

Research Article

Diversity of Oribatids (Acari) at different land use types in Mentebah, Kapuas Hulu, West Kalimantan

Endang Sulistyorini^{1*}, Rahayu Widyastuti¹, Sugeng Santoso²

¹ Department of Soil Science and Land Resources, Faculty of Agriculture, Bogor Agricultural University, Bogor

² Department of Plant Protection, Faculty of Agriculture, Bogor Agricultural University, Bogor

*corresponding author: endang_sulistyorini@yahoo.com

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Abstract : Kalimantan forests are mostly managed by human. Deforestation will affect the ecosystem and species inside. Oribatids are the most abundant soil mesofauna. They have an important role in decomposition of organic matter in the soil. Here, we investigated the effect of six different land use types (i.e. primary forest, secondary forest, jungle rubber, slash and burn, young fallow and old fallow) and evaluated the effect of environmental factors on the abundance and diversity of oribatids. The oribatids were collected using transect method along 100 m with 10 sampling points with the soil depth of 0-5 cm. Oribatids were extracted using Berlese Funnel Heat Extractor. Identification of oribatids was done to family level and diversity index was determined according to Shannon's diversity index. As much as 36 families of oribatids were recorded from the site at Mentebah, Kapuas Hulu. Oribatids in the jungle rubber showed the highest abundance (592.5 individuals/m²), followed by secondary forest (317.5 individuals/m²), primary forest (287.5 individuals/m²), slash and burn (195 individuals/m²), young fallow (157.5 individuals/m²) and old fallow (142.5 individuals/m²). The value of diversity index according to Shannon Wiener (H') ranged between 1.71-2.64 or categorized as moderate diversity values. The results of the research showed that there were strong coefficient correlation values of some families of oribatids with soil pH, C-organic, N total, C/N ratio, water content and soil temperature.

Keywords: *abundance, decomposer, diversity, land use type, Oribatids*

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Introduction

Soil is an important part of an ecosystem. Environmental changes, especially land use or management systems will rapidly alter soil conditions and functions, and they will subsequently alter the structure and function of biota or organisms, whose lives are heavily dependent on the carrying capacity of the soil. In developing countries like Indonesia, land degradation process is relatively fast due to high population. Since 1999, the conversion of forest to agricultural land has occurred on a large scale (Sugiarto et al., 2002). Kapuas Hulu is one of the districts located in West Kalimantan Province with high biodiversity, both at species and

ecosystem level. The forest management system in Kapuas Hulu is still far from optimal condition so that forest degradation keep continuing and resulting in decreasing forest quality (Bappeda Kapuas Hulu, 2017). Several studies have been conducted to determine the abundance of oribatids in various habitats as a resulted from forest conversion to non-forest. Postma-Blaauw et al. (2010) showed that land conversion from pasture to agricultural land negatively affected the abundance and function of biodiversity. The agricultural ecosystem affected the abundance of oribatids. Agricultural activity can change the pattern of organic matter intake into the soil (Coleman et al., 2004). According to Hulsman and Wolters (1998), the effect of soil processing

activities can reduce the abundance of oribatids more than 50%. Abundance and diversity of oribatids were influenced by environmental factors such as rainfall, soil conditions (soil pH, water content, soil temperature, C-organic and N total) and vegetation. Oribatida is one of the abundant microarthropods that play a role as decomposer and can be used as bioindicator of soil fertility. Ecosystem differences and land use can lead to differences in diversity and abundance of oribatids. Based on this, it is necessary to conduct research to determine the abundance and diversity of oribatids on different land use types in Mentebah, Kapuas Hulu, West Kalimantan so that the data can be used an information and consideration for policy maker in term of soil biological aspect in sustainable land management.

Materials and Methods

The soil and litter samples were taken from the six types of land use in Mentebah, Kapuas Hulu, West Kalimantan. Coordinates of each plot are 0.51901 LU 112.82246 BT (primary forest), 0.52176 LU 112.81462 BT (secondary forest), 0.53300 LU 112.81037 BT (jungle rubber), 0.49128 LU 112.80390 BT (slash and burn), 0.49213 LU 112.80833 BT (young fallow), 0.53396 LU 112.80935 BT (old fallow).

The soil fauna extraction was conducted at a field research station in the Nanga Mentebah. Identification and calculation of Oribatids and analysis of soil chemical properties was conducted in the Laboratory of Soil Biotechnology, Department of Soil Science and Land Resources, Faculty of Agriculture, Bogor Agricultural University (IPB). Soil and litter samples were collected using transect method. At each location of land use type, transects were constructed along 100 m, then 10 sampling points were chosen with a distance of 10 m (Suhardjono et al., 2012).

Soil and litter samples were taken using 20 cm x 20 cm square box with a depth of 5 cm. Composite soil sampling with a depth of 5 cm was performed in each plot with 3 replications in one type of land use to measure soil pH, moisture content, organic carbon and total soil nitrogen. As much as 120 soil samples were extracted using the modification Berlese Funnel Extractor. All samples of oribatids were sorted and counted in the laboratory using stereomicroscope. Oribatids were classified into family levels. Identification was based on Krantz and Walter (2009) and Balogh and Balogh (1988 and 1990). The number of individuals (abundance and diversity) of the extracted was calculated as follows (Meyer, 1996):

$$N = \frac{IS}{A}$$

where

IS : Mean number of individuals per sample

A : Surface area of the corer (cm²)*

N : Number of individuals

* area of the corer = 20x20 cm=0.04 m² the value was then converted into m²

The diversity index was calculated following *Shannon diversity index* (Magurran, 2004)

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

where

H' : Shannon's diversity index

Ni : Number of individual families of Oribatids in the sample

N : the total of number individuals in the sample

The value of H' range:

< 1.5 : Low diversity

1.5-3.5 : Medium diversity

> 3.5 : High diversity

The data of this study were analyzed by analysis of variance (ANOVA) and tested by Duncan's Multiple Range Test at 5% level using SAS software version 9.4 to evaluate the differences between abundance of the oribatids population on soil and litter and also on six different types of land. Pearson correlation analysis was used to see the relationship between Oribatids families with environmental factors

Results and Discussion

Abundance and Diversity Index of Oribatids

The total number of oribatids found in the six land use types was 1242.5 individuals/m² in the litter and 450 individuals/m² in the soil, respectively. The Duncan test showed that there was a significant difference between oribatids abundance in litter and in soil (Table 1). The results were in line with Murvanidze et al. (2016) where the abundance of oribatids were highest in litter (4326 ± 2870 individuals/m²) and lowest in the soil (2120 ± 939 individuals/m²) in the Garden National Mtirala Georgia. The litter has a high amount of abundance compared to the soil. Lisafitri (2015) found the highest abundance of oribatids in litter lanes (4 560 individuals/m²) than in open lanes (1570 individuals/m²) in the oil palm plantation area, Bajubang, Batanghari,

Jambi. According to Schneider (2005), Oribatida is one of the Acari group which like feeding on microorganisms especially fungi, bacteria and litter. Oribatids were found highest in soil and litter of jungle rubber that consisted of 485 individuals/m² and 107.5 individuals/m², respectively. The high abundance of oribatids in jungle rubber both in the soil and in the litter were

due to the presence of certain dominant Oribatida families. In addition, according to Wibawa and Hendratno (2001), rubber plantation that is not carried out intensive management and maintenance have a level of biodiversity close to the level of natural forest and higher than the rubber plantation monoculture that was managed intensively.

Table 1. Abundance and Shannon diversity index of oribatids in soil and litter in six land use types (average over ten replications)

Land use type	Litter		Soil		Litter		Soil	
	(Individual/m ²) ^a				Shannon's diversity index			
Slash and burn	135	b	60	b	1.99		1.71	
Young fallow	100	b	57.5	b	2.18		1.99	
Old fallow	92.5	b	50	b	2.54		2.41	
Secondary forest	230	b	87.5	b	2.57		2.64	
Primary forest	200	b	87.5	b	2.62		2.02	
Jungle rubber	485	a	107.5	b	1.81		2.00	
Total number of oribatids	1242.5		450					
Average	207.08	a	75	b				

Note: ^aNumbers followed by same letters in the same column have non-significant difference based on DMRT test with 5% degree; ^bNumbers followed by same letters in the same line have non-significant difference based on DMRT test with 5% degree; Values 1.5-3.5 show moderate diversity (Magurran, 2004)

Diversity indices were calculated according to Shannon's diversity index (Magurran 2004). The value of diversity index ranged from 1.71 to 2.64 (Table 1). This means that six types of land use in Mentebah, Kapuas Hulu (i.e. slash and burn, young fallow, old fallow, secondary forests, primary forests and jungle rubber) have moderate diversity with fairly balanced ecosystem conditions.

Abundance of Oribatids family on soil and litter

Family of oribatids found in six land use types amounted to 36 families from 172 families of oribatids previously discovered (Krantz and Walter, 2009). The highest abundance of the oribatids family in the six land use types are indicated in Table 2.

Table 2. Abundance of the Oribatida families in the six land use types

Family	Land use type						Total
	SB	YF	OF	SF	JR	PF	
	Individual/m ²						
Galumnidae	10	13	8	18	180	5	234
Trhypochthoniidae	0	10	5	3	203	5	226
Scheloribatidae	23	20	10	55	70	30	208
Oppiidae	70	40	15	13	3	38	179
Haplozetidae	43	18	10	30	13	65	179

Note: SB: slash and burn; YF: young fallow; OF: old fallow; HS: secondary forest; JR: jungle rubber; HP: primary forest

In general, the most families found were Galumnidae, Trhypochthoniidae, Scheloribatidae, Oppidae and Haplozetidae. Galumnidae and Trhypochthoniidae were the most frequent families found in jungle rubber, with the highest total abundance of 234 individuals/m² and 226 individuals/m², respectively. Galumnidae is a

large assemblage of 450 species in 50 genera while Trhypochthoniidae, an assemblages of 12 genera and more than 70 species (Krantz and Walter, 2009). The highest abundance of Galumnidae and Trhypochthoniidae were found in jungle rubber i.e. 180 individuals/m² and 203 individuals/m², respectively. This was due to the

jungle rubber is located close to the river and to allow a favourable condition for both families. These families are known to be specific to wet and humid habitats (Krantz and Walter, 2009). The Oppiidae is the largest family in the Oribatids and includes its most species-rich family. The Oppiidae, comprising more than 1 000 species in approximately 170 genera (Krantz and Walter, 2009). The highest abundance of the Oppiidae family was found in slash and burn and young fallow, i.e. 70 individuals/m² and 40 individuals/m², respectively. Oppiidae is ubiquitous and wide spread taxa that can tolerate extreme condition, were the first to recover and colonize burned areas (Murvanidze et al., 2008). The highest abundance of Scheloribatidae and Haplozetidae were found in jungle rubber that was 70 individuals/m² and primary forests that was 65 individuals/m². Scheloribatidae is among the most common and abundant mites in soil and litter, even in anthropogenic habitats while Haplozetidae

is the most diverse in the tropics (Krantz and Walter, 2009).

Abundance of Oribatids community in relation to soil characteristics

Data presented in Table 3 show the results of the soil characteristics analysis. Soil pH in six land use types showed acid criteria with a pH range of 4.5 to 5.5. The result of organic carbon analysis in slash and burn had low criteria with a range of 1% to 2% while in jungle rubber had very high criteria that was > 5%. N total in the slash and burn had very low criteria of < 0.1% whereas young fallow, secondary forests and primary forests had low criteria of 0.1% to 0.2%, jungle rubber and old fallow with medium criteria ranging from 0.21% to 0.50 %. Six types of land use had a high C/N ratio of 16-25 to very high > 25. Criteria of soil chemical properties refer to Soil Research Institute of 2009.

Table 3. Characteristics of soil (soil depth 0-5cm; averages over three replications) in six land use types

Type of land use	pH	Organic Carbon (%)	N Total (%)	C/N (%)	Water Content	Soil Temperature (°C)
Slash and burn	5.04	1.38	0.07	20.02	3.80	27.3
Young fallow	5.04	3.03	0.10	30.29	12.80	27
Old fallow	4.97	4.72	0.22	21.32	18.96	26
Secondary forest	5.07	3.67	0.10	35.56	16.60	26
Jungle rubber	5.21	7.45	0.26	28.97	38.30	26.5
Primary forest	4.76	5.04	0.13	40.17	18.09	24.3

Soil temperatures in the slash and burn was higher at 27.3°C while the lowest soil temperature in primary forest was 24.3°C. High soil temperatures will affect the water content in the soil. The water content of slash and burn was lower at 3.80% while the highest water content in the jungle rubber was 38.30%. It was due to the jungle rubber in the research location is located on the banks of the river. Soil temperature is one of the soil physics factors that determine the presence and density of soil organisms. Ermilov and Lochynska (2008) suggested that high temperatures might affect the respiration, tropical activity, reproduction and development of oribatids. Abundance and diversity of oribatids are greatly influenced by environmental conditions. Table 4 shows the correlation between oribatids abundance and soil characteristics. An increase in soil pH could increase the abundance of the Nanhermanniidae although the increase of pH was only in the range of 5.04 to 5.21. Soil pH might affect the distribution of oribatids. According to Erdmann (2012), soil pH also correlates with oribatid mites density but the

correlation is negative. According to Maraun and Scheu (2000), Oribatida is an acidophilic soil mesofauna where abundance in acidic forest is higher than in natural forest with the value of 200 000 individuals/m² and 20 000 individuals/m², respectively. The abundance of Phtiracaridae, Malaconothridae, and Neoliodidae were positively correlated with soil organic carbon, i.e. 0.82; 0.86 and 0.82, respectively whereas the abundance of Oppiidae was negatively correlated with soil organic carbon of -0.81. The existence of soil fauna is strongly influenced by soil conditions, for example the presence of organic matter in the soil. Phtiracaridae is an Oribatida family that feeds on litter and fungi as well as important decomposers in conifer forests while Malaconothridae and Neoliodidae are Oribatida families that inhabit peat lands, soil and litter under vegetation (Krantz and Walter, 2009), so that the number of three families will increase along with the increase in organic carbon because their function as a decomposer of organic matter. The abundance of Oppiidae is influenced by organic carbon and water content.

Table 4. Correlation between Oribatids abundance with soil characteristics

Family	Soil Characteristics					
	Soil pH	Organic Carbon %	Total-N %	C/N %	Soil Temperature °C	Water Content
Lohmanniidae	0.33	-0.06	0.003	-0.03	0.14	0.02
Brachychthoniidae	0.77	0.08	0.05	-0.05	0.39	0.26
Hypochthoniidae	0.18	-0.13	-0.30	0.36	-0.08	-0.06
Parhypochthoniidae	-0.15	0.12	0.47	-0.51	-0.08	0.04
Mesoplophoridae	-0.53	0.11	-0.32	0.94*	-0.76	0.004
Gehypochthoniidae	-0.13	-0.76	-0.63	-0.41	0.71	-0.67
Epilohmanniidae	-0.38	-0.12	0.20	-0.48	0.002	-0.15
Oribotritiidae	-0.79	0.25	0.29	0.14	0.75	0.03
Euphthiracaridae	0.39	0.70	0.95**	-0.42	0.05	0.72
Phthiracaridae	0.38	0.82*	0.622	0.40	-0.32	0.86*
Trhypochthoniidae	0.64	0.78	0.74	-0.01	0.14	0.88*
Malaconothridae	0.57	0.86*	0.89*	-0.05	-0.04	0.92**
Nanhermanniidae	0.83*	0.09	0.10	-0.25	0.72	0.29
Tectocephidae	0.79	0.37	0.06	0.71	-0.45	0.39
Plasmobatidae	-0.68	0.21	-0.14	0.68	-0.80	0.05
Neoliodidae	0.60	0.82*	0.90*	-0.20	0.12	0.89*
Compactozetidae	0.21	-0.33	-0.48	0.35	0.23	-0.23
Astegistidae	-0.15	0.12	0.47	-0.50	-0.08	0.04
Eremulidae	0.03	-0.01	0.14	-0.09	-0.13	-0.02
Oppiidae	-0.35	-0.81*	-0.75	-0.27	0.27	-0.83*
Microtegeidae	0.08	-0.67	-0.49	-0.58	0.52	-0.62
Suctobelbidae	0.33	0.11	0.48	-0.67	0.22	0.14
Dampfiellidae	0.08	-0.67	-0.49	-0.58	0.52	-0.62
Tetracondylidae	-0.43	-0.19	-0.47	0.67	-0.30	-0.25
Otochepeidae	-0.25	0.01	-0.11	0.42	-0.50	-0.05
Oribatellidae	-0.44	-0.62	-0.65	-0.11	0.06	-0.67
Carabodidae	0.30	0.78	0.63	0.18	-0.16	0.80
Hemilleidae	-0.52	0.05	-0.32	0.84*	-0.75	-0.05
Scheloribatidae	0.57	0.59	0.34	0.40	-0.04	0.70
Protoribatidae	-0.79	0.15	-0.21	0.81	-0.91*	-0.02
Haplozetidae	-0.73	-0.27	-0.55	0.50	-0.57	-0.40
Galumnidae	0.68	0.75	0.71	-0.02	0.17	0.87*
Hermanniellidae	0.08	0.35	0.11	0.71	-0.45	0.37
Zetorchestidae	-0.38	0.20	-0.20	0.86*	-0.73	0.12
Heterobelbidae	0.65	0.51	0.34	0.28	0.05	0.64
Hermannidae	-0.52	0.05	-0.32	0.84*	-0.75	-0.05

Note : *significant at 5% level; **significant at 1% level

From the results of correlation analysis, Oppiidae negatively correlated with organic carbon and water content that were -0.81 and -0.83, respectively. This means that increasing in organic carbon up to 7.45% and increasing in water content up to 38.30 in jungle rubber could decrease in the abundance of Oppiidae in this study. This was presumably because Oppiidae prefers habitats that contain organic carbon ranging from 1.38% to 4.76% and water content ranging from 3.8 to 18.96 obtained from the results of this study. Krantz and Walter (2009) suggested that high population densities in

Oppiidae are associated with high C/N ratios. The abundance of Euphthiracaridae, Malaconothridae and Neoliodidae were positively correlated with total nitrogen of 0.95; 0.89 and 0.90, respectively. It was caused nitrogen is a source of food for Oribatida. The family Mesoplophoridae, Hemilleidae, Zetorchestidae and Hermannidae were positively correlated with C/N ratio of 0.94; 0.84; 0.86 and 0.84, respectively. Zetorchestidae and Mesoplophoridae are families associated with litter, and moss. Zetorchestidae may migrate where its habitat is impaired, the movement of Zetorchestidae as far as 14.6 cm is approximately

290 times the length of its body size (Krantz and Walter, 2009). The family Protoribatidae was negatively correlated with soil temperature of -0.91. An increase in soil temperature of 26.5°C to 27.3°C caused a decrease in abundance Protoribatidae. The abundance of family Phtiracaridae, Thrypochthoniidae, Malaconothrida, Neoliodidae and Galumnidae were positively correlated with soil water content of 0.86; 0.88; 0.92; 0.89 and 0.87, respectively. Thrypochthoniidae and Malaconothridae are more common in moist and wet habitats (Evans, 2003) in the same way, Murvanidze et al. (2016) found Galumnidae very abundant in the litter on the river bank in Georgia's Mtirala National Park and is a species known to specifically inhabit wet habitats in Georgia (Murvanidze et al., 2011; Mumladze et al., 2013).

Conclusion

The numbers of families found in the six types of land use were 36 families of the total population of the Oribatids of 1242.5 individuals/m² in the litter and 450 individuals/m² in the soil, respectively. Oribatids in the jungle rubber showed the highest abundance (592.5 individuals/m²), followed by secondary forest (317.5 individuals/m²), primary forest (287.5 individuals/m²), slash and burn (195 individuals/m²), young fallow (157.5 individuals/m²) and old fallow (142.5 individuals/m²). The value of diversity index according to Shannon Wiener (H') ranged between 1.71 and 2.64 or categorized as moderate diversity values. Some families of oribatids have relationships with environmental factors such as soil pH, organic carbon, total N, water content and soil temperature. There are sensitive and not sensitive to environmental change, this is indicated by the value of the correlation that is different.

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References

Balittanah (Soil Research Center). 2009. Analysis of Soil, Plant, Water and Fertilizers Chemistry. Bogor (ID) : Balai Besar Litbang Sumberdaya Lahan Pertanian (*in Indonesian*).

- Balogh, J. and Balogh, P. 1988. Oribatid Mites of The Neotropical Region I. Elsevier Science Publishing, USA. 335 pp.
- Balogh, J. and Balogh, P. 1990. Oribatid Mites of The Neotropical Region I-II. Elsevier Science Publishing, USA. 335 pp.
- BAPPEDA. 2017. Kapuas Hulu District [internet]. [Downloaded 2018 March 12]. Available at: <http://bappeda.kapuashulukab.go.id/products/language/books-rpjmd/> (*in Indonesian*).
- Behan-Pelletier, V.M. 1999. Oribatid mite biodiversity in agroecosystems : role for bioindication. *Agriculture, Ecosystem & Environment* 74: 411-423
- Coleman, D.C., Crossley, D.A. and Hendrix, J.P.F. 2004. Fundamentals of Soil Ecology. 2nd Ed. California [US] : Elsevier Academic Press. 386p
- Erdmann, G., Scheu, S. and Maraun, M. 2012. Regional factors rather than forest type drive the community structure of soil living Oribatid mites (Acari, Oribatida). *Experimental and Applied Acarology* 57 : 157-169.
- Ermilov, S.G. and Lochynska, M. 2008. The influence of temperature on the development time of three oribatid mite species (Acari, Oribatida). *North-Western Journal of Zoology* 4(2): 274-281.
- Evans, O.G. 2003. Principles of Acarology. University College, Dublin. CAB International.
- Hulstman, A. and Wolters, V. 1998. The effects of different tillage practices on soil mites, with particular reference to Oribatida. *Applied Soil Ecology* 9: 327-332.
- Krantz, G.W. and Walter, D.E. 2009. A Manual of Acarology. 3rd Ed. Texas Tech University Press, USA. p 430-564.
- Lisafitri, Y. 2015. Population Dynamics of Oribatid Mites in the Oil palm Plantation Area at Bajubang Batanghari Jambi. [Thesis]. Bogor (ID):Bogor Agricultural University (*in Indonesian*).
- Magurran, A.E. 2004. Measuring Biological Diversity. Blackwell Publishing, Maiden.
- Maraun, M. and Scheu, S. 2000. The structure of oribatid mite communities (Acari, Oribatida): patterns, mechanisms and implications for future research. *Ecography* 23: 374-383.
- Meyer, E. 1996. Mesofauna. In. E. Schinner, R. Ohlinger, E. Kandeler, and R. Margesin (Eds). Methods in Soil Biology. Springer-Verla, Berlin. p. 343.
- Mumladze, L., Murvanidze, M. and Behan-Pelletier, V. 2013. Compositional patterns in Holarctic peat bog inhabiting oribatid mite (Acari: Oribatida) communities. *Pedobiologia* 56(1):41-48.
- Murvanidze, M., Mumladze, L., Arabuli, T., Barjadze, S. and Salakaia, M. 2016. Oribatida diversity in different microhabitats of Mtirala National Park. *Journal of The Acarological Society of Japan* 25 (S1): 35-49.
- Murvanidze, M., Mumladze, L., Arabuli, T. and Kvavadze, E.R. 2011. Landscape distribution of oribatid mites (Acari, Oribatida) in Kolkheti National Park (Georgia, Caucasus). *Zoosymposia* 6:221-223.
- Postma-Blaauw, M.B., Goede, R.G.M., Bloem, J., Faber, J.H. and Brussaard, L. 2010. Soil biota

- community structure and abundance under agricultural intensification and extensification. *Ecology* 91(2):460-473.
- Schneider, K. 2005. Feeding biology and diversity of Oribatida. vom Fachbereich Biologie der Technischen Universität Darmstadt genehmigte Dissertation zur Erlangung des akademischen Grades eines Doctor rerum naturalium.
- Seniczaki, S., Kaczmareki, S., Seniczak, A. and Graczyk, R. 2012. Oribatid mites (Acari, Oribatida) of open and forested habitats of Korčula Island (Croatia). *Biological Letters* 49(1): 27-34.
- Stefaniak, O. and Seniczak, S. 1981. The effect of fungal diet on the development of Oppianitens (Acari, Oribatei) and on the microflora of its alimentary tract. *Pedobiologia* 21: 202-2010.
- Sugiarto, Sugito, Y., Handayanto, E. and Agustina, L. 2002. Influence of forest land use system to diversity of soil macroinvertebrate in RPH Jatirejo, Kediri, East Java. *Biosmart* 4(2): 66-69 (in Indonesian).
- Suhardjono, Y.R., Deharveng, L. and Bedos, A. 2012. Biology-Ecology-Collembola Classification (Spring Tail). Bogor (ID): Vegamedia. (in Indonesian).
- Suwondo. 2002. Composition and diversity of microarthropods on the soil as an indicator of biological characteristics in peat soils. *Jurnal Natur Indonesia* 4 (2): 112-186 (in Indonesian).
- Wibawa, G. and Hendratno, S. 2001. Rubber Wastes [Information Sheet 2]. ICRAF.