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The Diversity and Abundance of Springtail (Collembola) on Forests and Smallholder in Jambi

Widrializa, Rahayu Widyastuti, Dwi Andreas Santosa and Gunawan Djajakirana

Departement of Soil Science and Land Resource, Bogor Agricultural University Bogor 16680, Indonesia, e-mail: widrializa@gmail.com

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ABSTRACT

Harapan forests is the first restoration forest in Indonesia, includes several different ecosystems. Different ecosystems have different characteristic to affect the diversity and abundance of Collembola. In the ecosystem, Collembola have an important role in biocontrol, decomposition, soil nutrient distribution, stimulation of soil microbial activity and as an alternative feed for predators. This study was aimed to investigate the diversity and abundance of Collembola in four ecosystems at Harapan forest, *i.e.* secondary forest, rubber forest, rubber smallholder and oil palm smallholder. To achieve the objective, soil samples were taken at 48 observation points in the four ecosystem. The soil samples were then extracted by Kempson Extractor. The diversity and abundance of Collembola in four ecosystems were categorized as medium to high. The total of individual and population of Collembola in the secondary and rubber forest ecosystems were likely to be higher than in the rubber and oil palm smallholders. This study had also identified four orders, 14 families and 31 genera of Collembola, where *Isotomiella* and *Proisotoma* dominated the genus of Collembola in the four ecosystems.

Keywords: Collembola, rubber forest, rubber and oil palm, secondary forest, smallholder

INTRODUCTION

Harapan Forest is located at frontier of Jambi and South Sumatera, 98 554 hectare in wide. Based on Decree of Forestry Minister Number 327/ Menhut-II/2010, about 46 385 hectare of Harapan Forest is located in Jambi (Ministry of Forestry, Republic of Indonesia 2010). About 42% of the forest was converted to rubber forest, rubber smallholder and oil palm smallholder (Saturi 2013). Condition of land and canopy in four ecosystems are different. Rubber forest has wood, rattan, herbs, cover crop, and extensive agriculture. Secondary forest has species like rubber forest but the wood of secondary forest has wood diameter more than 30 cm and without extensive agriculture. Rubber and oil palm smallholders have cover crops and intensive agriculture. Condition of four ecosystems are correlated with canopy. Rubber and oil palm smallholders have 50-70% canopy, while more than 70% in secondary forest and rubber forest (Rubiana 2014).

Canopy is related to total and type of litter. Canopy and land transformation affect the diversity and abundace of Collembola. Respectively each landuse have different characteristics so that influence the number and diversity of Collembola in landuse. The total and diversity of Collembola are related to individual ability to adapt with the environmental changed and food availability. Fatimah *et al.* (2012) reported that plot with densely canopy, humid, and 2 cm in litter thickness had higher diversity and abundance of Collembola than plot in rarely canopy, dry, and more than 2 cm in litter thickness. According to soil depth, diversity and abundance of Collembola indicated vertically difference. The diversity and abundance of Collembola at litter layer and top soil (0-2.5 cm in depth) was moderate to high (Widyawati 2008).

Collembola is one of the most abundant group of soil mesofauna in terrestrial ecosystem. The high abundance is caused Collembola can survive in several habitat and condition. The abundance of Collembola in ecosystem has an important role. The role is not indirectly perceived by human. Collembola serve as a biocontrol agent so that plant disease which caused by fungi *Fusarium culmorum* and *Gaeumannomyces graminis var tritici* can be controlled by *Protaphorura armata* (Sabatini *et al.* 2004). Collembola also affect soil fertility and stimulate microbial activity (Mussury *et al.* 2002) because of their function in decomposition of organic matter, redistribution nutrient and energy cycle. Collembola influence C/N ratio in litter (Xiadong *et al.* 2012) so that nutrient mineralization running fast.

The abundance of collembola make them as prey or alternative food for predators. Indirectly Collembola balanced the ecosystem because of its effect to predator population. Reznikova and Panteleeva (2001) proved that ant *Myrmica rubra* L. is actively collembola's pedator and can find an abundant habitat of Collembola. Agusti *et al.* (2003) investigated Collembola as alternative prey to spider in productive ecosystem. In the ecosystem spider is predator of aphids. While there are no major prey, Collembola can be alternative prey. Collembola in the ecosystem maintain spiders indirectly as biocontrol agent of aphids.

According to the explanation, Collembola have an important role to maintain environment toward the ecosystem. Few preservation create ecosystem balanced. Therefore, this research was aimed to investigate the diversity and abundance of Collembola in four ecosystems at Harapan forest (secondary forest, rubber forest, rubber and oil palm smallholder).

MATERIALS AND METHODS

Study Area

The research was conducted from February until June 2015 at secondary forest, rubber forest, rubber smallholder and oil palm smallholder in Landscape of Harapan forest, Province of Jambi (Table 1 and Figure 1). Collembola Extraction was done at Laboratory of CRC, University of Jambi, while Collembola identification was done at Laboratory of Soil Biotechnology, Bogor Agriculture University. The experiment used a survey method which consisted of two steps. First steps were sampling and extracting soil, while second steps were identification and calculation of Collembola. Variables that have been observed were the total, diversity, and dominance of Collembola. Result data of Collembola was analyzed quantitatively used table and diagram to describe the different of diversity and abundance of Collembola in four ecosystems.

Some points of observation was appointed previously in every landuse to sampling soil by purposive sampling methods, that determinated of representatif location intentionally. In the appointed location, there were four plot obserations of 50 m x 50 m in wide consisted of three point of observations respectively. Overall there were 48 points of observation in four locations. Every appointed point was conducted sampling soil to observe Collembola by Kempson Extractor method.

Kempson Extractor method was conducted by sampling soil used shovel 16 cm x 16 cm in wide and 5 cm in depth. Soil samples and litters were separated, placed in calico cloth and carried to be extracted in laboratory. Extraction of soil fauna by Kempson Extractor for 3-4 days to extracting litter and 7 days to soil at $\leq 40^{o}$C. Soil and litter sample were placed in the box with filter 2 mm at the bottom, then put container which was filled by

Table 1. Coordinate of observation plot at four landuses in landscape of Harapan forest, Jambi Province.

Observation Plot	Latitude (LS)	Longitude (BT)
Oil Palm 1	01°54'35.9''	103°15'56.8''
Oil Palm 2	01°52'03.0''	103°16'01.7''
Oil Palm 3	01°51'14.8''	103°18'28.4''
Oil Palm 4	01°47'08.4''	102°16'14.2''
Rubber 1	01°54'41.2''	103°15'59.3''
Rubber 2	01°52'48.5''	103°15'55.7''
Rubber 3	01°51'34.9''	103°18'01.8''
Rubber 4	01°48'20.2''	103°15'53.7''
Jungle Rubber 1	01°55'39.2''	103°15'35.5''
Jungle Rubber 2	01°52'41.7''	103°16'38.2''
Jungle Rubber 3	01°50'59.0''	103°17'57.9''
Jungle Rubber 4	01°47'55.4''	103°16'36.8''
Secondary forest 1	02°09'09.5''	103°21'41.8''
Secondary forest 2	02°09'48.4''	103°20'03.4''
Secondary forest 3	02°10'43.0''	103°20'00.1''
Secondary forest 4	02°11'17.8''	103°20'33.3''

CRC990 EFForTS (2012); 1-4, plot number.

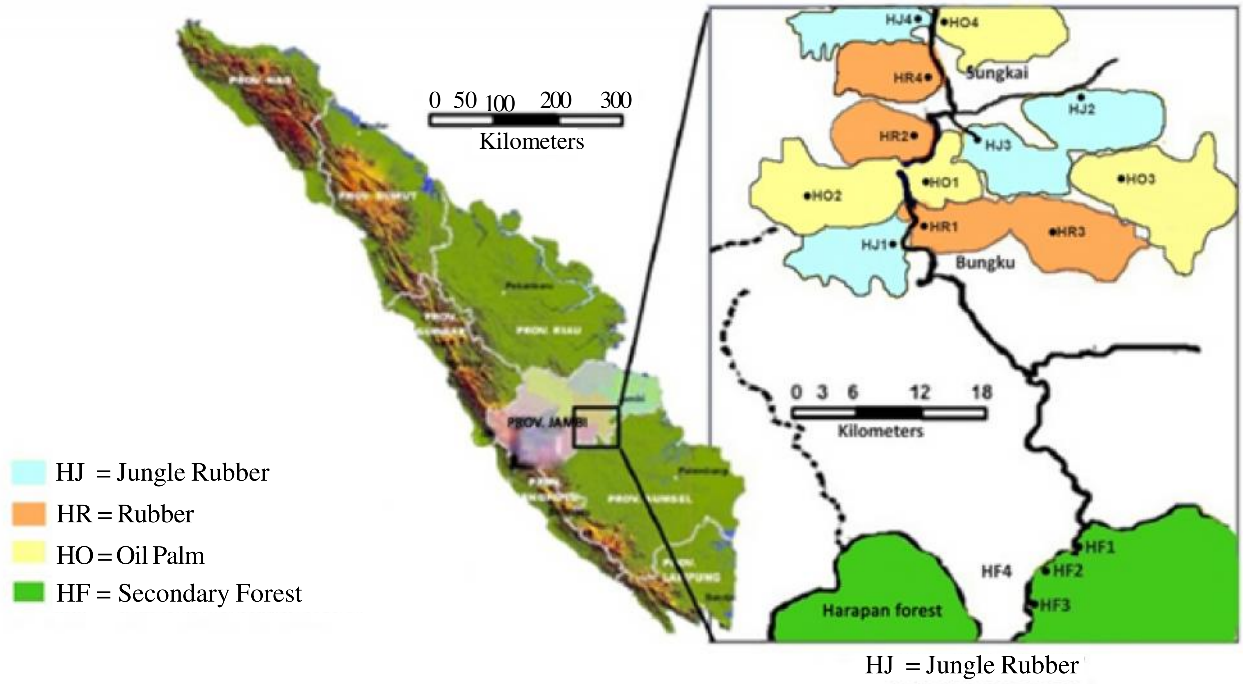

Figure 1. Map of observation location in four landuses.

ethylene glycol below to gather soil fauna. Above the series, infra red 150 watt was installed as source of thermal to promote soil fauna came down to avoid the thermal. There was temperature control that up gradually and stabile in ≤ 40°C consistently. After extraction process, soil fauna were placed in collection tube which was filled by alcohol 96% to separation and identification.

Separation was conducted previously to identify of Collembola so Collembola was separated from other soil fauna. Collembola was counted and identified into genus by Suharjono *et al.* (2012). Identified into order was characterized by body shape, thorax, segment of abdomen and oselus. Collembola family was observed by character of setae, pigment of body, mandible, furcula, and tenaculum. Character of structure and design of setae, and mouth shape was used to identify into genus (Suhardjono *et al.* 2012).

Analysis of total Collembola was counted by formula (Meyer 1996) :

$$N = IS/A$$

IS: number of individu per point, A: point area of observation, N: number of individu m^{-2}. Factor correction of N : 39.0625

The diversity of Collembola indicated total genus in the habitat was counted by Shannon's diversity formula (Ludwig and Reynolds 1988) :

$$H' = -\sum_{i=1}^{s}\left[\left(\frac{ni}{n}\right)\ln\left(\frac{ni}{n}\right)\right]$$

H': Shannon's diversity index, ni: number of Collembola individu, n: total individu of Collembola. Criteria was used to interpret Shannon's diversity by Magurran (1988) was <1.5: low diversity; 1.5-3.5: moderate diversity; > 3.5 : high diversity.

Dominance of genus about 0-1 where index nearly 1 was dominant genus (Ludwig dan Reynold 1988) :

$$D = \sum_{i=1}^{s}\left(\frac{ni}{n}\right)^2$$

D: index of dominance, ni: number of Collembola individu, n: total individu of Collembola.

RESULTS AND DISCUSSION

Collembola showed varies population based on four landuse. Collembola found in soil and litter (Table 2) can be grouped in to 4 orders, 14 families, and 31 genera spread in secondary forest, rubber forest, rubber smallholder and oil palm smallholder. The most family found was Entomobryidae, especially genus *Isotomiella* (2.972 individu m^{-2}) and *Proisotoma* (3.776 individu m^{-2}). Both genera were abundant, because they moved actively and agregated so they could survive in unfavourable conditions. *Isotomiella* and *Proisotoma* also have cosmopolitan distribution (Suhardjono *et al.* 2012) so they can be found easily.

Population of Collembola in four ecosystems exhibit different of population and number of

Table 2. Number of individual, orders, families, and genera of Collembola in the litter and the soil at rubber smallholder, oil palm smallholder, rubber forest, and secondary forest.

Order	Family	Genus	HO		HR		HJ		HF	
			S	T	S	T	S	T	S	T
			Individu m^{-2}							
Entomobryomorpha	Coenaletidae	Coenalestes	0	88	0	111	7	65	3	127
	Cyphoderidae	Chyphoderopsis	20	215	0	238	39	127	143	352
	Entomobryidae	Acrocyrtus	0	0	0	0	13	3	7	0
		Ascocyrtus	7	33	10	33	166	39	10	23
		Entomobrya	0	0	127	98	7	75	732	247
		Homidia	0	0	0	0	16	7	0	0
		Lepidocyrtus	0	7	3	0	0	0	13	7
		Lepidosira	0	0	39	0	42	0	0	0
		Rambutsinella	3	39	7	150	42	13	72	130
		Pseudosinella	0	0	0	0	0	3	0	0
	Isotomidae	Folsomides	94	13	319	290	752	107	400	153
		Folsomina	0	29	36	10	0	218	143	20
		Isotomodes	0	16	0	0	0	20	10	29
		Isotomiella	0	78	39	462	313	840	628	612
		Proisotoma	91	313	130	329	856	527	1201	329
		Pseudisotoma	3	10	0	0	0	3	0	0
	Oncopoduridae	Oncopodura	0	0	0	3	0	0	39	13
	Paronellidae	Bromachantus	0	0	3	0	0	0	0	0
		Pseudoparonella	0	3	23	0	0	3	13	0
	Tomoceridae	Tomocerus	0	3	0	0	0	10	0	7
Poduromorpha	Neanuridae	Cephalochorutes	0	0	13	0	7	0	378	42
		Ceratrimeria	10	0	7	7	0	10	72	7
		Pronura	0	0	0	0	0	0	46	3
		Pseudachorutes	0	0	0	0	7	0	7	3
	Onychiuridae	Thalassaphorura	0	0	10	0	0	0	0	16
Neelipleona	Neelidae	Megalothorax	0	0	0	7	16	0	26	36
		Neelus	0	0	3	0	20	3	7	0
Symphypleona	Arrhopalitidae	Collophora	0	0	0	0	20	0	10	0
	Dicyrtomidae	Papirioides	0	0	0	0	0	0	10	10
	Sminthuridae	Sphyrotheca	0	0	0	3	7	7	280	33
	Sminthurididae	Sphaeridia	0	0	85	163	62	23	371	59
4 Orders	14 Families	31 Genera								
		Total of individual m^{-2}	228	846	853	1901	2389	2103	4619	2256

HO, oil palm smallholder; HR, rubber smallholder; HJ, rubber forest; HF, secondary forest; S, litter; T, soil.

individu. Collembola have found mostly in secondary forest and rubber forest, whereas that least in rubber and oil palm smallholder. Collembola have found in soil and litter in secondary forest consist of 26 genera and 6.875 individu m^{-2}. It is caused Collembola is very dependence on temperatur, humidity, and food sources availability from litter decomposition.

In secondary and rubber forest there are many litter and canopy reaches >70% that cause microclimate is favourable for Collembola, food avalability is also overflow. The profitable environment condition is attractive to Collembola to live in forest habitat. If its compared with rubber and oil palm smallholder, both ecosystem have low number of individu. Smallholder ecosystem has 50-70% canopy and less litter. Rarely canopy and less litter cause incoming sunlight to soil surface and it make high temperature and low humidity. This situation shows how important liter and cover crop as soil cover and shelter for Collembola. Sugiyarto (2005) suggested land clearing caused shifting environment for soil fauna icluded Collembola causing pressure toward life under the soil, restriction on rate of reproduction even dead. This unfavourable conditions cause Collembola move to deeper or more favourable subsoil.

Number of litter biomass have returned to soil every year in four ecosystem were different. Landuse change related to the number of litter that will affect the existence Collembola. Secondary forests produce the highest number of litter 0.18 g cm^{-2}, then successively on jungle rubber (0.12 g cm^{-2}), a rubber (0.09 g cm^{-2}) and palm oil (0.03 g cm^{-2}) (Krashevska *et al.* 2015). The results are consistent with the results Zulkaidah *et al*. (2014). Where in secondary forests, number of litter that is returned to the soil per year for 19 Mg ha^{-1} yr^{-1}, then agroforestry (15 Mg ha^{-1} yr^{-1}), and monokultur smallholder (1.9 Mg ha^{-1} yr^{-1}). Number of litter biomass produced will affect diversity and abundance of Collembola. The more litter produced, the higher feed finding activity (Mugerwa *et al.* 2011). Feed finding activity is related to number and genus of Collembola.

Unfortunately, collembola was higher in soil than litter in oil palm and rubber smallholders. It is likely more light intensity can be exposed causing high temperature and dried, least even no vegetation cover and litter. Collembola communities may shift to another equilibium stage following changes in vegetation cover (Ponge *et al.* 2003). The unfavourable condition make collembola change over into the soil to get more appropriate condition.

Abiotic factor also contribute to affect the abundance and diversity of collembola. It is related to collembola adaptability in their habitat and nutrition source avalability. Results of chemical analysis showed pH, C-total, N-total, and C/N ratio determined fauna soil lived in the ecosystem (Table 3). Hasibuan and Ritonga (1981) suggested pH affected development of collembola in different soil condition. pH caused stress to fauna directly and indirectly even it can disturb reproduction of collembola. Crommentuijn *et al.* (1997) reported effect of pH and soil organic matter to toxicity of Cd in *Folsomia candida*. Identification data showed abundance and diversity of collembola is high in forest and smallholder ecosystem although pH soil is low. It is likely collembola have wide range pH tolerance that is pH 2 to 9 (de Boer *et al.* 2010). Collembola also can adapt in extreme soil condition and continuing activity to suitable condition such as in litter and microhabitat.

C-total and N-total are related to energy source avalability of microbes that is food source of collembola. Kaneda and Kaneko (2004) reported growth of collembola increased in high C-total and N-total soil. C-total and N-total in forest ecosystem is higher than other ecosystem (Krashevska 2015). Diverse of canopy and vegetation caused higher litter was produced, so organic matter of decomposition and microbes was high. It provides rich and abundance food nutrition to soil arthropod include collembola.

C/N ratio in four landuses showed no different rate, that is HF>HJ>HR>HO (Table 3). Meanwhile Setiawan *et al.* (2003) suggested C/N ratio was related positively to individu number and diversity index of soil fauna although it was weak. It was likely C/N ratio is related to number and activity of microba. The rate is in accordance with Krashevska *et al.* (2015) that land conversion from secondary forest to rubber forest, rubber and oil palm smallholder caused soil microbes community decreased. Secondary forest have abundance and diversity of collembola was higher than other

Table 3. Number of litter, pH, C-total, N-total and C/N ratio in secondary forest, rubber forest, rubber smallholder and oil palm smallholder.

Variable	Oil plam smallholder	Rubber smallholder	Rubber Forest	Secondary Forest
Number of litter (g cm^{-2})	0.03 ± 0.02	0.09 ± 0.04	0.12 ± 0.03	0.18 ± 0.05
pH	4.70 ± 0.36	4.39 ± 0.10	4.34 ± 0.14	3.78 ± 0.32
C-total (%)	3.42 ± 1.08	3.51 ± 1.62	5.70 ± 2.37	6.04 ± 3.77
N-total (%)	0.25 ± 0.10	0.24 ± 0.07	0.38 ± 0.13	0.36 ± 0.15
C/N ratio	13.7 ± 3.61	14.6 ± 3.61	15.0 ± 3.61	16.8 ± 3.61

Krashevska *et al.* (2015)

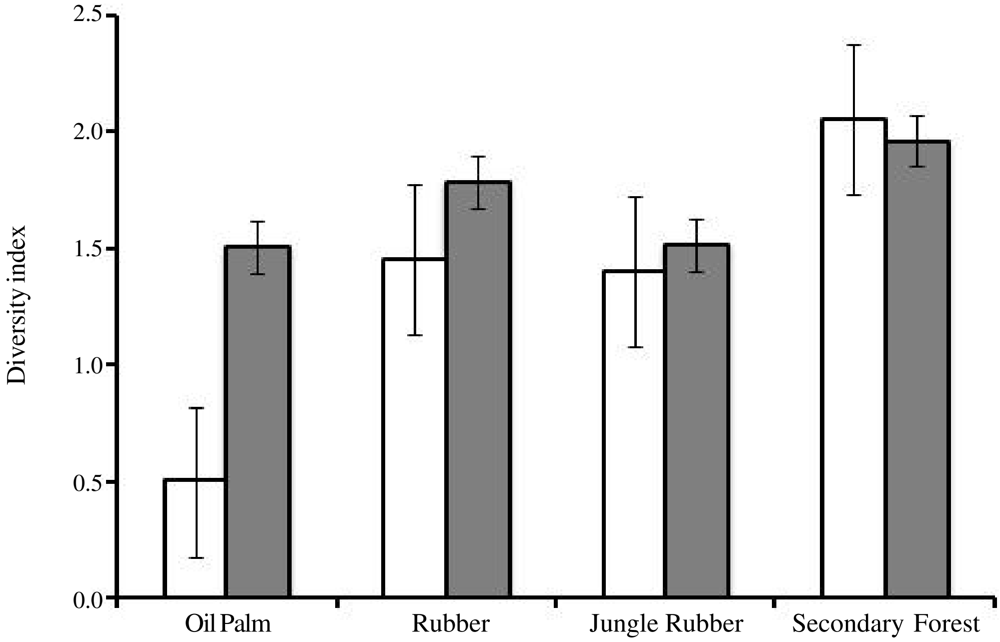

Figure 2. Diversity index of Collembola genus in litter and soil at rubber smallholder, oil palm smallholder, rubber forest, and secondary forest. □ : litter, ■: soil.

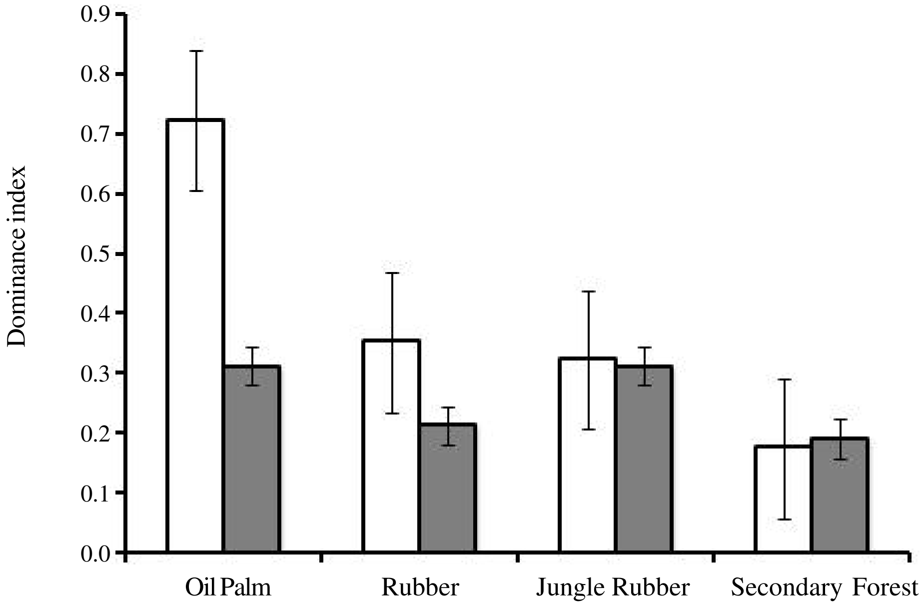

Figure 3. Dominance index of Collembola genus in litter and soil at rubber smallholder, oil palm smallholder, rubber forest, and secondary forest. □ : litter, ■: soil.

landuse. It was likely the higher C/N ratio in secondary forest, the higher number and activity of microbes. The higher number and activity of microbes have advantage to collembola in food and energy sources availability in longer time.

The diversity and dominance index of Collembola in four observatory location indicated diverse rate (Figure 2 and Figure 3). Diversity and dominance index indicated there was no different in four ecosystems. However, according to criteria from Magurran (1988) diversity rate in four ecosystems was 2.0-4.0 indicated moderate to high diversity. Vegetation is important habitat and food source for Collembola. The more vary vegetation, the more litter was produced and more varied. Rahmadi *et al.* (2004) suggested litter can be used by Collembola as food source. Surely litter was used by macro- and microfauna previously to be smaller fragments. The more availability of food, the more vary Collembola can survive in the habitat. Exixtence of vegetation also make condition of microhabitat as litter, twig, and subsoil is better to support life of various Collembola. Vegetation in four landuse are *Clibadium surinamense*, *Ficus* sp., *Clidemia hirta*, *Gleichenia linearis*, *Gomphrena* sp., *Melastoma malabatrichum*, *Selaginella* sp., *Licopodium* sp., *Ligodium* sp., *Polypodium* sp., *Sida rhombhifolia*, and *Tetracera indica*.

The dominance index of soil fauna family in four ecosystems showed rate of 0.368-1.036, that was moderate to high in dominance index rate (Ludwig dan Reynolds 1988). Community have low diversity because one or more species become dominant. Community of Collembola that have a dominate species Collembola will indicated low evenness. Ecosystem of forest have various plant caused genus Collembola spread evenly. Conversely, ecosystem of smallholder only have a variety plant (monoculture) that caused Collembola tend to dominate. This is likely food source for Collembola in smallholder is not vary or limited. Therefore, Collembola can only survive in the habitat that its can utilize avalability of food source.

CONCLUSIONS

The number of individual and population of collembola was higher in forest ecosystem was higher than in smallholder. Overall, there are 4 orders, 14 families, and 31 genera of Collembola have been found in the four ecosystems of secondary forest, rubber forest, rubber smallholder, and oil palm smallholder. According to the analysis of diversity and dominance index for Collembola genus, there were no different in four ecosystems. However diversity and dominance index rate of genus Collembola was moderate to high.

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