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Diversity of Soil Dwelling Collembola in a Forest, Vegetable and Tea Ecosystems of Assam, India

Sudhansu Bhagawati [1,*], Badal Bhattacharyya [1], Binoy K. Medhi [2], Snigdha Bhattacharjee [1] and Himangshu Mishra [3]

1 Department of Entomology, Assam Agricultural University, Jorhat 785013, Assam, India; badal.bhattacharyya@aau.ac.in (B.B.); snigdha.bhattacharjee@aau.ac.in (S.B.)
2 Department of Soil Science, Assam Agricultural University, Jorhat 785013, Assam, India; binoy.medhi@aau.ac.in
3 Krishi Vigyan Kendra, Assam Agricultural University, Karimganj 788712, Assam, India; himangshu.mishra@gmail.com
* Correspondence: sudhansubhagawati@gmail.com; Tel.: +91-60018-91159

Abstract: Land use change has a great impact in determining the diversity patterns of soil fauna. Adoption of any land use pattern significantly affects the soil structure and its physico-chemical characteristics, which often leads to the loss of biodiversity. Considering the collembolans as the key organism in the indicator shopping basket of soil environment, the response of Collembola communities under three different land uses represented by forest, vegetable and tea ecosystems was studied. Collembolans were sampled at monthly intervals using Tullgren funnel and identified by standard taxonomic keys. Diversity analysis and soil chemo-edaphic factors were studied to establish the impact of different land uses on Collembola communities. Five genera of Collembola *viz*., *Cyphoderus*, *Entomobrya*, *Isotoma*, *Folsomia* and *Hypogastrura* were recorded from the forest ecosystem whereas *Folsomia* was completely absent in vegetable ecosystem and the tea ecosystem soil was devoid of both *Folsomia* and *Hypogastrura*. Seasonal diversity and density of Collembola were recorded to be higher in the forest ecosystem indicating the presence of relatively stable habitats as compared to vegetable and tea ecosystems showing relatively disturbed habitats. Correlation studies between different chemo-edaphic factors and collembolan population revealed that the moisture and organic carbon content of soil had significant positive correlation during all the four seasons in all the ecosystems studied. Higher adoption of mechanical and chemo-centric agriculture depletes the available resources of the soil and makes it less habitable and conducive for the growth and sustenance of collembolans in vegetable and tea ecosystem as compared to forest. Appropriate landscape planning, land management strategies and developing proper methods of land use practices may pave the way for the improvement of collembolan diversity at landscape level.

Keywords: density; ecosystem; edaphic factors; seasonal variation; springtails

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1. Introduction

Soil is a living entity that serves as the primary nutrient base and the unique habitat of a multitude of organisms. These soil fauna, commonly recognized as the ecosystem engineers, have spectacular effects on the soil functioning and development system. However, anthropogenic modifications of the soil mostly related to land use practices has often led to the loss of biodiversity of the soil organisms. Land use practices repeatedly alter both the soil structure, as well as the chemo-edaphic factors, which finally exert some negative influences on the soil fauna [1]. Among the soil fauna, collembolans can be considered as the key organism in the indicator shopping basket of soil environment due to their quick response towards various environmental changes including human induced disturbances [2].

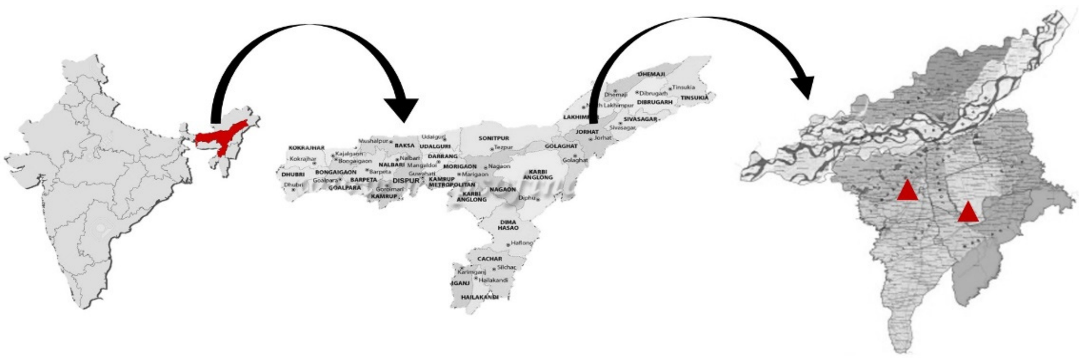
Collembola, commonly known as springtails, are small apterygote hexapods mostly occurring in large numbers in the surface and subsurface layers of the soil. Approximately 8143 described species of collembolans belonging to 764 genera and 19 families have been reported globally, whereas Indian Collembola fauna is represented by 301 species under 109 genera belonging to 19 families [3]. Collembola diversity is well represented in the soil system, which provides many ecological services, like feeding the dead organic substances and plant parasitic microorganisms, decomposition of plant cadavers, as well as enhancing the growth of mycorrhizae [4]. Despite being a potential candidate of "Ecosystem service providers", collembolan community structure is gradually changing due to various anthropogenic activities. Changes in the collembolan community structure due to the gradient of different land uses have already been well established in different corners of the globe [5–8].

Despite the existing valuable information, the collembolan community structure of Assam is yet in infancy. Moreover, being the "Biodiversity hotspot", as well as "Organic hub" of India, the rich treasure of collembolan diversity in Assam cannot be overlooked. In the present study, efforts were made to fulfil the gap by analysing the response of Collembola communities under three different land uses represented by forest, vegetable and tea ecosystems. Especially, this paper aims to analyse the linkage between changes in land use pattern and their possible impact on collembolan biodiversity, which may be helpful for the development and implementation of conservation strategies, as well as monitoring of natural and human disturbed landscapes.

2. Materials and Methods

2.1. Site Description

Investigations were carried out at three different ecosystems, i.e., forest, vegetable and tea ecosystems of Jorhat, Assam, India. Soil samplings were carried out at the Hoollongapar Gibbon Sanctuary (26°40′ N and 94°19′ E) as forest ecosystem, whereas vegetable and tea ecosystem soils were drawn from Instruction Cum Research Farm and Experimental plot for plantation crops, respectively, situated at Assam Agricultural University, Jorhat (26°72′ N and 94°19′ E) (Figure 1). The study sites were located in a subtropical zone where mean temperature ranged between 30–35 °C during summer and 10–15 °C during winter. The average annual rainfall of the study area is more than 2000 mm with approximately 85% humidity. The pre-monsoon shower starts from mid-March onwards, reaching peak during June and continues up to September. The average soil moisture generally ranges from 16.1% to 24.31% [3]. Figure 2 below summarizes the monthly meteorological data of the examined period, i.e., March 2017 to February 2018, collected from the India Meteorological Department recognized Agrometeorological Observatory, Department of Agricultural Meteorology, Assam Agricultural University, Jorhat.



(**a**) (**b**) (**c**)

Figure 1. Map indicating the location of the study sites. (**a**) Map of India highlighting Assam; (**b**) map of Assam highlighting Jorhat district; (**c**) map of Jorhat highlighting the location of the study sites.

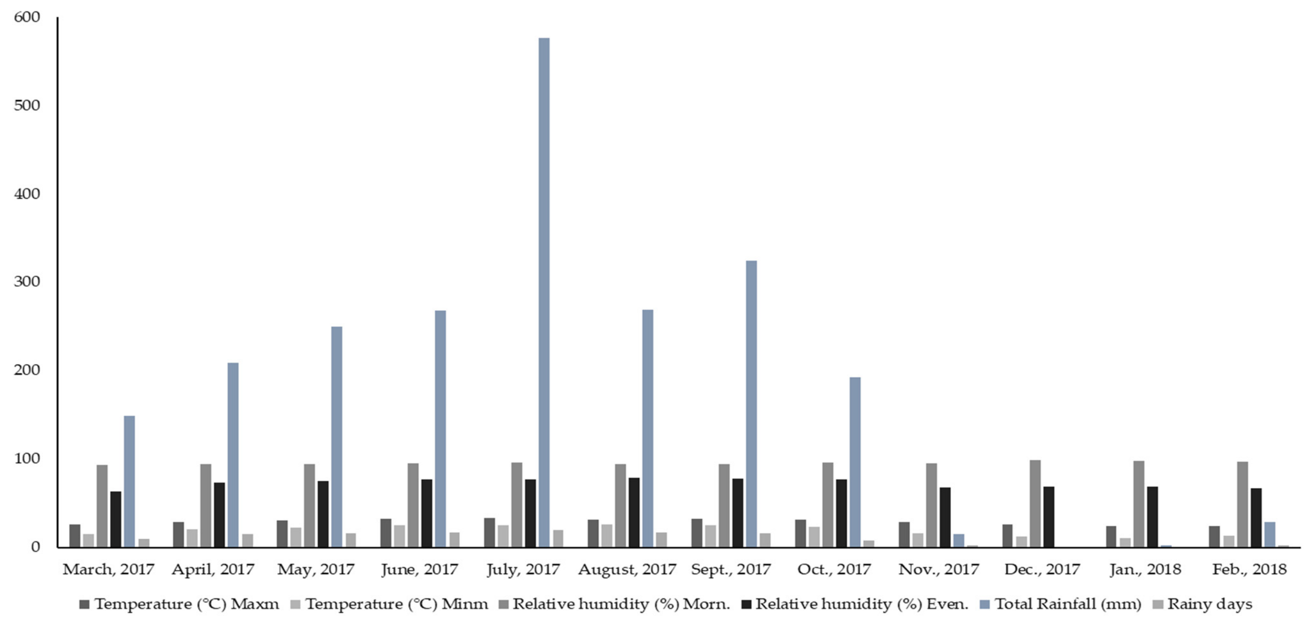


Figure 2. Monthly meteorological data of the study period.

2.2. Collection of Soil Samples

Soil sampling was done at each of the ecosystems in four seasons (spring, summer, autumn and winter) between March 2017 and February 2018. Samples were collected with the help of rectangular soil sampler (30 cm × 11 cm × 8 cm) at a constant depth of 0–10 cm [9]. Ten samples were collected per sampling during each season. Without disturbing the soil profile, the soil was taken out from the sampler and then soil samples were properly sealed, tagged and transported to the Laboratory of Soil Arthropod Pests, Department of Entomology, Assam Agricultural University, Jorhat for the extraction of Collembola.

2.3. Extraction and Identification of Collembolans

Extraction of soil microarthropods was done by Tullgren funnel operated through Tungsten bulbs (40 Watt) kept at high light intensities for 72 hrs [10]. Soil microarthropods were collected in collection tubes (40 mL) containing 70 per cent ethyl alcohol and was transferred into clean Petri dish (15 cm diameter) for separation of collembolans. Collembolans were then examined under a Stereozoom Microscope (Model: Carl Zeiss Stemi 2000-C; Magnification: 5× and above) and identified by using standard taxonomic keys proposed by Santeshwari et al. [11]. The identified collembolans were further classified into three life-form groups, i.e., epigeic, hemiedaphic and edaphic, based on the ecomorphological characters [8]. Relative abundance and frequency of the collembolans genera, as well as the seasonal fluctuation of total collembolan density in each ecosystem were calculated out [4,12].

2.4. Analysis of Soil Physicochemical Properties

Three soil samples were also collected in each season from each of the ecosystems for the analysis of soil physico-chemical properties. The physicochemical properties of collected soil samples were determined at the laboratory of All India Coordinated Research Project on Water Management, Department of Soil Science, Assam Agricultural University, Jorhat, India. International pipette method was used for mechanical analysis of the soil [13]. Moisture content of the samples was determined by following the standard AOAC [14] whereas bulk density was determined from the soil cores [15]. Organic carbon and soil microbial biomass carbon were determined by dichromate oxidation method [16] and fumigation extraction method [17], respectively.

2.5. Statistical Analysis

Diversity of collembola in three different ecosystems were established by calculating the Shannon-Weiner Index, Simpson Diversity Index and evenness, respectively [18–20]. The density data of collembolans were analysed using analysis of variance (ANOVA) for randomized block design [21] whereas simple correlation and regression was done to understand the effect of different soil physico-chemical properties on collembolan population and the p value was calculated for statistical significancy at $p < 0.05$ and $p < 0.01$.

3. Results

3.1. Species Composition and Relative Abundance

A total of 4186 specimens were extracted from the three ecosystems and identified as five genera, i.e., *Cyphoderus*, *Entomobrya*, *Isotoma*, *Folsomia* and *Hypogastrura*, representing four families, i.e., Cyphoderidae, Entomobryidae, Isotomidae (includes both *Isotoma* and *Folsomia*) and Hypogastruridae. During the study period, a change in the composition of collembolans along the land use gradient was observed in which all the five genera were only recorded in the forest ecosystem. Collembolan composition in the vegetable ecosystem was found to be similar except for the absence of *Folsomia* whereas not a single individual of either *Folsomia* or *Hypogastrura* was recorded from the tea ecosystem. *Cyphoderus* genus was most frequently sampled registering 54.84%, 43.18% and 56.00% in forest, vegetable and tea soil, respectively (Figure 3). *Cyphoderus* genera also showed highest frequency of occurrence (52.05%), followed by Isotoma (21.00%) and Entomobrya (15.38%). Rest of the two genera, i.e., *Hypogastrura* and *Folsomia*, recorded an accumulative frequency of less than 10% (Table 1). Altogether, 17 eco-morphs of collembolans were recorded during the study period in which a predominance of epigeic group of springtails was observed, followed by hemiedaphic and edaphic groups in all the three ecosystems (Figure 4).

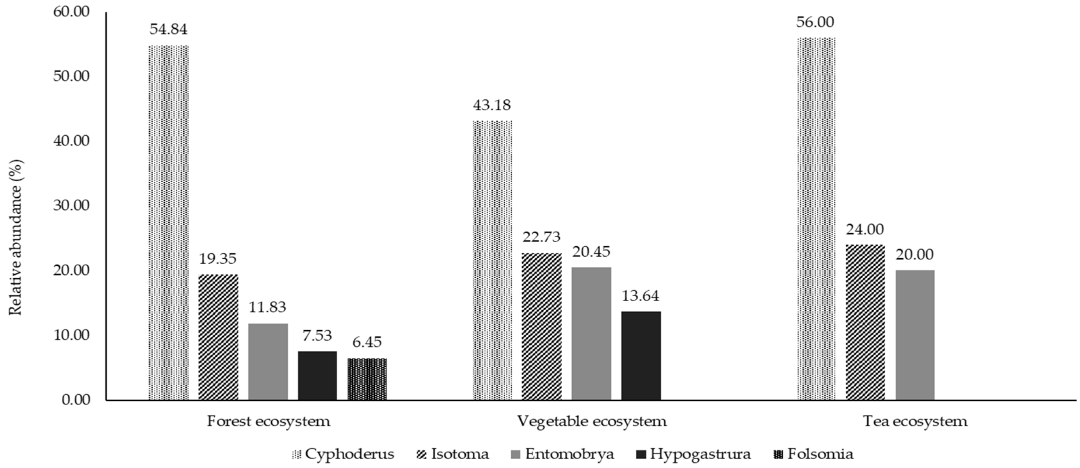


Figure 3. Per cent relative abundance of identified collembolans in forest, vegetable and tea ecosystems.

Table 1. Frequency of occurrence of Collembola in different land use systems.

Genera	Number of Collembola	Accumulative Frequency	Cumulative Frequency
Cyphoderus	2179	52.05	52.05
Isotoma	879	21.00	73.05
Entomobrya	644	15.38	88.43
Hypogastrura	333	7.96	96.39
Folsomia	151	3.61	100.00
Total	4186	100.00	

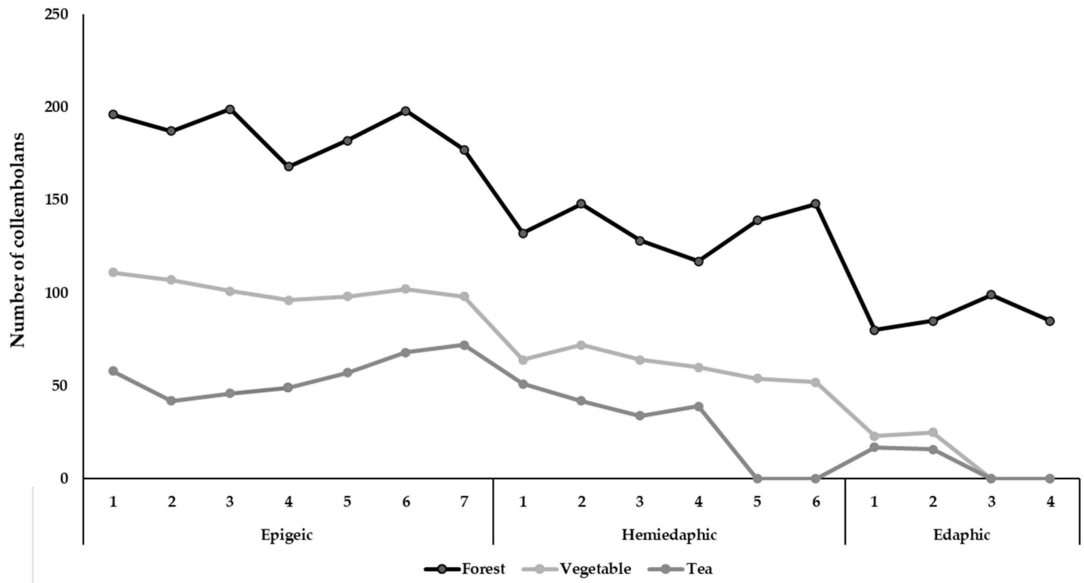


Figure 4. Eco-morph composition of collembolans in forest, vegetable and tea ecosystems.

3.2. Seasonal Fluctuation of Collembolan Community Diversity and Density

Diversity of collembola studied through Shannon-Wiener Index revealed the highest diversity in forest ecosystem (H′ = 1.41–1.48) indicating favourable ecological niche for the collembolans as compared to vegetable growing land (H′ = 1.19–1.33) and tea ecosystem (H′ = 0.95–1.05) suggesting relatively disturbed habitats (Figure 5a). The Simpson Index of Diversity (1-D) in all the three ecosystems, i.e., forest, vegetable and tea ecosystem exhibited a seasonal trend of increasing values from spring (0.65, 0.75 and 0.67) to summer (0.81, 0.90 and 0.85) and autumn (0.71, 0.87 and 0.83), which gradually decreased during winter (0.60, 0.70 and 0.62), respectively (Figure 5b). Evenness values of the individuals of each genus was closer to 1 denoting equal distribution of the collembolans in all the ecosystems during all the seasons (E = 0.72–0.96).

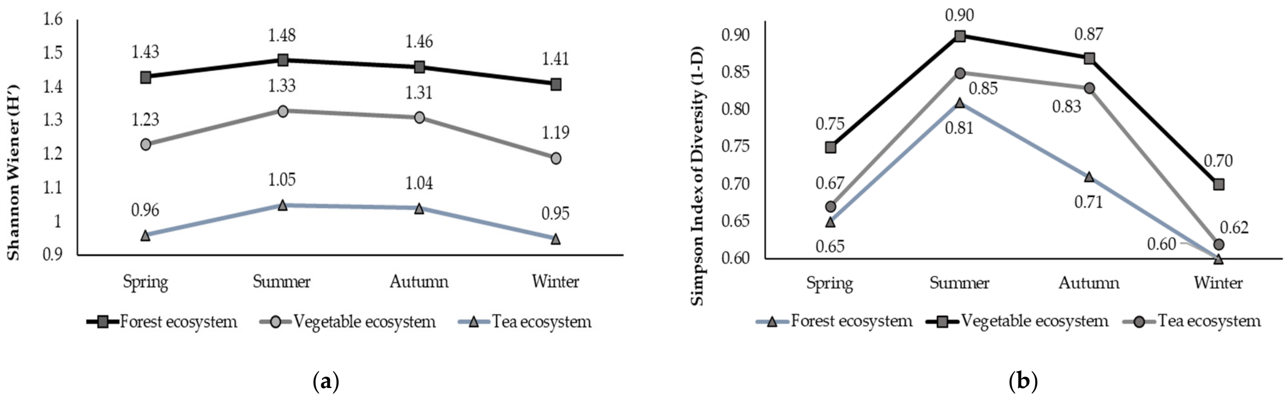


Figure 5. Seasonal fluctuation of collembolan diversity in forest, vegetable and tea ecosystems.

Comparatively higher density of collembola was recorded in the forest ecosystem, which differed significantly ($p < 0.05$) from vegetable and tea ecosystems during all the seasons (Table 2). Season wise, the highest density of collembolans (340.91, 172.73 and 86.36 numbers/m^2) was registered during the summer season followed by autumn (252.73, 125.45 and 62.73 numbers/m^2) and spring (161.82, 50.91 and 31.82 numbers/m^2) whereas the lowest density was recorded during the winter season (81.82, 34.55 and 20.00 numbers/m^2) in forest, vegetable and tea ecosystem, respectively.

Table 2. Seasonal variation of collembolan density in forest, vegetable and tea ecosystems.

Ecosystems	Seasonal Density (Number of Collembolans/m^2) (Mean ± SD)			
	Spring	Summer	Autumn	Winter
Forest	161.82 ± 20.91	340.91 ± 58.17	252.73 ± 36.57	81.82 ± 17.67
Vegetable ecosystem	50.91 ± 13.00	172.73 ± 30.60	125.45 ± 18.08	34.55 ± 11.18
Tea ecosystem	31.82 ± 9.82	86.36 ± 19.28	62.73 ± 6.71	20.00 ± 5.75
S.Ed(±)	9.37	22.54	16.41	5.48
CD ($p < 0.05$)	19.68	47.35	34.49	11.52

SD: standard deviation; S.Ed: standard error of difference; CD: critical difference.

3.3. Effect of Physicochemical Properties of Forest, Vegetable and Tea Ecosystem Soil on Density and Diversity of Collembola

Key soil chemo-edaphic factors were correlated with both the density and diversity of collembolans in each ecosystem. Key soil properties like moisture and organic carbon content, soil microbial biomass carbon, as well as pH were recorded higher in forest soil as compared to vegetable and tea ecosystem soil (Table 3). Season wise, soil moisture and organic carbon content of all the ecosystem soil showed a trend of increasing pattern from spring to summer which gradually decreased during autumn and recorded lowest in winter. pH was ranged between 4.8–5.9 indicating a slightly acidic soil with bulk density ranged between 1.32–1.44 g/cc in all the ecosystem soil during the period of study.

Density and diversity of collembolans showed significant positive correlation ($p \leq 0.05$ and $p \leq 0.01$) with soil moisture and organic carbon in all the ecosystems during all the seasons (Tables 4 and 5). Rest of the soil physicochemical properties, i.e., per cent of sand, silt and clay content, soil microbial biomass carbon, pH and bulk density did not exhibited any distinct significant relationship with density and diversity of collembolans in the selected ecosystems during all the four seasons, except the case of soil microbial biomass carbon (r = 0.899) of vegetable growing land during spring which exhibited an exceptional significant positive relationship ($p \leq 0.05$) with collembolan density.

Table 3. Collembolan density and diversity along with soil properties in three different land use systems.

Soil Property	Forest Ecosystem				Vegetable Ecosystem				Tea Ecosystem			
	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win
	(Mean ± SD)											
Den (Nos./ m^2)	161.82 ± 20.9	340.91 ± 58.1	252.73 ± 36.5	81.82 ± 17.6	50.91 ± 13.0	172.73 ± 30.6	125.45 ± 18.08	34.55 ± 11.1	31.82 ± 9.8	86.36 ± 19.2	62.73 ± 6.7	20.00 ± 5.75
Div (1-D)	0.65 ± 0.01	0.81 ± 0.02	0.71 ± 0.01	0.60 ± 0.01	0.75 ± 0.01	0.90 ± 0.01	0.87 ± 0.01	0.70 ± 0.01	0.67 ± 0.01	0.85 ± 0.01	0.83 ± 0.01	0.62 ± 0.01
Sand (%)	44.2 ± 2.53	43.9 ± 2.39	44.3 ± 1.77	44.2 ± 1.71	71.2 ± 1.27	70.3 ± 0.71	71.7 ± 0.82	74.5 ± 0.54	55.6 ± 0.48	48.1 ± 0.88	54.6 ± 0.94	51.2 ± 1.10
Silt (%)	29.3 ± 1.12	30.9 ± 1.30	30.3 ± 1.12	30.4 ± 0.74	16.7 ± 0.71	16.3 ± 0.51	15.4 ± 0.50	13.2 ± 0.41	32.6 ± 0.70	34.7 ± 0.84	31.8 ± 0.87	30.4 ± 0.49
Clay (%)	26.5 ± 2.14	25.2 ± 1.55	25.4 ± 0.77	25.4 ± 0.85	12.1 ± 0.57	13.4 ± 0.61	12.9 ± 0.52	12.3 ± 0.38	11.8 ± 0.45	17.2 ± 0.44	13.6 ± 0.40	18.4 ± 0.31
SM (%)	33.20 ± 2.33	37.11 ± 0.36	34.17 ± 1.03	31.52 ± 0.67	24.22 ± 0.45	25.39 ± 0.64	24.50 ± 0.38	23.58 ± 0.44	23.45 ± 0.47	27.15 ± 0.56	25.65 ± 0.55	22.55 ± 0.70
OC (%)	0.82 ± 0.05	0.89 ± 0.03	0.85 ± 0.02	0.81 ± 0.03	0.46 ± 0.02	0.53 ± 0.02	0.49 ± 0.03	0.42 ± 0.02	0.33 ± 0.03	0.40 ± 0.01	0.37 ± 0.04	0.31 ± 0.02
SMBC (μg/g)	154.67 ± 0.40	158.18 ± 0.62	162.45 ± 0.81	157.22 ± 1.35	119.41 ± 1.06	113.24 ± 0.72	117.19 ± 0.88	116.73 ± 0.43	75.57 ± 0.50	78.72 ± 0.72	77.28 ± 0.68	87.22 ± 0.86
pH (1:2.5)	5.8 ± 0.09	5.9 ± 0.07	5.7 ± 0.07	5.6 ± 0.07	5.4 ± 0.22	5.1 ± 0.11	5.1 ± 0.11	5.3 ± 0.16	4.9 ± 0.34	4.8 ± 0.29	4.8 ± 0.29	5.1 ± 0.11
BD (g/cc)	1.33 ± 0.01	1.39 ± 0.02	1.35 ± 0.02	1.34 ± 0.01	1.43 ± 0.01	1.38 ± 0.02	1.36 ± 0.02	1.36 ± 0.02	1.44 ± 0.01	1.35 ± 0.02	1.39 ± 0.02	1.32 ± 0.01

Den: density; Div: diversity; Spr: spring; Sum: summer; Aut: autumn; Win: winter; SM: soil moisture; OC: organic carbon; SMBC: soil microbial biomass carbon; BD: bulk density; soil properties are mean of 3 samples.

Table 4. Correlations between collembolan density and soil properties in three different land use systems.

Soil Property	Forest Ecosystem				Vegetable Ecosystem				Tea Ecosystem			
	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win
Sand (%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Silt (%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Clay (%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SM (%)	0.941 **	0.821 *	0.915 *	0.922 *	0.914 *	0.868 *	0.943 **	0.857 *	0.974 **	0.868 **	0.852 *	0.886 *
OC (%)	0.937 **	0.962 **	0.801 *	0.965 **	0.777 *	0.856 *	0.944 **	0.967 **	0.914 *	0.923 *	0.874 *	0.807 *
SMBC (μg/g)	NS	NS	NS	NS	0.899 *	NS	NS	NS	NS	NS	NS	NS
pH (1:2.5)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BD (g/cc)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Spr: spring; Sum: summer; Aut: autumn; Win: winter; SM: soil moisture; OC: organic carbon; SMBC: soil microbial biomass carbon, BD: bulk density; NS: non significant; ** $p \leq 0.01$; * $p \leq 0.05$.

Table 5. Correlations between collembolan diversity and soil properties in three different land use systems.

Soil Property	Forest Ecosystem				Vegetable Ecosystem				Tea Ecosystem			
	Spr	**Sum**	**Aut**	**Win**	**Spr**	**Sum**	**Aut**	**Win**	**Spr**	**Sum**	**Aut**	**Win**
Sand (%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Silt (%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Clay (%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SM (%)	0.928 **	0.890 *	0.881 *	0.919 **	0.710 *	0.669 *	0.752 *	0.942 **	0.923 **	0.771 *	0.773 *	0.836 *
OC (%)	0.907 **	0.921 **	0.645 *	0.964 **	0.823 *	0.873 *	0.726 *	0.887 *	0.823 *	0.836 *	0.634 *	0.903 *
SMBC (μg/g)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
pH (1:2.5)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BD (g/cc)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Spr: spring; Sum: summer; Aut: autumn; Win: winter; SM: soil moisture; OC: organic carbon; SMBC: soil microbial biomass carbon, BD: bulk density; NS: non significant; ** $p \leq 0.01$; * $p \leq 0.05$.

4. Discussion

In the present study, a decreased pattern of collembolan density and diversity in a gradient of land use pattern, ranging from a forest ecosystem with minimum interventions to vegetable growing areas and tea plantation sites with complete exposure to anthropogenic disturbances has been well established. An important result obtained in the study is that the forest ecosystem soil harboured a rich composition of collembolan species as compared to vegetable and tea ecosystem soil. In addition, diversity analysis as depicted in Figure 5 also confirmed the higher diversity of collembolan community in the forest than the vegetable and tea growing lands. Occurrence of relatively stable habitats in forest generally ensures the availability of moisture, organic matter and other nutrients for the collembolans which improved the species richness as compared to the vegetable and tea ecosystems [9,22]. Usually, the agricultural soil is frequently subjected to continuous disturbances like tillage operations and harrowing which leads to the drying of the uppermost layers, as well as remove the litters from the soil surfaces, making the ecological niche quite unfavourable for the soil fauna [23,24]. Adoption of chemo-centric agriculture as well as injudicious application of synthetic pesticides in tea plantations for biotic stress management also alters the chemical properties of the soil and exerts lethal impact on collembolan population [25,26].

Seasonal variation of collembolan density and diversity presented in Figure 5 and Table 1 confirmed the positive response of collembolans towards summer season compared to the other seasons in all the land use types, as reported earlier by other authors [27–29]. During summer, the collembolan population coincided with the maximum proportion of soil moisture due to the prevalence of monsoon season. Raised soil moisture coupled with temperature, increased the rate of litter and organic matter decomposition during summer which accelerated the release of carbon in soil and made a congenial environment for the collembolan assemblages [30,31]. Short term increase in the soil temperature during summer might have also positively influenced the abundance of soil dwelling collembolans [32].

Another important finding in this study is that both the collembolan density and diversity as presented in the Tables 3 and 4 revealed a significant positive correlation with moisture and organic carbon content of soil during all the four seasons in all the land use systems. The relationship of collembolan community with moisture and organic carbon content of soil can be related to the involvement of collembolans in the decomposition of dead organic materials [33]. Conversion of such decomposed matter into organic carbon and their further deposition in the topsoil served as source of sufficient nutrients and provide a healthy ecological niche for the collembolans [34]. Moisture content of topsoil also determines many physiological activities of collembolans and thereby influenced their growth and development [35,36]. During the study period, collembolans were sampled from the top layers of the soil and their congregation in the top 0–10 cm layer of soil can be related to the availability of sufficient organic matter and moisture which favors their growth and development [37]. Moreover, organic matter and water content of soil together exerted direct or indirect influence on the collembolan fauna by maintaining the soil reaction, controlling humification and stimulating the growth of micro and macro flora [38]. The increased population of Collembola with the increase in organic matter and moisture content of soil as observed in the present investigation was also reported by Hazra and Bhattacharyya [39]. However, the rest of the soil chemo-edaphic factors responded positively but non-significantly towards density and diversity of collembolans irrespective of the ecosystem and season. In the present study, availability of soil carbon to microbial community through collembolans' litter decomposition process was not established [8], except for the spring season in the vegetable ecosystem. Seasonal soil samples collected from the three land use systems were mostly acidic in nature with bunk density ranging between 1.32–1.44 g/cc, which perhaps failed to exert any direct significant impact on collembolan population [3,4].

Ecologically, collembolans pose a strong interaction with both biotic and abiotic matters and often exert a strong response towards environmental and spatial factors [40]. It is evident from the present study that the collembolans are the good indicators of different land use intensities and hence, their diversity can be explored to understand the gradient of soil disturbances. Knowing this fact, alternative method of land use practices may be standardized for the sustainable soil health management to maintain soil biological communities and ecosystem resilience.

5. Conclusions

In this study, information has been provided on the density and diversity of collembolans in three land use systems of Assam, India. From the current study, it is evident that Collembola communities are good indicators of land use intensity as higher density and diversity was recorded in forest ecosystems as compared to vegetable and tea cultivated soil. This might be indicative of comparatively lower intensity of disturbances and stable habitats in the forest as compared to vegetable and tea ecosystems having continuous disturbances like tillage, harrowing, irrigation, fertilizer and pesticide application, etc., which alter the physicochemical properties of soil and finally make the soil less habitable to the collembolans. Based on the results obtained from this study, as well as considering the importance of collembolans in soil genesis, alternative methods of land use practices may be adopted to support the fauna below ground soil. Although collembolans represent a small fraction among the soil biota, maintaining their sustainable growth and development in soil finally determines the soil ecosystem resilience. Hence, concerted efforts should be given on this aspect, as well as on the systematics of collembolans to overcome the taxonomic impediments in the country. In this study, soil moisture and organic carbon significantly increased the density and diversity of the collembolans, but other chemo-edaphic factors did not significantly affect the community. The moisture content of soil and organic carbon together played an important role either directly or indirectly on collembolan biology by maintaining soil reaction, controlling humification and stimulating the growth of other micro, meso and macro flora and fauna, but further controlled experiments are still needed to test this aspect. During the course of this study, it was also realized that the different key soil enzymes viz., dehydrogenase, phosphomonoesterase, β-glucosidase, urease, arylsulphatase and arylesterase may also exert some effects on collembolan density and diversity and so far, no research has been reported on this aspect. Thus, for the future study, more attention should be paid to the possible effects of key soil enzymes on collembolan community.

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