Microarthropod community structures (Oribatei and Collembola) in Tam Dao National Park, Vietnam

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A study on the microarthropod community with special reference to species diversity of Oribatid and Collembola communities (Microarthropoda: Oribatei and Collembola) in Tam Dao National Park of Vietnam, a subtropical evergreen broad leaf alpine forest, was undertaken with the aim to explain how they are related to forest decline, and whether they can be used as bioindicators of forest plant succession.

The results have shown that microarthropod community structures, particularly species diversity of oribatid and collembolan communities, are related to forest decline. Therefore they can be used as bioindicators of forest plant succession. In Tam Dao National Park, there was an inverse relation between species diversity of the oribatid and collembola communities. The species diversity of the oribatid community gradually decreased with forest decline whereas the species diversity of the collembola community gradually increased.

1. Introduction

Oribatids (Acari: Oribatei) and collembolans (Insecta: Collembola) are small arthropods (body size of 0·2–2·0 mm) which live a free existence, mainly in soils but not infrequently in wet biotopes. These soil animals are widely distributed around the world, playing a biological role of great importance both in natural and agricultural ecosystems. In recent years, much attention has been paid to them, especially because of their sensitivity to several chemicals used in agriculture. Oribatid mites and collembolans form the main part of soil microarthropods in terms of number of individuals and species. By their very number they play an important role in several soil processes, such as organic matter decomposition, material and energy cycles and soil formation. They also act as vectors of numerous parasites. As a dominant component of soil organisms, they are obviously suitable bioindicators (Peterson and Luxton 1982; Lee and Pankhurst 1992; Haq 1994).

Oribatid mites (Acari) are one of the richest acarine groups. Berlese (1913) first studied the oribatid fauna of Indonesia at the beginning of the 20th century. After that, for a long time there was no intensive work on this group of soil mites in southeast Asia. In the 1960s investigation on oribatids of this region started again, with the works of Csiszar (1961), and Balogh and Mahunka (1968) from Indonesia, Aoki (1965a, b, 1967a, b) from Thailand and the Philippines, as well as Balogh and Mahunka (1967) from Vietnam. The collembolan fauna of the region had been studied by Borner (1913), Dennis (1934, 1935, 1948), Delamare-Debouteville (1948), Yosii (1961) and Stach (1965). In the last few decades, considerable work in Asian countries including India, has been undertaken on soil microarthropods (Imadate and Kira 1964; Bhattacharya 1974; Bhattacharya *et al* 1982; Chiba *et al* 1975; Sarkar 1990). In recent years, studies have been done on the faunal composition, population densities, spatial and vertical distribution of soil microarthropods in Vietnam (Vu *et al* 1985, 1987, 1993; Vu 1995; Nguyen *et al* 1988; Nguyen 1995). But there have been no thorough studies on these groups in relation to the decline of forest ecosystems. At present over 6000 oribatid species in over 1000 genera have been recorded in the world.

Keywords. Collembola; forest decline; microarthropod; Oribatei; species diversity; Tam Dao National Park; Vietnam

And the number of newly discovered species increases every year. Balogh and Balogh (1992) estimated that the present number of described species may be only 20% of the actual world fauna. The known oribatid fauna of Vietnam with 167 species is only a part of the actually existing oribatids on Vietnamese territory (Krivolutsky *et al* 1998). Nguyen (1995) has recorded 113 collembolan species in the fauna of Vietnam.

Southeast Asia includes India and Sri Lanka, Thailand, Vietnam, Malaysia, Indonesia, the East Indies, and several other Pacific islands. This region is partly Gondwanan and partly Laurasian in origin. The region includes thousands of islands in which the climate is tropical and subtropical. The rate of speciation of the region could be high due to many different ecological niches. It is suggested that, although the region as a whole contains an appreciable element of Gondwanan oribatids, the fauna of the various islands or island groups within the region is a young one. Hammer and Wallwork (1979) believe that the source for the fauna of the south Pacific is probably southeast Asia and that dispersal has occurred over seas, via island "stepping stones".

Zoogeographically Vietnam is a highly interesting region. Although the whole country is mainly in the Oriental region, there is distinct differentiation between the northern and southern parts of the country, and even between different sub-portions of the northern or the southern part. The northern part is closer to the south Chinese mountain range which makes it possible for some Palaearctic elements to infiltrate into this area, while the southern part of Vietnam is closer to the Pacific region. The problem of deforestation in Vietnam is critical. The cost of deforestation and its ecological, social and economic impacts already far exceeds initial benefits from development (Ministry of Forestry 1995). So, this study on the soil microarthropod community with special reference to the species diversity of oribatid and collembolan communities in the Tam Dao National Park is of importance in showing how they are related to forest decline, and whether they can be used as bioindicators of forest plant succession in Vietnam.

2. Materials and methods

Tam Dao is a long mountain range running along the north-western and south-eastern direction. It lies on the boundary of Vinh Phuc, Bac Can and Tuyen Quang provinces. The highest peak, the Nord, is 1592 m above sea level. Besides, there are three other peaks, over 1300 m above sea level. From afar these three peaks look like three islands (Tam Dao). Tam Dao National Park is situated between 21°22′ and 21°42′ northern latitude, and 105°22′ and 105°44′ eastern longitude. Its area is about 36,833 ha. Tam Dao National Park has a rich and diversified flora and fauna. Over 490 plant species in 130 families and 281 animal species in 84 families have been recorded for the area. Many of them are very rare, precious and of high economic and scientific value. The study site was the forest area surrounding the Tam Dao village, a habitation of about 500 people. It is located about 80 km north-northwest of Hanoi, at about 900 m above sea level. The study area is subtropical evergreen broad-leaf alpine forest of Tam Dao National Park. Its average temperature is 20–22°C, and absolute recorded temperatures range from a minimum of −0·2°C to a maximum of 33·1°C. Average annual rainfall for the area is 2630·9 mm, more than 90% of which is received during the rainy season, from June till September. Average humidity of the area is 87%, average evaporation rate is rather low, 561·5 mm per annum. The main soil type of the area is an acrisol in the northern mountainous areas, which is characteristic for the uplands and highlands of Vietnam (100–1000 m above sea level) and is derived from the decomposition of various rock types.

The study area is covered with herbs, shrubs and trees mainly of families Fagaceae, Lauraceae, Sapotaceae, Ericaceae, Magnoliaceae, Aceraceae, Theaceae and Hamamelidaceae. Especially important in the area are some trees of *Amentotaxus argotaenia* (Hance) Pilge, *Podocarpus fleuryi* (Hick.), *Podocarpus imbricatus* (Bl.) de Laubenf., *Fokenia hodginsii* (Dunn) Henry and Thomas. This forest formation fosters a development of epiphytic plants including the orchid *Aplenium nidus*, *Drynaria bonii* and others (Ministry of Forestry 1995). All undisturbed or slightly disturbed forests lie on the 600 m above sea level contour and can be divided generally into two elements: tropical lowland forest, from 600 m to 900 m above sea level and sub-mountain forest, above 900 m. The study habitat, namely natural forest is an undisturbed or slightly disturbed sub-mountain forest. V D Vu *et al* (1995) studied various basal parameters of soil and forest characteristics of this study site. The data reported here on the study site are taken from this source. Its tree canopy ranges from 40 to 60%; average height of ecologically dominant trees is 15.0 m, with between 490 to 570 primary stems, and between 5000 to 6000 secondary stems per hectare; and wood productivity is 110–130 cubic metres per hectare. Thickness of litter layer of the habitat is 3–5 cm, with total mass of 2600–5200 g per 50×50 cm^2 (average 3630 g). Analyses of the soil surface layer of 0–20 cm in natural forest showed that: pH/H_2O = 7·26; pH/KCl = 5·40; P_2O_5 (mg/100 g) = 3·80; organic matter (%) = 4·86; content (mg/100 g) of exchangeable calcium (Ca^{2+}) = 0·86, of exchangeable magnesium (Mg^{2+}) = 1·71, and of total exchangeable calcium and magnesium ($Ca^{2+} + Mg^{2+}$) = 2·57.

The human-impacted forest of the study area is the heavily disturbed forest, found mainly around human habitation. Its tree canopy ranges from 20 to 30%; average height of ecologically dominant trees is 10·0 m, with between 330 to 350 primary stems, and between 5000–5500 secondary stems per hectare; and wood productivity is 70–80 cubic metres per hectare. Thickness of litter layer is smaller than 3 cm and with total mass of 1100–3800 g per 50×50 cm^2 (average 2600 g). Shrubland includes mainly shrubs and some trees of families Rubiaceae, Myrtaceae, Euphorbiaceae, Poaceae and Caesalpiniaceae. The grassland includes herbs and grasses mainly of families Poaceae, Asteraceae and Fabaceae. The shrublands and grassland are not natural but are derived from forest loss. The cultivated land is the agricultural field surrounding habitations with mixed agricultural plants, whereas the tea plantations include only 5–7 year-old tea bushes (Theaceae: *Camelia sinensis* (L) O Ktze).

To represent a gradient in vegetation cover, samples were taken from 6 habitat types as follows: (I) natural forest, (II) human-impacted forest, (III) shrublands, (IV) grassland, (V) cultivated land, and (VI) tea plantation. For study purposes, samples of 4 vertical layers were taken in May 1995 as follows: (+ 1) decaying wood debris and moss lying on 0–100 cm above surface forest litter; (0) all of the forest litter lying on the soil surface of 50×50 cm^2; soil samples of $5 \times 5 \times 10$ cm^3, (– 1) surface layer of 0–10 cm, and (– 2) deep layers of 11–20 cm. Soil samples for (– 1) and (– 2) were taken by rectangular metal sampler, with 5×5 cm^2 surface area, 20 cm in depth and with both ends open. From habitat types (I) and (II), samples were taken from all 4 vertical layers, with 3 replicates. In habitat (III) and (IV), samples were taken only from layers (– 1) and (– 2), with 4 replicates. In habitat types (V) and (VI), samples were taken from layers (– 1) and (– 2), with 10 replicates. Modifications of Berlese-Tullgren funnels were used for extraction of soil microarthropods from the collected materials. Collembolans were not sampled in natural forest owing to sampling difficulties. An extraction lasted one week in the laboratory at normal air temperature of about 27–30°C. Details of methods are outlined in Krivolutsky (1975) and in Edwards (1991).

Jaccard's index and trellis diagrams were used and prepared to show the affinities between the microarthropod associations in study habitat types. This index is defined by the expression:

$$J\ (\%) = \frac{c}{a+b-c} \times 100,$$

where a = the number of species recorded in habitat A; b = the number of species recorded in habitat B; and c = the number of species common to both habitats A and B (Wallwork 1976).

3. Results and discussion

Table 1 presents species diversity of the oribatid community in the study area of Tam Dao National Park and their distribution according to 4 vertical layers, and 5 habitat types. The 63 species extracted from the samples are arranged in 25 families after the classification of Balogh and Balogh (1992). These families are Cosmochthonidae, Euphthiracaridae, Lohmanniidae, Epilohmanniidae, Trhypochthonidae, Liolidae, Plateremaeidae, Microtegeidae, Eremulidae, Zetochestidae, Astegistidae, Peloppiidae, Carabodidae, Tectocepheidae, Otocepheidae, Eremellidae, Oppiidae, Parakalummidae, Xylobatidae, Haplozetidae, Scheloribatidae, Oripodidae, Oribatellidae, Achipteridae and Galumnidae. There are some unidentified species of the family Galumnidae which were named as *Trichogalumna* spp. Among the 63 species, 36 are first records for the fauna of Tam Dao National Park, among which 4 species are new to the oribatid fauna of Vietnam. Newly found oribatid species for the fauna of Vietnam are *Papillacarus undirostratus*, *Eremella vestita*, *Xylobates gracilis* and *Achipteria distincta* (Berlese 1913; Aoki 1959, 1982; Jeleva and Vu 1987; Mahunka 1988).

According to the change in forest cover, the species diversity of the oribatid community decreased in the following order (table 1): from natural forest (37 species), to human-impacted forest (30 species), cultivated land (17 species), shrubland (15 species), and grassland (4 species). *Perxylobates brevisetosus* is the most widespread species in the study area, the only one (1·6% of the total) found in all of the 5 study habitat types. There are two species (3·2%), *Cosmochthonius lanatus* and *Multoppia tamdao*, common in 4 of the study habitat types. And other 7 (11·1%) and 15 species (23·8%) are common in 3 and 2 study habitat types, respectively.

Among the total 50 species found in the natural and human-impacted forests, 15 species (30% of the total) are common in the both. Between the shrubland and cultivated land the number of the common species is smaller, only 5 species (18·5% of the total).

Jaccard's index (J) was calculated to show the degree of association between the microarthropod communities in the study habitat types. The indices of species similarity of oribatid faunal associations in 5 study habitat types vary much (figure 1a) from a minimum of 2·5% between two associations in natural forest and in grassland (I and IV) to a maximum of 31·4% between two associations in natural forest and in human-impacted forest (I and II). In the trellis diagram the clear delimitation of two oribatid faunal associations is seen: the first in natural and human-impacted forests (I and II), and the second in grassland and cultivated land (IV and V). Between these two faunal associations a third, intermediary oribatid faunal association was formed in cultivated land, shrubland and

Table 1. Vertical distribution of oribatids in different habitats.

		Distribution													
		Natural forest				Human-impacted forest				Shrub-land		Grass-land		Cultivated land	
Species		+1	0	−1	−2	+1	0	−1	−2	−1	−2	−1	−2	−1	−2
1	*Cosmochthonius lanatus** Michael	+							+	+	+				+
2	*Rhysotritia ardua** (Koch)	+	+			+	+								
3	*Rhysotritia* sp.													+	+
4	*Papilacarus arboriseta** Jeleva and Vu											+			
5	*P. undrirostratus*** Aoki													+	
6	*Epilohmannia cylindrica** (Berlese)									+	+				
7	*Archegozetes* sp.													+	
8	*Loides theleproctus** (Hermann)	+	+				+								
9	*Lopheremaeus* sp.	+													
10	*Microtegeus* sp.						+							+	
11	*Eremulus* sp.									+					
12	*Zetochestes saltator** Oudemans						+								
13	*Cultroribula* sp.					+	+								
14	*Ceratoppia crassiseta* Balogh and Mahunka						+								
15	*Austrocarabodes* sp.		+					+							
16	*Tectocepheus cuspidentatus** Knulle		+	+											+
17	*T. velatus** (Michael)									+				+	+
18	*Acrotocepheus duplicornutus discrepans** Balogh and Mahunka					+									
19	*Dolicheremaeus aokii** Balogh and Mahunka		+			+	+	+		+					
20	*D. inaequalis** Balogh and Mahunka		+												
21	*D. ornata** Balogh and Mahunka					+									
22	*Dolicheremaeus* sp. 1		+												
23	*Dolicheremaeus* sp. 2		+												
24	*Fissicepheus* sp.		+												
25	*Eremella vestita*** Berlese	+													
26	*Lasiobella remota** Aoki		+												
27	*Multoppia tamdao* Mahunka		+		+		+			+				+	
28	*Multoppia* sp.			+	+										
29	*Neoamerioppia vietnamica** (Mahunka)										+				
30	*Oppia arcualis** (Berlese)			+	+										
31	*Oppiella nova** (Oudemans)						+								
32	*Pulchroppia granulata* Mahunka			+											
33	*Neoribates aurantiacus** (Oudemans)	+	+			+									
34	*Neoribates* sp. 1	+	+												
35	*Neoribates* sp. 2				+				+						
36	*Brasilobates maximum* Mahunka										+				
37	*Perxylobates brevisetosus* Mahunka				+	+		+	+	+	+	+	+	+	+
38	*Setoxylobates foveolatus** Balogh and Mahunka		+		+										
39	*Xylobates capucinus** Berlese		+		+	+		+						+	+
40	*X. gracilis*** Aoki				+			+							
41	*X. lophotrichus** (Berlese)			+										+	
42	*X. monodactylus** (Haller)		+	+	+	+									
43	*X. vietnamensis** Jeleva and Vu													+	+
44	*Xylobates* sp. 1						+								
45	*Xylobates* sp. 2													+	+
46	*Peloribates kazabi** Mahunka		+												
47	*Peloribates* sp.					+									
48	*Rostrozetes areolatus** (Balogh)											+	+	+	+
49	*Nannobates clavatus* Mahunka		+				+					+			
50	*Schaeloribates laevigatus** (Koch)					+									
51	*S. latipes** (Koch)	+				+					+				

	Species	Distribution													
		Natural forest				Human-impacted forest				Shrub-land		Grass-land		Cultivated land	
		+ 1	0	– 1	– 2	+ 1	0	– 1	– 2	– 1	– 2	– 1	– 2	– 1	– 2
52	*S. praeincisus** (Berlese)					+	+					+		+	
53	*Cosmospirnudus tridactylus** Mahunka	+													
54	*Cosmospirnudus* sp.	+													
55	*Oripoda excavatus* Mahunka	+													+
56	*Truncopes orientalis** Mahunka	+				+	+								
57	*Oribatella sculpturata** Mahunka										+				
58	*Achipteria distincta*** Aoki	+													
59	*Pergalumna granulatus* Balogh and Mahunka						+			+					
60	*P. punctulatus** Balogh and Mahunka		+	+											
61	*Pergalunna* sp.		+			+									
62	*Trichogalunina vietnamica** Mahunka					+				+	+			+	
63	*Trichogalumna* sp.	+	+			+	+		+	+	+				
	Total	14 – 21 – 7 – 9 / 37				17 – 14 – 6 – 4 / 30				11 – 9 / 15		4 – 2 / 4		14 – 10 / 17	

+ 1, Decaying wood debris and moss lying on 0–100 cm above surface forest litter; 0, Forest litter lying on the soil surface; – 1, Soil surface layer of 0–10 cm; – 2, Deeper soil layer of 11–20 cm.
*Species new to the oribatid fauna of Tam Dao National Park.
**Species new to the oribatid fauna of Vietnam.

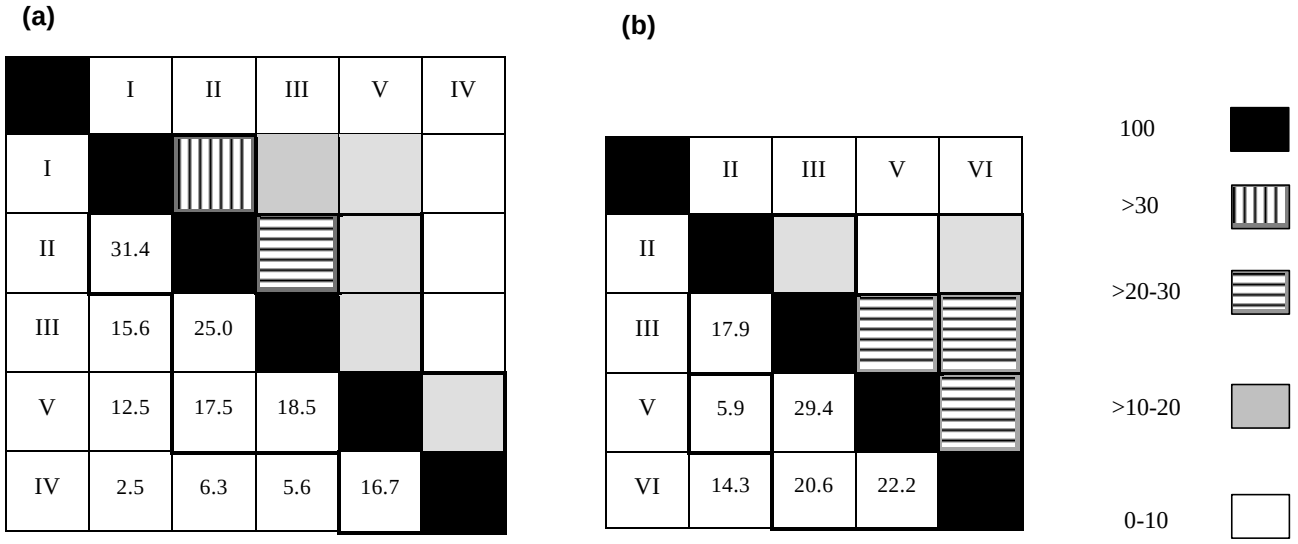

Figure 1. Trellis diagram to show the affinities between the oribatid associations (**a**) in 5 study habitat types; and between the collembola associations (**b**) in 4 study habitat types. Values are Jaccard's index. I, Natural forest; II, Human-impacted forest; III, Shrubland; IV, Grassland; V, Cultivated land; VI, Tea field.

human-impacted forest (V, III and II). According to the change in forest cover in the Tam Dao National Park, formation of 3 oribatid faunal associations was found. The trellis diagram clearly showed that the change started from natural and human-impacted forests, through shrubland and cultivated land, and ended in the grassland.

On the basis of the study material, it is found that in human-impacted habitats of Tam Dao National Park, particularly in human-impacted forest, shrubland, grassland

Table 2. Vertical distribution of collembola in different habitats.

		Distribution				
		II		III	V	VI
	Species	0	– 1	– 1	– 1	– 1
1	*Choreutinula inermis* (Tullberg)					+
2	*Hypogastrura* sp.		+	+		
3	*Xnylla maritima* Tullberg			+		
4	*Protophorura tamdaona* Nguyen			+	+	
5	*P. yodai* Yosii				+	
6	*P. hortensis* Gisin				+	
7	*P. armatus* Tullberg				+	
8	*Odontella lamellifera*** Axelson		+			
9	*Friesea sublimis* MacNamara				+	+
10	*Friesea* sp. 1		+			+
11	*Friesea* sp. 2		+			
12	*Isotomodes pseudoproductus* Stach	+		+	+	+
13	*Proisotoma tenella* (Reuter)				+	
14	*P. submuscicola* Nguyen			+	+	+
15	*P. muscicola* Stach			+	+	
16	*Folsomia inoculata* Stach					+
17	*Folsomina onychiurina* Denis		+	+		
18	*Isotomiella minor* Schaffer			+		
19	*Folsomides americanus* Denis	+	+	+	+	+
20	*F. exiguus* Folsom	+		+		
21	*F. parvus* Stach		+			
22	*Cryptopigus orientalis* Stach		+			
23	*C. gracilis* Stach			+	+	
24	*Isotomurus palustris* (Muller)				+	
25	*L. pracinus* (Reuter)					+
26	*Isotoma nivea* Schaffer				+	+
27	*I. notabilis* Schaffer				+	
28	*Entomobrya muscorum* (Nicolet)				+	
29	*E. oleniensis* Tchelnokov				+	+
30	*E. lanuginosa* (Nicolet)					+
31	*Entomobrya* sp.			+		+
32	*Haloentomobrya* sp.					+
33	*Sinella monoculata* Denis				+	
34	*Pseudosinella fujiokai* Yossi			+	+	
35	*P. immaculata* Lie-Pettersen			+		
36	*P. wahlgreni* Borner			+		
37	*Lepidocyrtus paradoxus* Uzeil			+	+	
38	*L. (Asco.) cinctus* Schaffer				+	
39	*Sphaeridia pumilis* Krausbauer			+	+	+
40	*Sphaeridia* sp.			+		
41	*Sminthurinus* sp.	+				+
42	*Sphyrotheca macrochaetus* Nguyen				+	+
43	*S. nepalica* Yosii				+	
44	*Sphyrotheca* sp.	+				
45	*Dicyrtomina antenus* Nguyen			+	+	+
46	*Dicyrtomina* sp.			+		+
47	*Papiriodes aequituberculata* Stach					+
48	*Papiriodes* sp.			+		+
	Total	$\frac{5-8}{12}$		21	24	20

II, Human-impacted forest; III, shrubland, V, cultivated land; VI, tea field. 0, Forest litter lying on the soil surface; – 1, soil surface layer of 0–10 cm.
**Species new to the collembola fauna of Vietnam.

and cultivated land, the species biodiversity of the oribatid community decreased as follows: from (+ 1) decaying wood debris and moss lying on 0–100 cm above the surface forest litter, to (0) forest litter lying on the soil surface, (– 1) soil surface layer of 0–10 cm, and (– 2) deep soil layers of 11–20 cm. However, the natural habitat, particularly the natural forest exhibited a different picture.

Table 2 presents the species diversity of the collembolan community, their distribution in 2 vertical layers and 4 study habitat types, in the study area of Tam Dao National Park. The 48 species are distributed over 25 genera under 10 families (Hypogastruridae, Onychiuridae, Odontellidae, Neanuridae, Isotomidae, Entomobryidae, Sminthurididae, Katiannidae, Sminthuridae and Dicyrtomidae). Two species (4·1% of the total), *Isotomodes pseudoproductus* and *Folsomides americanus* were found in all of the 4 study habitat types; and 3 others (6·1%), *Proisotoma submuscicola*, *Sphaeridia pumilis* and *Dicyrtomina antenus*, were common in 3 study habitat types. Among the 48 species, only *Odontella lamellifera* is the species newly added to the collembolan fauna of Vietnam (Borner 1913; Denis 1948; Stach 1965; Yosii 1961, 1983; Nguyen 1995).

Figure 1b presents the indices of species similarity of collembolan faunal associations in 4 study habitat types. These indices of collembolan associations do not vary very much from that of the oribatid associations, from a minimum of 5·9% between the associations in human-impacted forest and in cultivated land (II and V), to a maximum of 29·4% between the associations in shrubland and in cultivated land (III and V). The trellis diagram showed that there is a formation of two collembola faunal associations: one between the human-impacted forest and shrubland (II and III), and the second between tea plantation, cultivated land and shrubland (VI, V and III). The delimitation of these two collembolan faunal associations is not very clear.

Change in the species diversity of collembolan communities of the study area is interesting. The species diversity of collembolan communities increased gradually as follows (table 2): from human-impacted forest (12 species), to tea field and shrubland (20 and 21 species, respectively), and cultivated land (24 species).

In general, the results of studies on microarthropod community structures showed that there is a significant relation between the species diversity of oribatid and collembolan communities and changes in forest cover; furthermore an inverse correlation of species diversity between oribatid and collembolan communities was observed. While the species diversity of oribatid community gradually decreased from natural forest to cultivated land, the species diversity of the collembolan community increased.

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