing depth in land-use systems (croplands and Grassland). The highest worm density was recorded during the rainy season in the Grassland (67.3m^{-2}), followed by croplands (28.1 m^{-2}). Biomass during the Rainy season was recorded higher in grassland soil (11.5 g m^{-2}) than in the croplands (8.7 g m^{-2}).

Keywords: *Amynthas alexandri*, *population dynamics, cultivated soil, Grassland, vertical distribution*

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INTRODUCTION

Earthworms are the essential soil macrofauna for all ecosystems and play a key role in soil dynamics. There is a vast relationship between earthworms and land-use patterns; these terrestrial Oligochaetesmaintain soil porosity and fertility, resulting in enhanced soil microbial activity. Soil quality depends on population dynamics, species composition, depth distribution and climatic change. Earthworms perform many activities and respond to various biological, chemical, Physico-chemical and environmental factors with different land-use systems. Earthworms have been considered valuable bio-tools because of their varied role in converting leaf litter and unsalable agricultural materials into readily available nutrients, initiation of humification to increase soil fertilityand increased soil microbial activity and nitrogen fixation processes leading to the formation of nutrient-rich soil with earthworm castings. Earthwormsare being widely used for organic farming and solid waste management through vermiculture practices worldwide.

The population density of earthworms in various agro-ecosystems significantly contributes to restoring and sustaining soil fertility; more specifically, their presence in agricultural fields increases crop production and maintains the quality of agriculture products, simultaneously in grassland

ecosystems, for proper growth of grasses. The fertile agricultural fields and grasslands grossly depend on the density of earthworms and their burrowing activity. The present study was performed to understand the relationship between population density, biomass and nutrient dynamics in two different land-use systems having *Amynthas alexandri* as a dominant species.

Earthworms playa key role in nutrient recycling of leaf litter and other agricultural waste products by decomposition and degradation of organic waste, maintaining soil structure and function (Lavelleet al.,1988). Information on the role of earthworms in the maintenance of soil fertility of temperate soil has been extensively studied (Edward and Lofty, 1978; Edward, 1983; Lee, 1985). However,the information on tropical soil is limited (Barois and Lavelle, 1986; Blanchart, et al., 1999; Martin, 1991;Lavelle and Martin,1992)**.**Reports are scantyregarding comparative investigations on population dynamics, Age structure and nutrient cycling in ecologically different soil systems in Kumaun Himalayas. In India, earthworm research was pioneered and popularized byDash and Patra, 1977; Mishra and Dash 1984; Julka, 1986), (Kaushal & Bisht, 1994; Kaushal et al., 1995) present study deals with the comparative study of earthworm *Amynthas alexandri* in two different agro-ecosystems particular references to population dynamics, nutrient cycling and seasonal variation in earthworm density and biomass.There are few recent reports on earthworm growth and development (Maniand Thirumagal, 2017), earthworm population and diversity (Goswami and Mondal, 2015), rehabilitation (Ribeiro et al., 2018), effects of earthworms on native grassland root system (Arnone and Zaller, 2014) have been studied extensively. There are many recent reports from various countries on earthworms and their role in different ecosystems especially in soil restoration, C: N ratio studies, nutrient dynamics and other ecological parameters (Phillips, 2019; Singh et al., 2020; Sohrabi et al., 2021; Li, 2021; Nahberger et al., 2021).

METHOD AND MATERIAL

Study sites

Earthworms were collected from the three study sites, Chanfi, Khurpatal and Government house areas located atDistrict Nainital, Uttarakhand. The geographical locationof various sites, i.e.,Government house Nainital (29 ° 22́ N, 79 ° 28́ E, altitude 2200 m), Chanfi altitude (29 ° 22́ N, 70 ° 35́ E, altitude 1300 m), Khurpatal (29 ° 20́ N, 79 ° 20́ E, altitude 1650 m).

Sampling

Samplingwas performed using 50×50cm quadrate attwo depths (0-10cm and 10-20cm) at selected study sites. Earthworms were collected by hand sorting method every month. Collected earthworms were properly cleansed, rinsed, weighed before preservation in 4% formalin for further analysis (Julka, 1968b). pH of the soil was measured using an electronic pH meter, temperature bysoil probe thermometer,Organic carbon by(Jackson, 1958), Soil nitrogen by Kjeldahl technique (Mishra, 1968). Potassium was determined as per Jackson, 1979.

Soil Type

Government house grassland soil was observed as yellowish, containing 48% Sand, 28% silt, 20% gravel, 4% clay. In Chanfi it was Sand 54%, Silt 21%, gravel 18% and clay 7%, Khurpatal Sand 50%, Gravel 22%, silt 18% and clay 5% respectively. (Kotpal and Bali, 1975)

Figure 1: Study sites Grassland and cropland

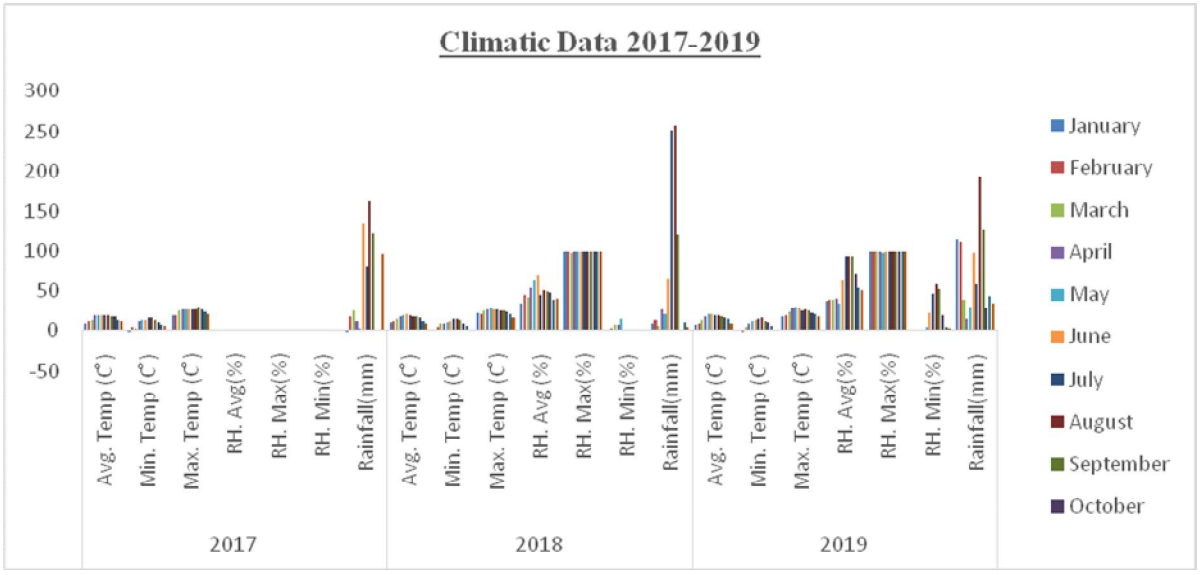

Figure 2: Climatic Data of Nainital as provided by Aryabhatta Research Institute of Observational Sciences (ARIES), Nainital

RESULTS

During the present investigation, significant differences were observed in terms of earthworm density, biomass and vertical distribution of earthworms in all study sites, for example, Chanfi, i.e., the maximum soil moisture recorded was 25.1% and 18.9% in 0-10cm and 10-20cm deep soil layers. At Khurpatal, maximum soil moisture was 19.1% and 15.9% in0-10cm and 10-20cm soil layers. At government golf field, Nainital maximum soil moisture was recorded 22.9% and 20.01% at 0-10 and 10-20cm, respectively. Soil pH was recorded as nearly neutral in all study sites.

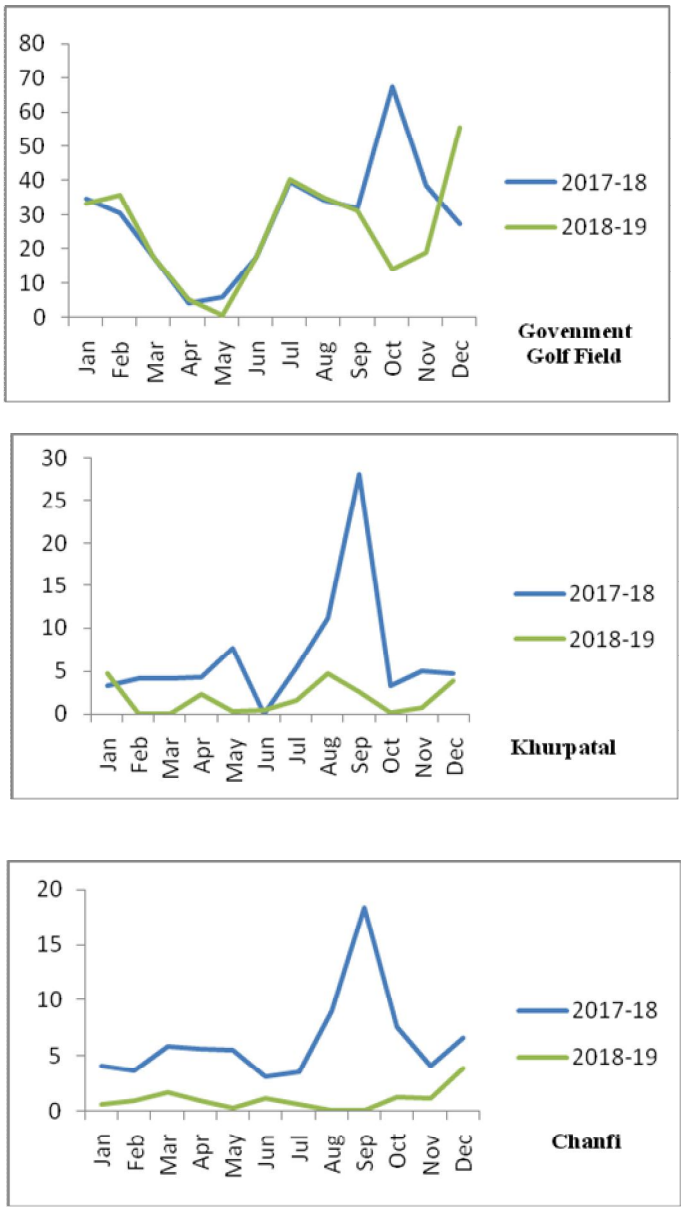

Figure 3: Density in two different land use system

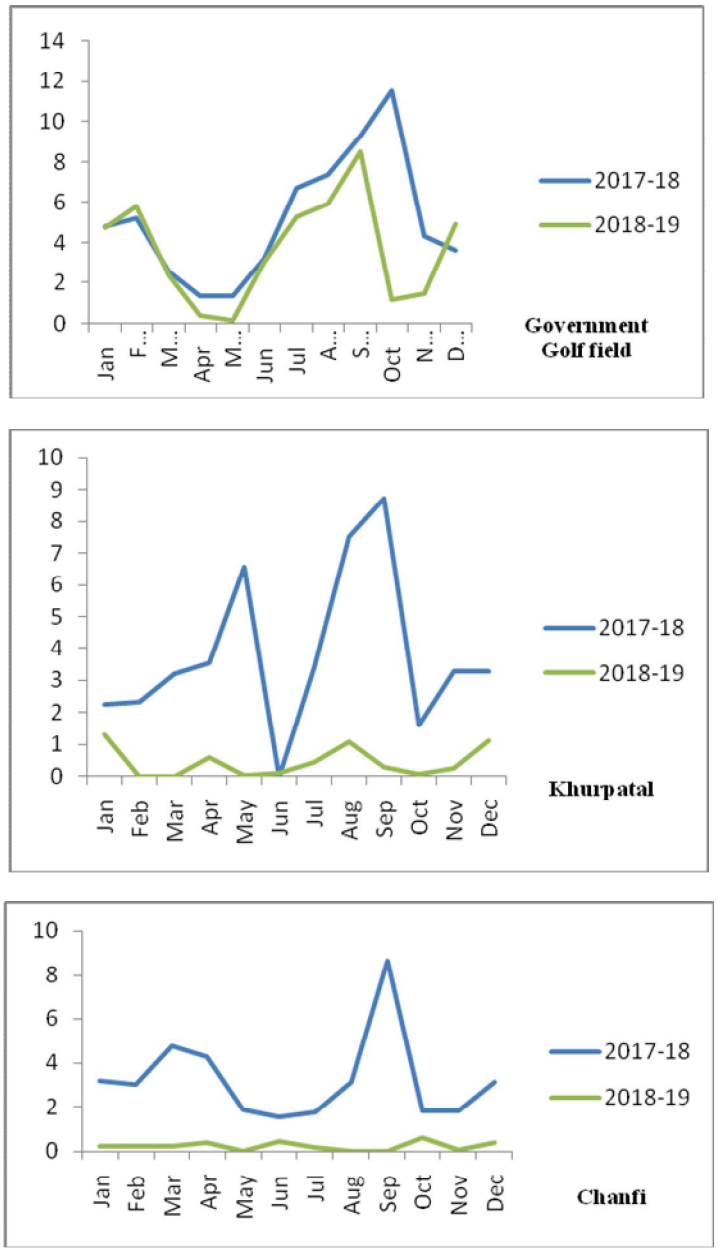

Figure 4: Earthworm biomass in two different land use system

Table 1: Chemical characteristics of soil (2017-2018)

Soil characteristics 2017-2018	Study sites and Soil layer					
	Government Golf Field (Grassland)		Khurpatal (Cropland)		Chanfi (Cropland)	
	0-10cm	10-20cm	0-10cm	10-20cm	0-10cm	10-20cm
Density (%)	65.5	34.5	67.5	32.4	60.5	39.5
Biomass (%)	63.5	36.5	83.1	16.9	54.9	45.1
pH	6.7	6.3	7.1	6.5	6.2	6.1
Temperature (℃)	10.56	10.7	20.24	20.21	19.64	19.62
Moisture (%)	22.27	20.01	17.83	15.99	25.16	24.65
K (%)	0.022	0.018	0.013	0.012	0.018	0.016
P (%)	0.0012	0.0008	0.0034	0.0028	0.0032	0.0029
C (%)	1.56	1.56	3.01	2.6	3.11	2.11
N	0.15	0.14	0.24	0.25	0.21	0.13
C:N ratio	10.4:1	11.14:1	12.54:1	10.4:1	14.81:1	16.23:1

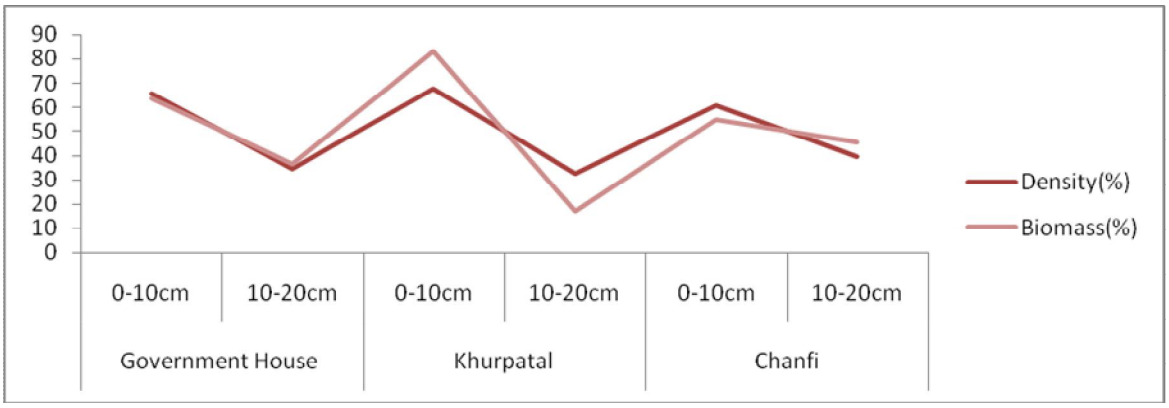

Figure 5: Density and Biomass in different land-use systems

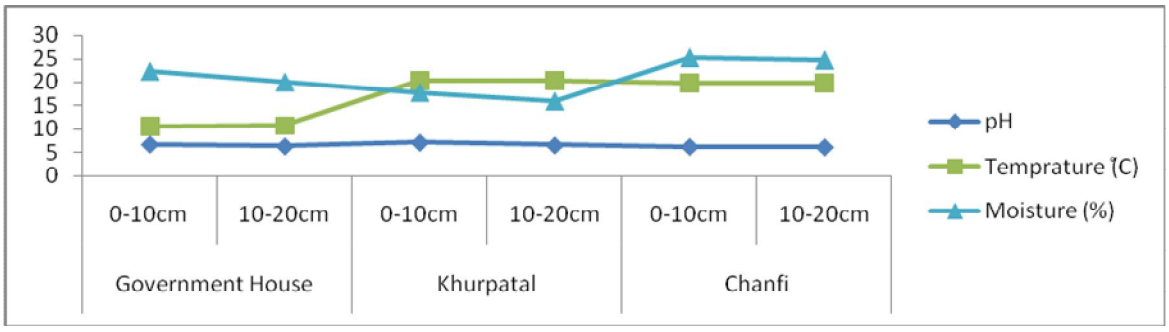

Figure 6: Soil pH, Temperature and Moisture at three study locations

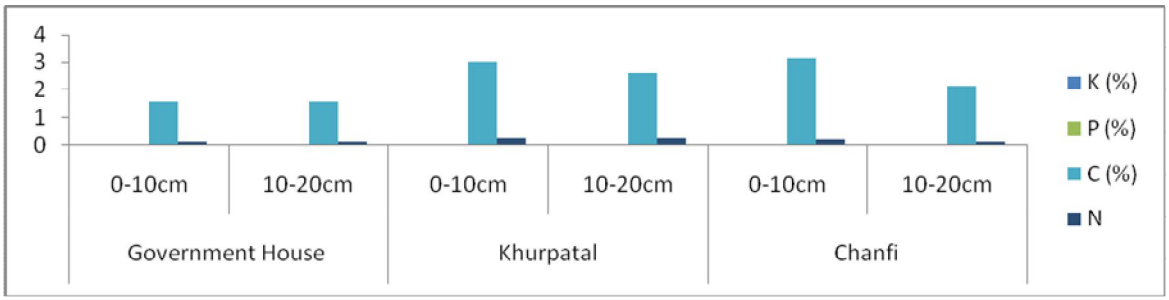

Figure 7: Soil characteristic in different land-use systems

Table 2: Chemical characteristics of soil layers

Soil characteristics 2018-2019	Study sites and soil layers					
	Golf Field		Khurpatal		Chanfi	
	0-10cm	10-20cm	0-10cm	10-20cm	0-10cm	10-20cm
Density (%)	62.6	37.8	65	35	55.4	44.6
Biomass (%)	62.8	37.2	54.6	45.4	50.6	49.4
pH	6.3	6.6	6.7	7.2	6.5	6.8
Temperature (℃)	11.12	11.12	11.16	11.16	12.55	12.55
Moisture (%)	22.92	20.81	19.13	18.66	19.92	18.91
K (%)	0.02	0.013	0.016	0.014	0.016	0.014
P (%)	0.0015	0.0009	0.0016	0.0014	0.0018	0.0013
C (%)	1.01	1.73	2.51	1.83	2.38	2.22
N	0.11	0.19	0.17	0.16	0.15	0.14
C:N ratio	9.18:1	9.1:1	14.7:1	11.43:1	15.86:1	15.85:1

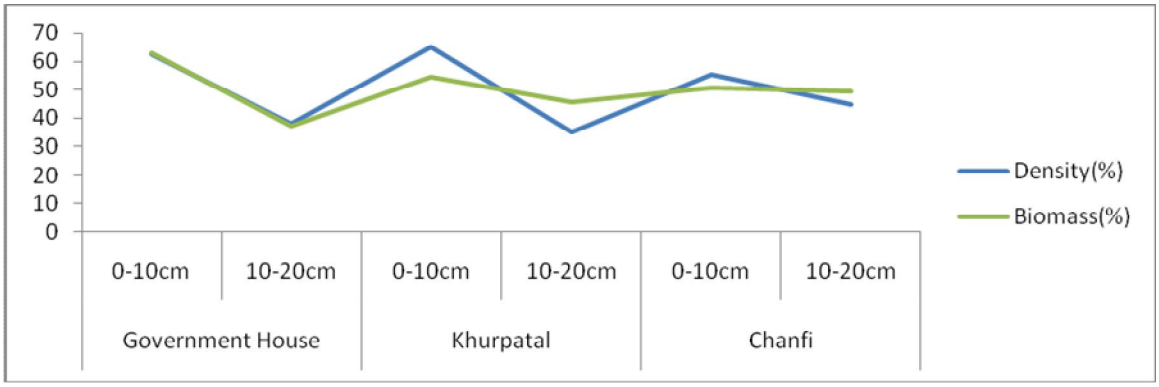

Figure 8: Earthworm density and biomass in different study sites

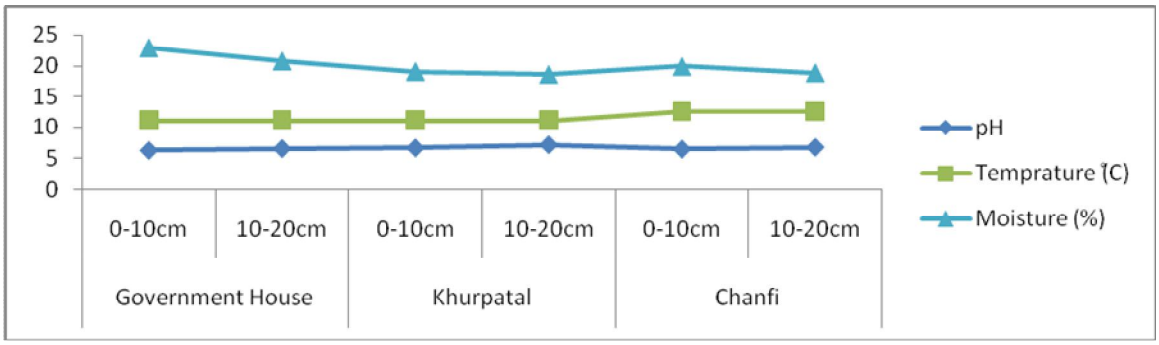

Figure 9: Soil pH, Temperature and Moisture at different sites

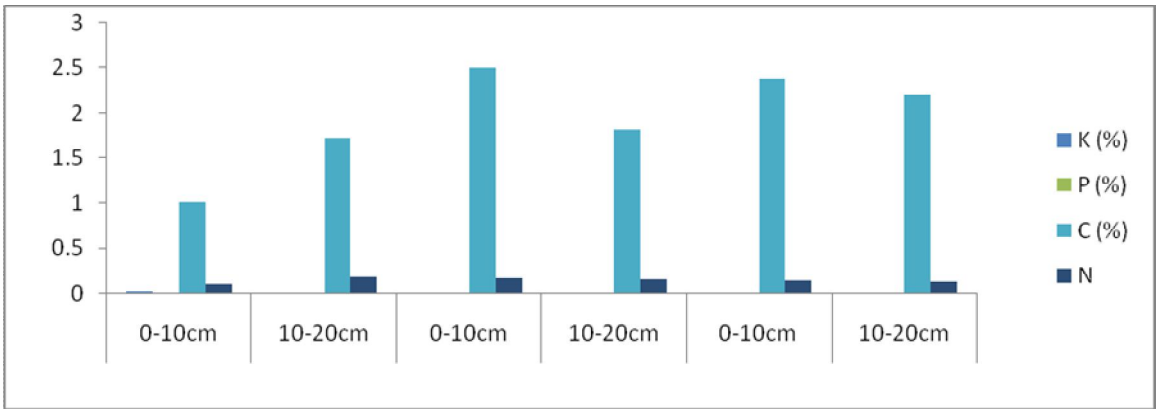

Figure 10: Soil chemical characteristics of the differentsoil system

Table 3: Percentage (%) of aclitellate and clitellate worms in different land use systems

Sites	Summer Season		Rainy Season		Winter Season		Total
2017-2018	Aclitellate	Clitellate	Aclitellate	Clitellate	Aclitellate	Clitellate	
Golf House	17.3	1.2	39.7	4.4	35.0	2.4	100.0
Khurpatal	-	-	9.0	91.0	-	-	100.0
Chanfi	0.4	3.9	6.9	80.1	1.7	7.0	100.0

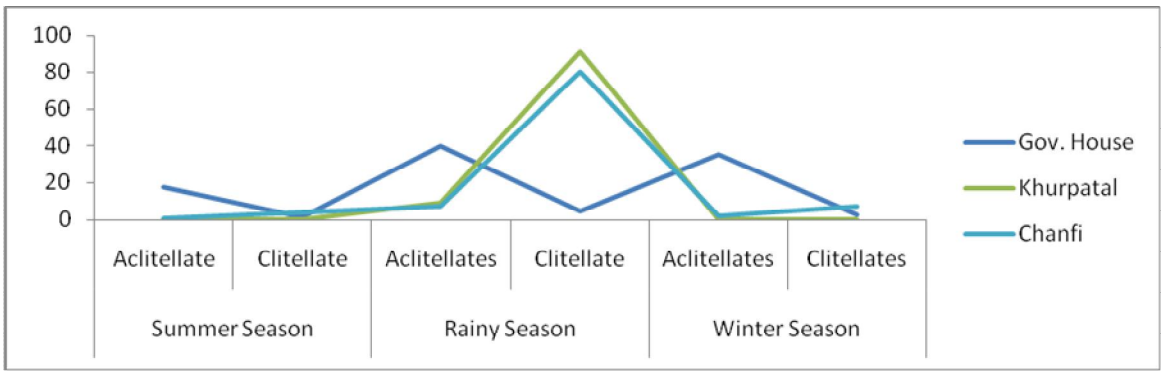

Figure 11: Graphical representation of number of earthworms in various seasons

Table 4: Percentage (%) of aclitellate and clitellate worms (Total number)

	Summer Season		Rainy Season		Winter Season		Total
2018-2019	Aclitellate	Clitellate	Aclitellate	Clitellate	Aclitellate	Clitellate	
Golf House	16.8	3.8	34.2	5.7	35.3	4.2	100.0
Khurpatal	8.8	35.2	-	-	11.2	44.8	100.0
Chanfi	11.1	61.6	-	-	2.6	24.7	100.0

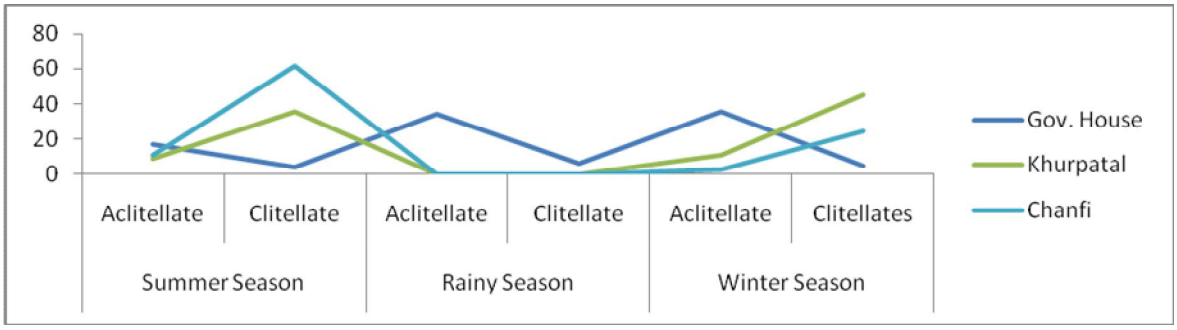

Figure 12: Graphical representation of number of earthworms in different seasons

Density and Biomass

In 2017-2018at government golf field,Nainital earthworm density ranged from 4.25m^{-2} to 67.3m^{-2} and in 2018-2019, the density ranged from 0.55$m^{-2}$to 55.3m^{-2}. At research site Chanfi, the cropland site, worm density ranged from 3.1m^{-2} to 18.4 m^{-2} in 2017-18 and 0.55 m^{-2} to 3.9 m^{-2}in 2018-19; similarly, at Khurpatal, worm density ranged from 3.25 m^{-2} to 28.1 m^{-2} in 2017-18 and 0.2 m^{-2} to 4.7 m^{-2} worm density during the year 2018-19. In 2017-18Government golf field earthworm biomass ranged from 1.3$gm^{-2}$to 11.5gm^{-2}, at Chanfi 1.5 to 4.7 and Khurpatal was 1.6 gm^{-2} to 8.7 gm^{-2}. In 2018-2019, atthe government golf field,it ranged from 0.1 gm^{-2} to 8.5 gm^{-2}. At Chanfi, earthworm biomass ranged from 0.2 gm^{-2} to 0.45 gm^{-2} and earthworm biomass at Khurpatal ranged from 0gm^{-2} to 1.3 gm^{-2}.

Age structure

Ingrassland soil, the aclitellates and clitellates worms of two age classes were analyzed to understand the age structure. The mean yearly ratio of *A. alexandri* was 1:7.3. During both years, the number of clitellate worm was lower than that of aclitellate. The age structure of *A. diffringens* and *Eisenia fetida* was not studied due to their negligible presence in terms of numbers at research site, the age structure analysis showed that clitellate worms were more at Chanfithan Khurpatal crop fields.

DISCUSSION

During the present investigation, the C: N ratio varied with the change in the soil depth, i.e., 0-10 cm and 10-20 cm soil layers; it established that changes occur in C:N ratio with the change in depth, pH, land type it indicates that nutrient dynamic in topsoil is in dynamic mode.It was also observed that the C:N ratio was usually higher in soil depth 0-10cm than 10-20cm in both cropland and Grassland.

A healthy andfertile soil usually has the C:N ratio from 9:1 to 21:1, which falls in the ca. Similar kind of observations have been made by various researchers in different soil systems, including forest and grassland ecosystems, the studies also substantiated the findings of the present study (Martinucci and Sala, 1979; Tsukamoto, 1985; Kaushal & Bisht, 1994, Kaushal et al., 1995). The density and biomass of earthworms was higher in 0-10cm depth of the soil than 10-20cm depth in all study sites from 2017-2018 to 2018-2019. While

observing the worm maturity, itwas observed that inthe year 2017-18 Clitellate worms were higher during the rainy season followed by the winter season (Table 3). In 2018-19 clitellate worms were higher in the summer season followed by the winter season and minimum in the rainy season, where as a clitellate worms were higher inthe winter season followed by the summer season and minimum during the rainy season (Table 4). During the present study, the most dominant earthworm species recorded was *Amynthas alexandri*. This is an exotic species and is available in most of the places of Kumaun region (Julka, 1986a, b). The species richness observed in the present study was low compared to those reported from other areas of Uttarakhand.

The seasonal dynamics in the annual cycle show the numbers of earthworms and biomass were higher during the rainy season and agradual decline in number during the winter season, even wholly absent during the second half of January and February, when soil temperature decreases (4.9-6.2°C). (Kale & Karmegam, 2010; Dash & Patra, 1977; Kale & Krishnamoorthy, 1982; Mohanjit, 1986) also reported similar trends thatthe maximum number of earthworms and biomass produced during the rainy and late rainy periods. It was also observed that clitellate worms were consistently more in number than aclitellates throughout the study period.

The earthworm population recorded in the agricultural system at both sites was low due to frequent ploughing.Ploughing usually decreases the earthworm population in various agricultural farms and farmlands (Low, 1972). Evans and McG uild, 1948; Edward and Lofty, 1978 also reported a fall in population density owing to the gradual decrease of organic matter with repeated arable cropping. (Nordstrom, 1975;Calvin and Cosin, 1985)recorded that the seasonal activity of Lumbricids as being regulated by soil factors.In the study it was observed specially in Chanfi and Khurpatal which are highly affected by anthropogenic and other agricultural activities showed the declining trend in the number of worms in comparison to Grassland studied; this observation reflects that earthworm density decreases due to mechanical injuries during tillage and exposure of earthworms to predators like birds.

While analyzing the habit preference, it was observed that earthworm *Amynthas alexandri* likes mineral-rich soil and produces earthworm cast on the soil surface. In both sampling years, i.e., 2017-2018 and 2018 -2019, 63% to 67% of the specimens recorded samples from 0-10 cm soil depth and 44 to 45% were recorded from 10-20cm soil depth.Earthworm biomass was also recorded in both soil monoliths 0-10cm and 10-20cm; the proportion of biomass in the 0-10 cm layer was higher (83.7% and 62.1%) than that of 10-20 cm soil layerduring the year 2017 -2019. (Table 3-4).Most of the findings on earthworm ecology stated that worms exclusively thrive in topsoil 0-50cm soil depth; out of it 80% live in 0 to 30 cm depth (Nordstrom and Rundgren, 1973; Bouche, 1977b; Aina, 1984; Matoet al., 1988; McCredieet al., 1992). The data on the vertical distribution of the earthworm population obtained during the present study gave similar results as observed by many researchers, (Phillips, 2019; Singh, 2020; Sohrabi, 2021; Li et al., 2021; Nahberger et al., 2021). It is evident from the present study that habitat preference, organic matter, and soil type, including human activities, affect the earthworm population.

CONCLUSION

The study characterized the distribution and dynamics of earthworms in 0-20cm depth for two years in two land-use systems i.e., Cropland and Grassland. In the grasslands, earthworm density was highest during all the seasons in both study years, and in terms of seasons, earthworm density was recorded highest during the rainy season followed by summer and winter seasons. No worms were recorded in the Khurpatal in Summer and winter seasons in 2017 – 2018. It indicates that this is the hibernation time of earthworms when usually they get coiled in the burrows. More studies are recommended in this area to explore the role of earthworms in nutrient dynamics in mountain agriculture and forest management.

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Conflict of Interest

Authors have no conflict of interest.

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