B I O D I V E R S I T A S
Volume 10, Number 4, October 2009
Pages: 195-200

ISSN: 1412-033X (printed edition)
ISSN: 2085-4722 (electronic)
DOI: 10.13057/biodiv/d100406

Diversity and Abundance of Beetle (Coleoptera) Functional Groups in a Range of Land Use System in Jambi, Sumatra

FRANCISCUS XAVERIUS SUSILO[1,♥], INDRIYATI[1], SURYO HARDIWINOTO[2, ♥♥]
[1]Faculty of Agriculture, Lampung University (UNILA), Bandar Lampung 35145, Indonesia
[2]Faculty of Forestry, Gadjah Mada University (UGM), Yogyakarta 55281, Indonesia

Received: 11th April 2009. Accepted: 10th June 2009.

ABSTRACT

Degradation of tropical rain forest might exert impacts on biodiversity loss and affect the function and stability of the related ecosystems. The objective of this study was to study the impact of land use systems (LUS) on the diversity and abundance of beetle functional groups in Jambi area, Sumatra. This research was carried out during the rainy season (May-June) of 2004. Inventory and collection of beetles have been conducted using winkler method across six land use systems, i.e. primary forest, secondary forest, *Imperata* grassland, rubber plantation, oilpalm plantation, and cassava garden. The result showed that a total of 47 families and subfamilies of beetles was found in the study area, and they were classified into four major functional groups, i.e. herbivore, predator, scavenger, and fungivore. There were apparent changes in proportion, diversity, and abundance of beetle functional groups from forests to other land use systems. The bulk of beetle diversity and abundance appeared to converge in primary forest and secondary forest and predatory beetles were the most diverse and the most abundant of the four major functional groups.

Key words: beetle, land use system, diversity, abundance, Sumatra.

INTRODUCTION

Land uses are changing (Vitousek, 1994) as linked with deforestation and agricultural intensification (GCTE, 1997). Tropical forests in Indonesia which are known as high biodiversity areas have been declining steadily, with estimated deforestation rate of about 2 million hectares per year (Suparna, 2005). Parts of the forested areas, for instance those in Sumatra, are cleared and changed into various land use systems, including oilpalm plantations, rubber plantations, cassava gardens, and *Imperata* grassland (van Noordwijk et al., 1995). Changes tropical rain forest to other land-uses might exert impacts on forest fragmentation and degradation, cause loss of diversity and affect the function and stability of the ecosystems.

There has been a perception that land use change affects soil biological diversity but more investigations are needed to collect the evidence (Giller et al., 1997). Jones et al. (2003) reported a reduction in diversity of termites as related to deforestation and agricultural intensification in Jambi, Sumatra. Does land use change affect diversity of soil-related beetles? Beetles are taxonomically diverse and common components of soil community which dwell mainly in litter (Lavelle and Spain, 2001). Soil beetles may play important roles in the ecosystem through their activities as predators, herbivores, and scavengers (Brussaard et al., 1997). Herbivorous beetles may cause crop injury and yield loss while, in contrast, predatory beetles can perform as biological control agents against the crop pests (Kalshoven, 1981). Scavenger beetles comminute and decompose soil organic matters. In agroecosystems beetles are often exposed to soil tillage, chemical pesticide, inorganic fertilizer application, and monoculture planting system. Tillage could damage beetle microniches and foraging sites while insecticide could toxify them. Meanwhile, monoculture system could in one hand limit food access for a number of species but in the other hand allow excessive exploitation for only few other species of herbivorous beetles. This study was aimed at inventorying the diversity and abundance of beetle functional groups in a range of land use systems of different intensity gradient in Jambi, Sumatra.

Corresponding address:
♥ Jl. Sumantri Brojonegoro No. 1, Bandar Lampung 35145
Tel.: +62-721-785665, Fax:+62-721-702767,
email: fxsusilo2000@yahoo.com

♥♥ Jl. Agro-Bulaksumur, Yogyakarta 55281
Tel.: +62-274-512102, 901420, Fax: +62-274-550541
email: suryohardiwinoto@yahoo.com

MATERIALS AND METHODS

Beetle field sampling was done during the end of rainy season (May-June) of 2004 across six land use systems (LUS) distributed over ca. 6 km^2 area in Jambi, Sumatra where a stratified-grid procedure (GW2, 2003) was used to select the sample points. The observed LUS were primary forest (Forest Less Intensive/FLI), secondary forest (Forest Intensive/FI), rubber plantation (Tree-based Intensive/TBI-1), oilpalm plantation (Tree-based Intensive/TBI-2), cassava garden (Crop-based Less Intensive/CBLI), and *Imperata* grassland (Shrubs/Shrb). Descriptions for each LUS can be found in Prastyaningsih (2005). The sampling area was first delimited into three windows of 2-3 km^2 size each, i.e. Muara Kuamang (South $01^o34'12.1''$-$01^o34'52.8''$ and East $102^o15'05.4''$-$102^o15'59.7''$) consisted of FLI and FI; Kuamang Kuning (South $01^o36'32.2''$-$01^o37'06.1''$ and East $102^o17'01.7''$-$102^o17'42.3''$) consisted of TBI-1, TBI-2, Shrb, and CBLI; and Rantau Pandan (South $01^o39'03.2''$-$01^o40'07.6''$ and East $101^o56'05.4''$-$101^o56'52.0''$) dominated by FLI, FI, and TBI-1. Next, undivided grid of 200 m x 200 m points was set over each window resulting in 64-72 prospective points per window. The grid points were then each ground-checked for feasibility. Feasible criteria included the ease of access and the minimum patch size. A minimum of 20 m x 20 m sampling area of the same patch of land use type should be fit somewhere in a feasible point. Finally, five out of existing feasible points were selected randomly per LUS in a window and taken to be the sample points. That way, the observed LUS and windows where the sample points were selected were as follow: FLI (Muara Kuamang), FI (Muara Kuamang), TBI-1 (Kuamang Kuning), TBI-2 (Kuamang Kuning), Shrb (Kuamang Kuning), and CBLI (Kuamang Kuning).

Winkler method (Chung and Jones, 2003) was used to collect beetles from litter in the sample points. In each sample point gross litter was taken from three Winkler quadrates of 1m x 1m along transect laid out 12 m from the center point (GPS grid). The distance between quadrates in transect was 6 m. The litter was sieved, weighed, and incubated (Susilo and Karyanto, 2005). The sieving was done by two persons for five minutes per quadrate using a Winkler sieve (Jones, 2003). The litter materials passing the sieve, i.e. fine litter (sized < 1 cm^2) was collected *in situ* into the Winkler collecting bag for further handling in the incubation room. The fine litter was weighed and placed in the Winkler sieves which were then suspended inside the Winkler bag for incubation for 72 hours under room temperature. During the incubation period the litter dried out, causing beetles to leave it and drop off into the collecting bottle containing 70% alcohol at the base of the Winkler bag. Beetle specimens were then transferred into vials containing 75% alcohol for labeling, storage, and identification. Identification up to family (and some to subfamily) level was done under a dissecting microscope using Chung (2003) and Borror et al. (1981).

The documented data included the beetle diversity and abundance. The diversity was the number of families and subfamilies found in three 1-m quadrates of litter (a sample point). The abundance was taken to be the number of individuals of each family per three 1-m quadrates (i.e. per sample point). Having five records of diversity as well as abundance data, a land use type had its mean diversity and mean abundance data and their corresponding standard errors. Mean diversity was the number of family averaged from five replications (five sampling points) of the same land use. Mean abundance was defined as the number of individuals of beetles (all species combined by sample point) averaged from five replications. The similarity in beetle communities between land use system was determined using Bray-Curtis measure of dissimilarity (B) as follow (Krebs, 1989)

$$B = \frac{\sum \left| X_{ij} - X_{ik} \right|}{\sum \left(X_{ij} + X_{ik} \right)}$$

X_{ij}, X_{ik} = number of individuals in i^{th} beetle family in each sample (i.e. land use system), *j* = one land use system (1, 2, 3, 4, 5, 6), and *k* = other land use system (1, 2, 3, 4, 5, 6) being compared with *j.* The resulting B values were used to compose a dendrogram and grouping of land use systems.

The collected beetles were then grouped by their functional groups. Six feeding groups identified in Chung et al. (2000) which followed Hammond (1990) were simplified into four, i.e. herbivores, predators, scavengers, and fungivores. The mean diversity and abundance data were calculated by land use systems, by beetle functional groups, and by combination of land use system-functional group. The mean values were compared between land use systems, between beetle functional groups, and between combination of land use system-functional group using ANOVA and LSD at 5% level of significance (Snedecor and Cochran, 1980). In addition, the diversity data, i.e. the number of beetle families of each functional group, was also pooled within each land use system and their proportion of each functional group was plotted by land use systems.

RESULTS AND DISCUSSION

The beetles recovered from litter of six land use systems in Jambi consisted of 47 families and subfamilies with four major feeding groups (Table 1). Figure 1 shows three groups of land use systems in Jambi based on dissimilarity (similarity) in their beetle community composition at (sub) family level, namely

(i) the primary forest (FLI)-secondary forest (FI), (ii) the rubber plantation (TBI-1)-oilpalm plantation (TBI-2), and (iii) *Imperata* grassland (Shrb)-cassava garden (CBLI). The beetle community assemblages in the second group are more similar to the third than to the first group. In other words, the beetle assemblages in the non-forested land use systems are less similar to those in the forested systems. However, the grouping might be clearer if the beetle community composition was delimited down to the lower taxonomic level, i.e. genus or species.

Table 1. Taxonomic and functional group diversity of beetles collected using Winklers in Jambi, Sumatra, May-June 2004

No.	Family and sub-family	Functional group*
1	Anthicidae	SCAVENGER
2	Brentidae	HERBIVORE
3	Byrrhidae	MOSS FEEDER
4	Carabidae	PREDATOR
5	Cerambycidae	HERBIVORE
6	Alticinae	HERBIVORE
7	Eumolpinae	HERBIVORE
8	Galerucinae	HERBIVORE
9	Coccinellidae	PREDATOR
10	Colydiidae	PREDATOR
11	Corylophidae	FUNGIVORE
12	Cryptophagidae	FUNGIVORE
13	Cucujidae	SCAVENGER
14	Chryptorhynchinae	HERBIVORE
15	Otiorhynchinae	HERBIVORE
16	Rhynchoporinae	HERBIVORE
17	Elateridae	HERBIVORE
18	Histeridae	PREDATOR
19	Hydrophilidae	PREDATOR
20	Languriidae	FUNGIVORE
21	Leiodidae	SCAVENGER
22	Lymnichidae	HERBIVORE
23	Mycetophagidae	FUNGIVORE
24	Mycteridae	SCAVENGER
25	Nitidulidae	FUNGIVORE
26	Pselaphidae	PREDATOR
27	Ptiliidae	SCAVENGER
28	Scaphididae	FUNGIVORE
29	Aphodiinae	SCAVENGER
30	Melolonthinae	SCAVENGER
31	Valginae	SCAVENGER
32	Scirtidae	SCAVENGER
33	Scolytidae	FUNGIVORE
34	Scydmaenidae	PREDATOR
35	Silvanidae	SCAVENGER
36	Aleocharinae	PREDATOR
37	Euaesthetinae	PREDATOR
38	Osoriinae	PREDATOR
39	Oxytelinae	PREDATOR
40	Paederinae	PREDATOR
41	Protopselaphinae	PREDATOR
42	Tachyporinae	PREDATOR
43	Staphylininae	PREDATOR
44	Asidinae	SCAVENGER
45	Tentyriinae	SCAVENGER
46	Tenebrioninae	SCAVENGER
47	Throscidae	FUNGIVORE

Note: *) based on Hammond (1990), Chung et al. (2000), and other sources (including Borror et al., 1981 and Kalshoven, 1981)

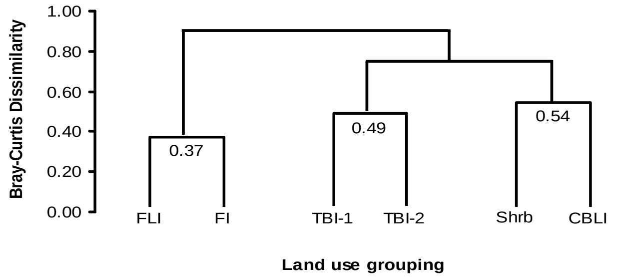

Figure 1. Dendrogram of dissimilarity in beetle communities in a range of land use systems in Jambi (FLI = primary forest, FI = secondary forest, TBI-1 = rubber plantation, TBI-2 = oilpalm plantation, Shrb = *Imperata* grassland, CBLI = cassava garden).

Based on the total diversity and total abundance, the functional groups can be arranged in a descending order, as follows: predator, scavenger, herbivore, and fungivore (Figure 2). One family, Byrrhidae, is the moss feeders. The pooled data showed apparent changes in proportion of some functional groups from forests to other land use systems (Figure 3 and Figure 4). Herbivore diversity and abundance were of higher proportion in agroecosystem or *Imperata* grassland as compared with those in the forest. Similar pattern held for scavengers. Predator's proportion, however, showed different pattern; while no apparent change occurred in its diversity proportion (Figure 3) the abundance proportion of predator pool decreased in non-forest land use systems (Figure 4). As for fungivores, there was no clear pattern of increase or decrease in their proportion relative to the other functional groups.

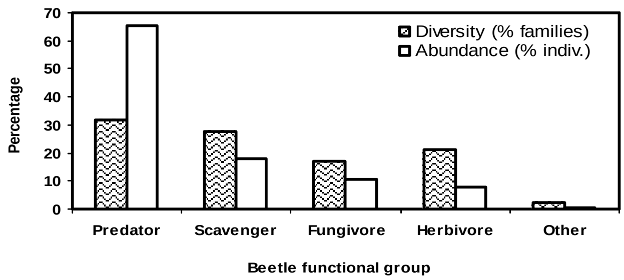

Figure 2. Total diversity and abundance of four major functional groups of beetles in Jambi

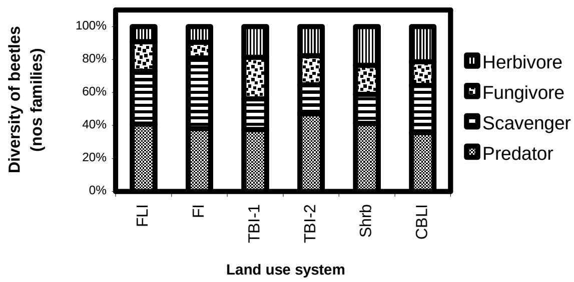

Figure 3. Total diversity proportions of four major functional groups of beetles in a range of land use systems in Jambi (FLI = primary forest, FI = secondary forest, TBI-1 = rubber plantation, TBI-2 = oilpalm plantation, Shrb = *Imperata* grassland, CBLI = cassava garden)

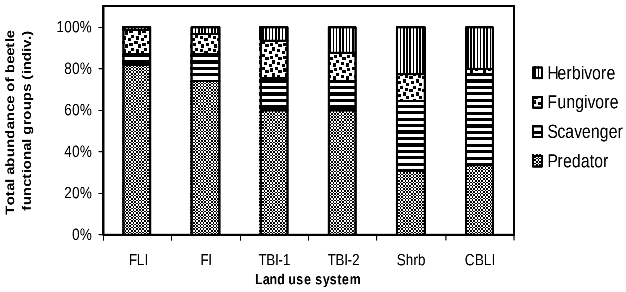

Figure 4. Total abundance proportions of four major functional groups of beetles in a range of land use systems in Jambi (FLI = primary forest, FI = secondary forest, TBI-1 = rubber plantation, TBI-2 = oilpalm plantation, Shrb = *Imperata* grassland, CBLI = cassava garden)

The overall bulk of beetle diversity appeared to converge in primary forest (FLI) and secondary forest (FI) (Table 2). Table 2 shows significant decrease in the beetle overall mean diversity (number of family) as the primary forest (FLI) were changed into non-forest systems (Shrb, TBI-1, TBI-2, CBLI). The predatory beetles were the most diverse of the four major functional groups (Table 3). Figure 5 separates the beetle mean diversity by land use systems and the beetle functional groups. It depicts the following information. The highest diversity of predatory beetles was found in primary forest. The diversities within other functional groups (scavengers, fungivores, or herbivores) did not significantly fluctuate across land use systems but the diversity between the functional groups varied within a common land use system. In primary forest, the diversities of scavenger, fungivore, and herbivore beetles were comparatively of the same level but less than that of predatory beetles. In secondary forest, the diversity of beetle functional groups could be clustered in three classes, i.e. relatively high diversity (predators), relatively low diversity (fungivores and herbivores), and in between the two (scavengers). Three classes of beetle diversity could also be seen in rubber plantation (TBI-1) and oilpalm plantation (TBI-2), i.e. relatively high diversity (predators), relatively low diversity (herbivores), and in between the two (scavengers and fungivores). No variation in diversities was shown between beetle functional groups either in *Imperata* grassland (Shrb) or cassava garden (CBLI). The diversities of each beetle functional group in the later two land use systems were unfluctuated and relatively of low level.

The highest beetle abundance was found in primary forest (FLI) and secondary forest (FI) (Table 2). Table 2 shows significant decrease in the beetle overall mean abundance as the primary forest (FLI) were changed into non-forest systems (Shrb, TBI-1, TBI-2, CBLI). Predatory beetles were the most abundant functional group (Table 3). Figure 6 shows differences in abundance between beetle functional groups within land use systems but no differences in abundance within beetle functional groups across land use systems (except those of predators). The highest abundance of predatory beetles was found in primary forest; while the second highest was in secondary forest. No abundance differences across land use systems were detected for scavenger, fungivore, and herbivore beetles. In primary forest and secondary forest, predatory beetles were more abundant than scavenger, fungivore, or herbivore beetles. However, no differences in abundance of all four functional groups were detected in rubber plantation (TBI-1), oilpalm plantation (TBI-2), *Imperata* grassland (Shrb), and cassava garden (CBLI). The collapse of beetle assemblage along a land-use intensification gradient from less disturbed (forested) to more disturbed (non-forested) land use systems as shown in this study is in accordance with the results of other soil insect studies done previously in Sumatra, including Susilo et al. (2006) on beetles in Lampung, Susilo and Hazairin (2006) on ants in Lampung, Susilo and Aini (2005) on termites in Lampung, and Jones et al. (2003) on termites in Jambi.

Table 2. Mean diversity and mean abundance of beetles in a range of land use systems in Jambi

Land use system	Mean diversity (number of family/sample point)	Mean abundance (indiv./sample point)
FLI	2.2 a	8.6 a
FI	1.7 ab	5.8 ab
Shrb	1.0 b	2.0 c
TBI-1	1.2 b	2.3 c
TBI-2	1.3 b	2.9 bc
CBLI	1.3 b	4.2 bc
$LSD_{0.05}$	0.8	3.1

Note: mean values followed by different letters are significantly different using LSD test at 0.05 level (FLI = primary forest, FI = secondary forest, TBI-1 = rubber plantation, TBI-2 = oilpalm plantation, Shrb = *Imperata* grassland, CBLI = cassava garden)

Table 3. Mean diversity of four major functional groups of beetles in Jambi

Functional groups	Mean diversity (number of family/sample point)	Mean abundance (indiv./sample point)
Predator	2.7 a	10.9 a
Scavenger	1.4 b	3.0 b
Fungivore	0.8 b	1.8 b
Herbivore	0.8 b	1.4 b
$LSD_{0.05}$	0.6	2.5

Note: mean values followed by different letters are significantly different using LSD test at 0.05 levels

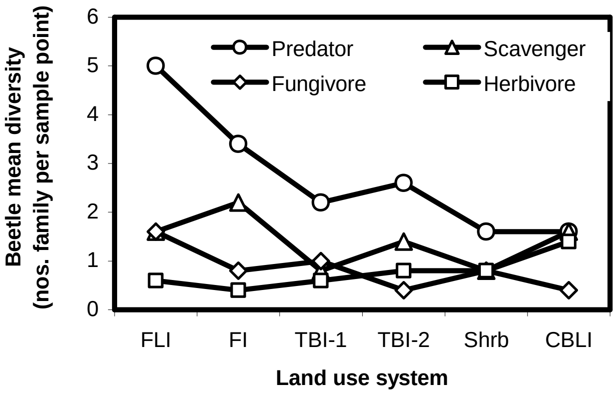

Figure 5. Mean diversity of four major functional groups of beetles in a range of land use systems in Jambi (FLI = primary forest, FI = secondary forest, TBI-1 = rubber plantation, TBI-2 = oilpalm plantation, Shrb = *Imperata* grassland, CBLI = cassava garden)

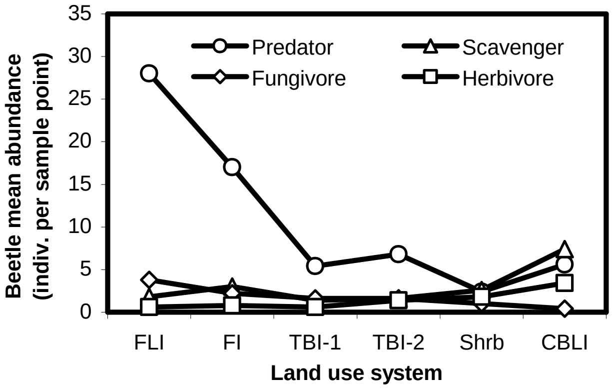

Figure 6. Mean abundance of four major functional groups of beetles in a range of land use systems in Jambi (FLI = primary forest, FI = secondary forest, TBI-1 = rubber plantation, TBI-2 = oilpalm plantation, Shrb = *Imperata* grassland, CBLI = cassava garden)

Environmental disturbance may lead to reorganizations of local resources available to consumers which in turn affects the food web structure (Chung et al., 2000). This process explains changes in tropic group proportion, especially in the most disturbed habitats. The disturbance is usually suitable for herbivores (Lawrence, 1996; Chung et al., 2000) but unfavorable for predators (Brown and Southwood, 1983; Pimm et al., 1991; Chung et al., 2000). Figure 4 seems to conform to the theory (decrease the proportion predator abundance and increase the proportion of herbivore abundance), as are Figure 5 and Figure 6 (decrease the mean diversity and mean abundance of predatory beetles). It is interesting to note, however, that the disturbance also seems to favor scavengers (Figure 4, increase the proportion of scavenger abundance).

CONCLUSIONS

The inventory resulted in 47 families and subfamilies of beetles with four major functional groups, i.e. herbivores, predators, scavengers, and fungivores. There was an apparent difference of the beetle familial assemblages between land uses or groups of land uses based on bray-curtis indices. Changes of beetle assemblages were also detected in proportion and abundance of beetle functional groups from forests to other land use systems. There were differences in diversity and abundance between beetle functional groups within land use systems but no differences in diversity and abundance within beetle functional groups across land use systems (except those of predators). The bulk of beetle diversity and abundance appeared to converge in primary forest and secondary forest while predatory beetles were the most diverse and the most abundant of the four major functional groups.

ACKNOWLEDGMENTS

This publication presents part of the findings of the international project “Conservation and Sustainable Management of Below-Ground Biodiversity (CSM-BGBD)” implemented in seven tropical countries, namely Brazil, Mexico, Cote d’Ivoire, Kenya, Uganda, India, and Indonesia. The project is coordinated by Tropical Soil Biology and Fertility Institute of CIAT (TSBF-CIAT) with co-financing from the Global Environment Facility (GEF) and implementation support from the United Nations Environment Programme (UNEP). A.M. Hariri and L. Wibowo deserve our special appreciation for their assistance in the identification and tallying the beetles in the laboratory. Our sincere gratitude also goes to Dr. Shahabuddin Saleh for critically reviewing this manuscript.

REFERENCES

Borror, D.J., D.M. De Long, and C.A. Triplehorn. 1981. *An Introduction to the Study of Insects.* 5th ed. Philadelphia: Saunders College Publ.

Brown, V.K. and T.R.E. Southwood. 1983. Tropic diversity, niche breadth and generation times of exopterygote insects in a secondary succession. *Oecologia* 56: 220-225.

Brussaard, L., V.M. Behan-Pelletier, D.E. Bignell, V.K. Brown, W. Didden, P. Folgarait, C. Fragoso, D.W. Freckman, V.V.S.R. Gupta, T. Hattori, D.L. Hawksworth, C. Klopatek, P. Lavelle, D.W. Malloch, J. Rusek, B. Soderstrom, J.M. Tiedje, and R.A. Virginia. 1997. Biodiversity and ecosystem functioning in soil. *Ambio* 26, 563-570.

Chung, A.Y.C. and D. T. Jones. 2003. Extraction rates of soil arthropods using the winkler bag sampling technique. *In*: Jones, D.T. (ed.). *Tools for the Rapid Assessment of Soil Invertebrate Biodiversity in the ASEAN Region*; *Handbook to Accompany the Training Course,* 13-25 October 2003. Kota Kinabalu: Universiti Malaysia Sabah.

Chung, A.Y.C. 2003. Manual for bornean beetle (Coleoptera) family identification. *In*: Jones, D.T. (ed.). *Tools for the Rapid*

Assessment of Soil Invertebrate Biodiversity in the ASEAN Region; *Handbook to Accompany the Training Course,* 13-25 October 2003*.* Kota Kinabalu: Universiti Malaysia Sabah.

Chung, A.Y.C., P. Eggleton, M.R. Speight, P.M. Hammond, and V.K. Chey. 2000. The diversity of beetle assemblages in different habitat types in Sabah, Malaysia. *Bulletin of Entomological Research* 90: 475-496.

GCTE (Global Change Terrestrial Ecosystem). 1997. *Living with Global Change: Linking Science and Policy in South East Asia. Workshop Summary and Synthesis.* GCTE Report No. 14/BIOTROP-GCTE Southeast Asian Impacts Centre (IC-SEA) Report No. 2. Canberra.

Giller, K.E., M.H. Beare, P. Lavelle, A.M.N. Izac, and , M.J. Swift. 1997. Agricultural intensification, soil biodiversity and agroecosystem function. *Applied Soil Ecology* 6: 3-16.

GW2 (Global Workshop II Report). 2003. *Conservation and Sustainable Management of Below-ground Biodiversity.* UNEP-GEF TSBF-CIAT Project GF/2715-02-4517 GF/1030-02-05. February 24-28, 2003. Sumberjaya-Lampung, Indonesia.

Hammond, P.M. 1990. Insect abundance and diversity in the Dumago-Bone National Park, North Sulawesi, with special reference to the beetle fauna of lowland rainforest in the Toraut region. *In*: Knight, W.J. and J.D. Holloway (eds.). *Insects and the Rainforests of South East Asia (Wallacea).* London: The Royal Entomological Society of London.

Jones, D.T. 2003. *In*: Jones, D.T. (ed.). *Tools for the Rapid Assessment of Soil Invertebrate Biodiversity in the ASEAN Region*; *Handbook to Accompany the Training Course,* 13-25 October 2003*.* Kota Kinabalu: Universiti Malaysia Sabah.

Jones, D.T., F.X. Susilo, D.E. Bignell, S. Hardiwinoto, A.N. Gillison, and P. Eggleton. 2003. Termite assemblage collapse along a land-use intensification gradient in lowland central Sumatra, Indonesia. *Journal of Applied Ecolology* 40: 380-391.

Kalshoven, L.G.E. 1981. *Pests of Crops in Indonesia.* Rev. and Transl. by P.A. van der Laan. Jakarta: P.T. Ichtiar Baru-van Hoeve.

Krebs, C.J. 1989. *Ecological Methodology*. New York: Harper Collins Publ.

Lavelle, P. and A.V. Spain. 2001. *Soil Ecology.* Amsterdam: Kluwer Academic Publisher.

Lawrence, W.T., Jr. 1996. Plants: the Food Base. *In*: Reagan, D.P. and R.B. Waide (eds.). *The Food Web of a Tropical Rainforest* Chicago: The University of Chicago Press.

Pimm, S.L., J.H. Lawton, and J.E. Cohen. 1991. Food web patterns and their consequences. *Nature* 350: 669-674.

Prastyaningsih, S.R. 2005. *Diversitas Makrofauna Tanah pada Berbagai Tipe Penggunaan Lahan di Jambi.* [Tesis]. Yogyakarta: Program Studi Kehutanan Jurusan Ilmu-ilmu Pertanian, Sekolah Pascasarjana Universitas Gadjah Mada.

Snedecor, G.W. and W.G. Cochran. 1980. *Statistical Methods*. 7th ed. Ames: The Iowa State Univ. Press.

Suparna, N. 2005. Meningkatkan produktivitas kayu dari hutan alam dengan penerapan silvikultur intensif di PT Sari Bumi Kusuma Unit Seruyuan-Kalteng. *Dalam:* Hardiyanto, E.B. (ed.) *Prosiding Seminar Nasional: Peningkatan Produktivitas Hutan.* Proyek ITTO PD 106/01 Rev. 1 (F). Yogyakarta: Fakultas Kehutanan UGM & International Tropical Timber Organization.

Susilo, F.X. and F.K. Aini. 2005. Diversity and density of termites in a range of land use types in the Rigis Hill Area, Sumberjaya-Lampung. *Jurnal Sains dan Teknologi* 11(3): 129-136.

Susilo, F.X. and M. Hazairin. 2006. Forest conversion into coffee-based agroforestry systems in Sumberjaya reduces abundance of predatory Myrmicine ants. *Agrivita* 28 (3): 238-251.

Susilo, F.X. and A. Karyanto. 2005. *Methods for Assessment of Below-ground Biodiversity in Indonesia.* Bandar Lampung: Universitas Lampung.

Susilo, F.X., A.M. Hariri, Indriyati, dan L. Wibowo. 2006. Keanekaragaman dan populasi kumbang pada berbagai sistem penggunaan lahan di Bukit Rigis Sumberjaya, Lampung Barat. *Jurnal Sains dan Teknologi* 12 (3): 143-148.

van Noordwijk, M., T.P. Tomich, R. Winahyu, D. Murdiyarso, Suyanto, S. Partoharjono, and M. Fagi (eds.) 1995. *Alternative to Slash-And-Burn in Indonesia. Summary Report Phase 1.* Bogor: ASB-Indonesia Report No. 4

Vitousek, P.M. 1994. Beyond global warning ecology and global change. *Ecology* 75: 1861-1876.