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SOIL-LITTER ARTHROPOD ASSEMBLAGE IN DIPTEROCARP FOREST, AGROFORESTRY AREA AND MAHOGANY PLANTATION IN MAKILING FOREST RESERVE, LAGUNA

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ABSTRACT – Arthropods are the most diverse among the animal groups and those in soil and litter play an important role in nutrient cycling but they received the least attention if not neglected in biodiversity conservation. This study compared the assemblages of soil and litter arthropods in dipterocarp forest (DF), agroforestry area (AA) and mahogany plantation (MP) at the Mt. Makiling Forest Reserve (MFR). They were extracted from soil and litter samples collected from each site during dry season (February 2009), sorted to lowest possible taxa, and assigned to morphospecies. Mean arthropod abundance in DF soil and that of MP litter were significantly higher compared to those in the other two sites, which were statistically similar. Soil and litter arthropod species richness (mean number of morphospecies) were not significant different among the sites. Arthropod diversity (Shannon index) in soil among the sites was statistically similar while in litter, DF and AA were statistically similar and more diverse than MP. There were few overlapping soil and litter arthropod species (lower than 50%) among the sites except for soil arthropods between DF and AA, which shared about 60% (Sorensens index = 0.60) of their species. Collembola, Hymenoptera (mainly ants), Coleoptera, and Acari were generally the most abundant among the soil and litter arthropod groups in the three sites and their species richness and diversity did not differ significantly except for litter Collembola which was significantly more diverse in DF than the two sites. Among these groups, abundance of Collembola and Coleoptera in soil and litter was significantly higher in DF than the two sites while litter Acari was significantly higher in AA and MP than in DF. Results support the idea that agroforestry system is more favorable in preserving the soil and litter arthropods than monoculture of trees and conformed the general trend of direct relationships between diversities of soil-litter arthropods and the surrounding vegetation.

Keywords: soil-litter arthropods, dipterocarp forest, mahogany plantation, agroforestry, forest reserve

INTRODUCTION

Tropical forests represent the largest terrestrial reservoir of biodiversity (Mayaux et al., 2005) and are well-known for high invertebrate diversity (Whitmore, 1998; Chazdon and Whitmore, 2002; Primack and Corlett, 2005). Their litter and soil harbor some of the Earth's most highly diverse with large number of organisms (Ruiter et al., 2002; Setälä, 2005; Fitter et al., 2005), most endangered, yet least understood biological communities (Emberton, 1996). These organisms play a central role in various terrestrial

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ecosystem functions that provide valuable ecosystem services that sustain soil quality and plant growth, as a driving force in nutrient cycling by fragmenting and ingesting litter material, and interacting with the microorganisms that decompose and mineralize the plant residue (Wardle et al., 1998; Höffer et al., 2001; Lavelle et al., 2001; Barros et al., 2004; Yang et al., 2007; Huhta, 2007). The activity of soil and litter arthropods together with other soil organisms is considered to be directly related to forest productivity (Mermut, 1985).

However, soil biological communities in the tropics greatly suffer from the rapid rate of land use changes (Achard et al., 2002) due to rapid forest conversion (FAO, 2006) for agricultural expansion, plantation development, commercial logging, mining industry, urbanization and road building (Geist and Lambin, 2002) resulting to soil degradation, which is related to drastic decline in activity and diversity of soil fauna (Bruyn, 1997). The rapid land use change leads to a massive extinction of tropical forest species (Pimm and Askins, 1995; Pimm and Raven, 2000) and unprecedented loss of biodiversity (Millenium Ecosystem Assessment, 2005). In particular, the intensification of land use practices and forest conversion into secondary forests, agroecosystems or agricultural fields often result in strong declines of the natural vegetation and its associated fauna (Franklin et al., 2001) including soil communities (Hedlund et al., 2004), the diversity of which is drastically reduced in man-made systems (Martius et al., 2001). Even small changes in soil arthropod communities may have major effects on the local nutrient dynamics (Heneghan and Bolger, 1998), and may eventually affect forest productivity.

Despite the recognized importance of soil and litter arthropod fauna in the crucial processes of ecosystem functioning (e.g., decomposition and nutrient cycling) (Wolters, 2001) in tropical forests (Vasconcelos and Laurance, 2005; Heneghan et al., 1999) and the serious effect of forest conversion on this group of organisms (Achard et al., 2002), the current knowledge of the soil fauna in the tropics is still "miserable" (Noti et al., 2003; Martius et al., 2004; Giller et al., 2005), while tropical soil-litter fauna remains poorly studied (Andre et al., 2002). Studies of local differences in the composition of soil-litter arthropods within old-growth or relatively undisturbed tropical forests are few (Atkin and Proctor, 1988; Burgess et al., 1999; Goehring et al., 2002; Wiwatwitaya and Takeda, 2005) and given less attention in most tropical countries like the Philippines, which is one of the megadiverse countries (Mittermeier et al., 1997) and biodiversity "hot spots" in the world (McNeely et al., 1990; Myers et al., 2000).

This paper compared the general soil and litter arthropod assemblages of the dipterocarp forest (DF), mahogany plantation (MP) and agroforestry area (AA) in Makiling Forest Reserve. The question asked was: How does the conversion of a tropical forest into tree plantation and agroforestry area affect the soil and litter arthropod assemblage? It was expected that the assemblage pattern of soil and litter arthropod in terms of abundance, species richness, diversity, and composition of the dipterocarp forest is different from man-made systems such as the mahogany plantation and agroforestry area. Likewise, it was expected that the species found in the natural forest is far from similar with those in the man-made systems.

MATERIALS AND METHODS

The Study Site

The Mt. Makiling Forest Reserve (MFR) is located in South Central Luzon (14°08' N and 121°11' E) within 65 km south of Metro Manila. With an area of 4,244 ha (80% of Mt. Makiling), the reserve covers the municipalities of Los Baños, Bay and Calamba of Laguna province and Sto. Tomas of Batangas province (Fig. 1), and is presently under the jurisdiction of the University of the Philippines Los Baños. The reserve serves as an educational and research resource, watershed, wildlife refuge, gene pool of biological diversity, recreational/ecotourism area, geothermal power source, and historical landmark.

Figure 1. Map showing the Mt. Makiling Forest Reserve (Source: ASEAN-Korea Environmental Cooperation Unit, 2004).

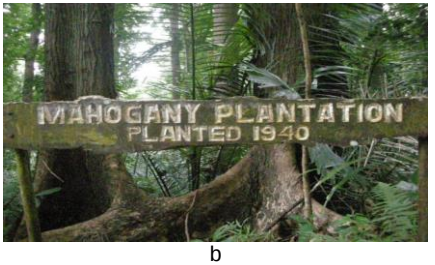
The Mt. Makiling is an isolated volcanic cone, but no eruption has been recorded in human history. The climate is tropical monsoon in character, with two pronounced seasons: wet from May to December and dry from January to April. The average annual precipitation is 2,397 mm and annual temperature ranges from 25.5 to 27.5 ºC. The dominant soil type of the area is clay loam, which is derived from volcanic tuff with andesite and a basalt base (Luna et al., 1999). The original vegetation surrounding the mountain base has been cleared and the land has been cultivated as well. However, remnant individuals in the ravines indicate that a dipterocarp forest zone was once present in the lowlands. The dominant dipterocarp species in the area are *Parashorea malaanonan*, *Shorea guiso*, and *Shorea contorta*. However, the lesser presence of dipterocarp species indicated that the species have suffered heavy utilization in the past, with the result that numerous non-dipterocarp tree species have now formed a species-rich secondary tropical rain forest (Luna et al., 1999). The area also consists of other land uses such as agroforestry, agricultural farm, plantations, leased areas, grasslands and the likes.

The study sites (Fig. 2) are situated at the north side of MFR. The dipterocarp forest (DF) of more than 10 ha is located near the mud spring at c. 270 m elevation. Labeled as high forest, it is characterized by being partly deciduous during dry season and dominated by tall and huge plants belonging largely to the family Dipterocarpaceae (Fernando et al., 2004). Agroforestry area (AA) is located few kilometers from the mud spring. It is a small farm of roughly 0.6 ha planted to a mixture of perennial and annual crops. Mahogany plantation (MP) is a 69-year old monostand of Swietenia macrophylla of c. 40 m tall with diameter reaching to c. 80 cm with an area of c. 0.9 ha located at 199 m elevation (Raceles *et al*., 2008). Soil and litter samples were collected from these study sites.

Arthropod Sampling

Soil and litter arthropod sampling was carried out during dry season (February 2009). Along a c. 2-km transect at each study site, soil and leaf litter (c. 2 li) samples were collected from three plots at c. 500-m distance. Transects were not necessarily straight but redirected when obstacles such as cliff were encountered or have reached the edge of the study site. Soil samples were collected from a 10 cm x 10 cm (100 cm^2) frame up to a depth of 5 cm, after removing the leaf litter on the surface. The soil and leaf litter samples were immediately brought to the laboratory for arthropod extraction using Tullgren funnel. Each sample was exposed to 50 W light bulb for 72 hours and the arthropod specimens were collected into plastic container with 70% alcohol. The arthropod specimens were sorted into class, order and, whenever possible, family (for insects). Within each group, the individuals were assigned to morphospecies (hereinafter referred to as species). Due to difficulty of assigning to which morphospecies the immatures belong, they were excluded in the analysis.

a



b

Soil-Litter Arthropod Assemblage in Dipterocarp Forest, Agroforestry Area and Mahogany Plantation in Makiling Forest Reserve, Laguna

Figure 2. The study sites: (a) agroforestry area; (b) mahogany plantation; (c) dipterocarp forest. (Photo by G.O. Sopsop)

Data Analysis

The data set on abundance and species richness (total count on the number of species per sample) were subjected to test for normality (Shapiro-Wilk's test) and homogeneity of variance (Levene's test). Transformation (log [x + 1]) was carried out when data departed from the assumptions of normality and homogeneity. Shannon diversity index was calculated per sample of each study site. Analysis of variance (ANOVA) was used to compare the mean abundance, number of species (species richness) and Shannon index across the sites. Least significant difference (LSD) was used to compare means among the sites. Presence/absence of species from the pooled data (three samples per site) was used for determining the similarity of species composition between sites using Sorensens Index.

RESULTS

From the pooled data of each study site, a total of 15 soil arthropod groups were collected from AA and DF while only nine from MP. At least 50, 54 and 43 soil arthropod species were recorded from DF, AA and MP, respectively. In litter, 18 litter arthropod groups collected from DF while 14 from MP and AA. DF, AA and MP had at least 82, 71 and 84 recorded litter arthropod species, respectively.

In mean soil arthropod abundance (Fig. 3a), DF was significantly higher than the two sites, which were statistically similar ($F_{[2,6]}$=6.39, p=0.033). In litter (Fig. 3b), arthropod abundance in MP was significantly higher than the two sites, which were statistically similar from each other ($F_{[2,6]}$=14.51, p=0.005).

Among the soil arthropod groups (Fig. 4a), Collembola in DF was highest in terms of percent abundance (41.92%) followed by Hymenoptera, mainly ants (22.93%), Coleoptera (15.94%) and Acari (11.79%). Acari predominated (28.67%) the soil of AA followed by ants (Hymenoptera) (27.64%), Collembola (20.82%) and Coleoptera (7.85%). The ants (Hymenoptera) constituted the highest percent abundance (34.01%) in MP soil followed by Collembola (28.75%), Acari (18.22%) and Coleoptera (8.91%). Other soil arthropod groups constituted only about 7.22%, 14.73% and 10.12% in DF, AA and MP, respectively.

In the litter of DF (Fig. 4b), Collembola predominated the arthropod groups (35.35%) followed by Hymenoptera (ants) (13.42%), Acari (12.93%) and Coleoptera (9.33%). In MP, Acari was the most abundant (41.89%) followed by Collembola (27.50%), Hymenoptera (9.07%) and Coleoptera (5.58%). Likewise, Acari was most abundant in AA soil followed by Collembola (13.88%), Hymenoptera (12.79%) and Hemiptera (4.52%). Coleoptera comprised only 2.96% of litter arthropod abundance in AA. Other litter arthropod groups comprised only about 23.99%, 14.29% and 12.67% in DF, AA and MP, respectively.

The results indicate that generally, Collembola, Hymenoptera, Acari and Coleoptera were the four most abundant groups in the soil and litter arthropods of the three sites, except for Coleoptera in AA litter, which was replaced by Hemiptera. Abundance, species richness and diversity of these groups were compared among the sites but Coleoptera, instead of Hemiptera, was considered in AA litter because the latter was not collected from MP litter.

Among the sites, Collembola, which was the predominant group in DF soil, was reduced in MP and AA (Fig. 4a). Soil Coleoptera followed the same abundance trend of soil Collembola. Statistically, Collembola ($F_{[2,6]}$=10.04, p=0.01) and Coleoptera ($F_{[2,6]}$=4.56, p=0.05) were higher in DF than in MP and AA, which were not significantly different from each other. Abundances of Hymenoptera ($F_{[2,6]}$=0.795,

p=0.494) and Acari ($F_{[2,6]}$=1.442, p=0.308) was lowest in DF soil but did not significantly differ among the sites.

In litter arthropods of the three sites, abundance of Collembola was highest in DF while lowest in AA (Fig. 4b). However, litter Collembola abundance in DF and MP were statistically similar but they differ significantly with that of AA ($F_{[2,6]}$=220.24, p<0.001). Similar trend in abundance among the sites and significant statistical results were observed with litter Coleoptera abundance ($F_{[2,6]}$=17.05, p=0.003). On the other hand, abundance of litter Acari was highest in AA and lowest in DF. Statistically, however, Acari abundances in AA and MP were not significantly different from each other, while they differ significantly with that of DF ($F_{[2,6]}$=121.96, p<0.001). Ants (Hymenoptera) abundance, which was highest in DF and lowest in MP, did not differ significantly among the sites.

In terms of the mean number of species was, DF was highest among the sites (Fig. 5), but was not significantly different from other sites both for soil ($F_{[2,6]}$=1.618, p=0.274) and litter ($F_{[2,6]}$=2.01, p=0.215).

In terms of soil arthropod groups, Acari was consistently the highest in the mean number of species in all sites (Fig. 6a). In DF and MP, Acari was followed by Collembola, Coleoptera and Hymenoptera in mean number of species. Among the sites, lowest Acari was observed in MP, which was followed by Coleoptera, Diptera, Hymenoptera and Collembola. Although Acari was highest in DF, it was statistically similar with other sites ($F_{[2,6]}$=0.832, p=0.48) so also with Collembola ($F_{[2,6]}$=1.5, p=0.296), Coleoptera ($F_{[2,6]}$=0.765, p=0.506) and Hymenoptera ($F_{[2,6]}$=0.765, p=0.506).

In litter, still Acari constituted the highest mean number of species in all sites (Fig. 6b). In DF, Acari was followed by Collembola, Araneida, Diptera and Coleoptera in mean number of species. Collembola, Hemiptera and Diptera, Hymenoptera and Homoptera followed Acari in AA in terms of species number. In MP, Acari was followed by Araneida, Collembola, Coleoptera and Hymenoptera. Among the litter arthropod groups with highest mean number of species in the three sites, only Collembola in DF was significantly higher than the two sites ($F_{[2,6]}$=7.0, p=0.027), while others were statistically not significant.

Shannon diversity index revealed no significant difference in overall diversity of soil and litter arthropods among the sites (Table 1). Likewise, no statistical difference was observed in the diversity of soil Hymenoptera, Coleoptera, Collembola and Acari among sites. In contrast, the overall litter arthropod diversity in DF and AA was significantly higher than MP. Litter Collembola showed significant results ($F_{[2,6]}$=7.0, p=0.027), in which DF was higher in mean number of species than AA and MP, while there was no significant difference of litter Hymenoptera ($F_{[2,6]}$=0.75, p=0.512), Coleoptera ($F_{[2,6]}$=2.905, p=0.131), and Acari ($F_{[2,6]}$=0.635, p=0.553) among the sites.

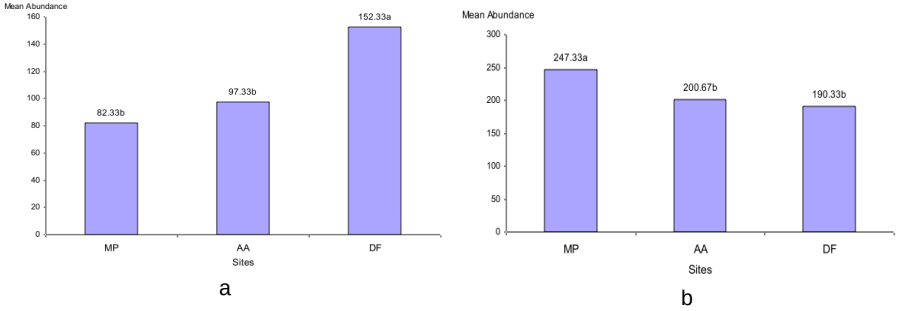


Figure 3. Mean abundance of soil-litter arthropods (a, soil; b, litter) of the three study sites. Values with the same letter are not significantly different at $p \leq 0.05$ confidence level using LSD.

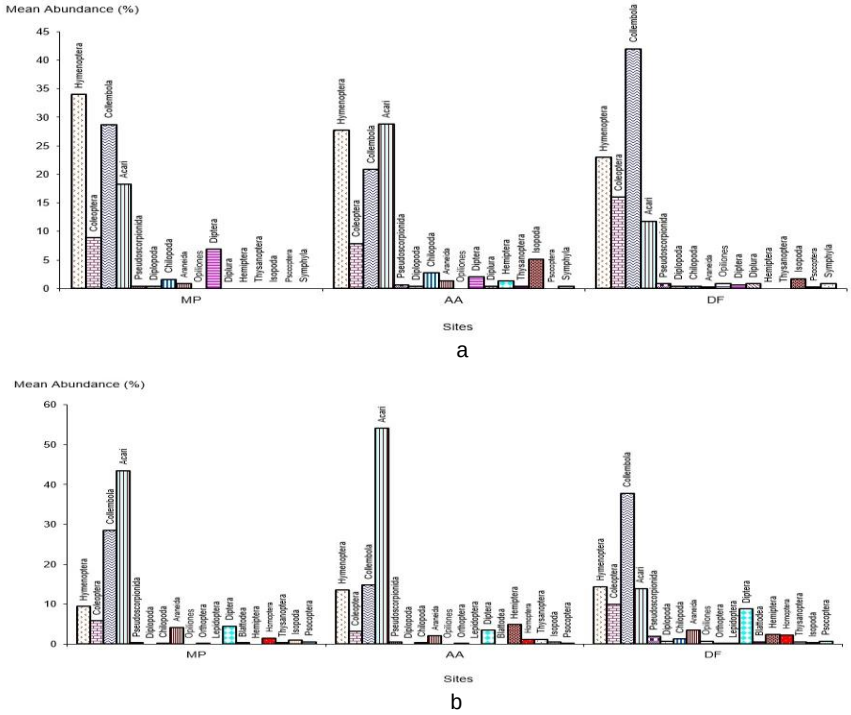


Figure 4. Mean abundance of different soil-litter arthropod groups (a, soil; b, litter) of the three study sites.

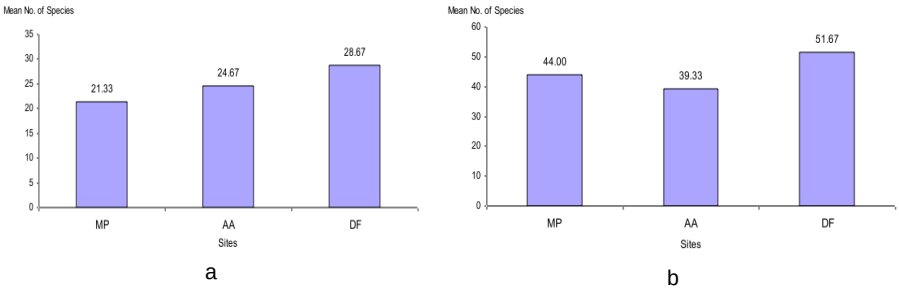


Figure 5. Mean abundance of soil-litter arthropods (a, soil; b, litter) of the three study sites. Values with the same letter are not significantly different at $p \leq 0.05$ confidence level using LSD.

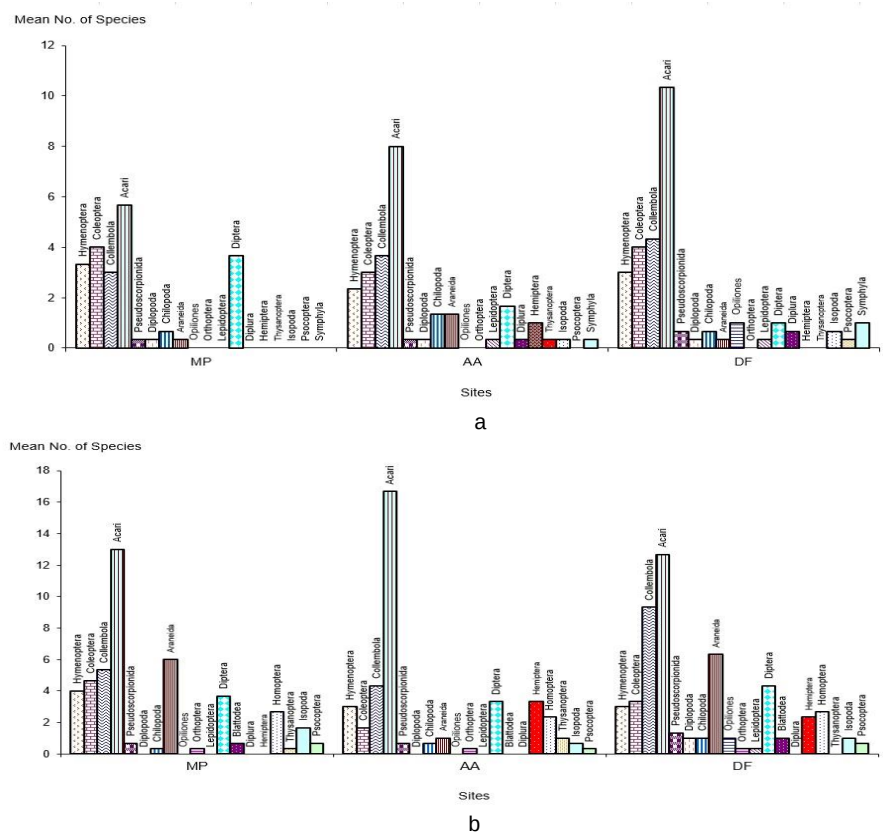


Figure 6. Mean number of species of different soil-litter arthropod groups (a, soil; b, litter) of the three study sites.

Table 1. Mean Shannon-Wiener diversity index values of soil-litter arthropods in the three sites.

Site	Soil	Litter
DF	0.9191	1.4611[a]
AA	1.0889	1.3558[a]
MP	1.0000	1.2454[b]

Mean of three replications. Means in a column with the same superscripts are not significantly different at $p \leq 0.05$ using LSD.

Regarding similarity of soil and litter arthropod species among the sites (Table 2), Sorensen's Index revealed that soil arthropod species between DF and AA had higher species overlap (60%) than any other pair of sites, which have less than 50%.

Table 2. Similarity of species among the three sites using Sorensen's Index.

Pair of Sites	Soil	Litter
DF & AA	0.60	0.44
DF & MP	0.47	0.49
AA & MP	0.48	0.49

DISCUSSION

Changes in soil microhabitat, which is more pronounced when natural forest is converted into agroforestry systems (Franklin et al., 2001) or tree plantations (Tsukamuto and Sabang, 2005) could be the possible reason for lesser abundant soil arthropods in AA and MP than DF (Fig. 3a). The presence of some soil and litter arthropod species in AA and MP that were found in DF as revealed by Sorensen's index (Table 2) is attributed to the nature of the original ecosystem of the two sites, which were previously DF. According to Lavelle et al. (1997), the nature of the original ecosystem greatly influences the effect of land use practices. AA and MP may have retained components of the original soil fauna because part of the original species is still present (Lavelle et al., 1997). The closer soil arthropod species assemblage between DF and AA (Sorensens index=0.60) is probably due to the agroforestry practices employed in AA. Agroforestry systems are generally considered to have positive effect on the conservation of biodiversity by minimum tillage, quantity and quality of litter, diversification especially the incorporation of trees of several species, shade, deep and perennial root systems that create a more suitable environment for soil faunal communities (Vohland and Schroth, 1999; Barros et al., 2003; Lopez-Hernandez et al., 2004; Brown et al., 2006). AA contains diversified perennial crops such as trees, and soil communities with perennial crops resemble that of natural ecosystems more closely (Ferris and Ferris, 1974; Wasilewska, 1979; Freckman and Ettema, 1993; Neher and Campbell, 1994). Although MP was originally DF, the monoculture of mahogany that provides lower plant diversity than AA explains why MP and AA had few overlapping soil and litter arthropod species.

On the other hand, although DF was numerically higher in species richness than the two sites, non-significant results were obtained on soil arthropod species richness (Fig. 5a) as well as diversity (Table 1) among the sites. Likewise, there was no significant difference on the species richness and diversity of the

four most abundant soil arthropod groups. This seems to contradict to the notion that reforestation with exotic species (e.g. mahogany) causes a decrease in diversity (Gama et al., 1994; Deharveng, 1996; Pinto et al., 1997; Sousa et al., 1997; Barrocas et al., 1998; Sousa et al., 2000) while disturbance linked to land use practices are likely to seriously affect species richness and diversity of soil invertebrates worldwide (Lavelle et al., 1997). According to Lindenmayer (2002), however, the greatest diversity and abundance of native animals in plantations occur in stands adjacent to native vegetation. It is suspected that there was recolonization going on particularly for mobile soil arthropods since AA and MP are just small patches presently embedded in the DF matrix that presumably served as recolonization sources in soil arthropods. But since environmental conditions are different, some species may not be able to persist. The non-significant difference in soil arthropod species richness and diversity across the sites does not necessarily translate into similarity of functional structure because their species assemblages were different as evidenced by the Sorensen's index value, most probably due to changes or differences in vegetation and soil condition (Hagvar, 1982; Ponge, 1993; Chagnon et al., 2000). Lindemayer et al. (2002) asserted that greater species diversity (and perhaps richness) is not always the best outcome for nature conservation and that it is often better to use the composition of particular assemblages as a measure. Conversely, comparing the soil arthropod species richness and diversity of the three sites in MFR may not be robust enough to discriminate their differences, and therefore misleading. Species assemblage must be considered in order to clarify the differences between sites.

Regarding litter arthropods, species richness across the sites was likewise not significantly different. This agrees with the findings of Samways et al. (1996) who found that species richness of litter invertebrates in pine and eucalypt plantations was not significantly different with that of indigenous forest. Likewise, Kattan et al. (2006) reported that there was no significant difference in litter insect richness between forest and alder plantation. The same explanation is offered to this findings with that of soil arthropods. For litter arthropod diversity, however, DF equals with AA and was significantly lower than MP, which could be attributed to the type of litter generated from the vegetation of each site. Arthropod diversity in litter depends on the type of litter and its complex microbial components, coupled with the heterogeneity of the litter layer (Ananthakrishnan, 1996). Data from natural forests and plantations indicate that litter types of varying structure and nutrient content influence the diversity and abundance of the litter fauna (Tian et al., 1993; Richardson et al., 2005). In AA, there were perennial crops such as trees of different species. Thus, the high tree diversity in DF and AA can create patchy litter habitats on a relatively small scale (Kaspari, 1996) including wood litter, which has been shown to harbor different litter arthropod communities depending on its decomposition stage (Kelly and Samways, 2003). Invertebrate assemblages are less diverse in plantations than in natural vegetation largely because of the relative structural simplicity of the former (Hobb et al., 2002). In monostand of mahogany, the abundant leaf litter can create a homogenous litter habitats allowing only those adapted species, most likely generalists, to harbor and become abundant, thus resulting to lower diversity. This explains why litter arthropods in MP were significantly more abundant than the two sites (Fig. 3b). Since the three sites have different vegetation types, it follows that they have few species overlap (Table 2).

Although agroforestry practices may conserve the species assemblage of soil arthropods similar to that of natural forest, they may affect particular groups of soil and litter arthropods such as Coleoptera and Collembola. Kouadio et al. (2009) reported that many beetle life cycles are associated with soil and ground litter and are affected by changes caused by human activities such as agriculture. It has been shown that in the soil and litter layer arthropods, such as Collembola, may be sensitive to silvicultural practices (Detsis et al., 2000; Chagnon et al., 2001). This explains the significantly higher abundance of soil and litter Collembola and Coleoptera in DF and MP than in AA. On the other hand, Collembola respond to changes in microclimate and microhabitat conditions like moisture (Verhoef and Van Selm, 1983; Pflug and Wolters, 2001), and amount and quality of litter (Cortet and Poinsot-Balaguer, 1998; Hasegawa, 2002). Also, different vegetation communities host different species assemblage of Collembola (Pozo et al., 1986; Setala et al., 1995; Gama et al., 1997; Benito and Sanches, 2001) and this

is particularly true when comparing open and closed habitat (Ponge, 1993). Crop management practices can also lead to changes in species assemblage and diversity of Collembola (Nakamura, 1988; Dekkers et al., 1994; Filser et al., 1995; Reddy et al., 1996; Loranger et al., 1999; Framptom, 2000; Alvarez et al.,, 2001; Gardi et al., 2002). This explains the higher litter Collembola species richness and diversity in DF than the two sites.

Interventions taking place in forests can induce multiple changes in mite communities particularly Oribatida (Gergócs and Hufnagel, 2009). The non-significant difference in litter Acari species richness and diversity in AA and MP with that of DF could be explained by intermediate disturbance hypothesis. This hypothesis indicates that species richness and diversity are highest at intermediate frequency or intensity of disturbance because both rapid colonizers and more competitive species do occur (Connell, 1978; Pickett and White, 1985; Wilson, 1994). Conversion of DF into patches of AA and MP may be an intermediate disturbance. The significantly higher abundance of litter Acari in AA and MP than DF agrees with Bedano *et al*. (2006) who found the abundance of pastures was higher than that of natural forests. This could be related to organic matter content, litter input and microbial biomass (Marra and Edmonds, 1998, Lindo and Visser, 2004).

CONCLUSION

In this study, it was hypothesized that soil and litter arthropod assemblages in terms of abundance, species richness, diversity and composition of DF differ with that of AA and MP. Varying responses of soil and litter arthropods to different land uses were observed.

Conversion of DF into AA and MP caused significant decreased in soil arthropod abundance and modified the species composition but tend to have no effect on species richness and diversity. Likewise, the species richness and diversity of the four most abundant groups (Collembola, Coleoptera, Hymenoptera and Acari) were not affected but the abundance of Collembola and Coleoptera was significantly reduced. There was a closer resemblance in soil arthropod species between DF and AA.

On the other hand, there was a significant increase in litter arthropod abundance in MP. Pattern of species richness among the sites did not differ but diversity was significantly decreased in AA and MP, while the species resemblance of the three sites was different. Species richness and diversity of the four most abundant groups was statisitcally similar except for Collembola, which was significantly decreased in AA and MP. Abundance of Collembola and Coleoptera was similar in DF and MP but lower in AA while that of Acari was similar in AA and MP but significantly lower in DF.

The overall results demonstrate that, in preserving the soil and litter arthropods, which are important in decomposition and nutrient cycling, agriculture using agroforestry system is more appropriate that monoculture of mahogany trees. Likewise, the results conformed the general trend of direct relationships between diversities of soil-litter arthropods and the surrounding vegetation.

STATEMENT OF AUTHORSHIP

The first author conceptualized and conducted the study under the guidance and supervision of the second author.

REFERENCES

Achard, F., H. Eva, H.J. Stibig, P. Mayaux, J Gallego, T. Richards, and J.P. Malingreau. 2002. Determination of deforestation rates of the world's humid tropical forests. Science 297:999–1002.

Alvarez, T., G.K. Frampton, and D. Goulson. 2001. Epigeic Collembola in winter wheat under organic, integrated and conventional farm management regimes. Agr. Ecosyst. Environ. 83:95-110.

Ananthakrishnan, T.N. 1996. Forest Litter Insect Communities: Biology and Chemical Ecology. Science Publishers, Lebanon, NH

Andre, H., X. Ducarme and P. Lebrum. 2002. Soil biodiversity: myth, reality or conning? Oikos 96:3–24.

ASEAN-Korean Environmental Cooperation Unit. 2003. Restoration of Degraded Forest Ecosystem in the Southeast Asian Tropical Region. Annual Report for 2003-2004, ASEAN-Korean Environmental Cooperation Project (AKECOP). ASEAN-Korean Environmental Cooperation Unit, National Instrumentation Center for Environmental Management, College of Agriculture and Life Sciences, Seoul National University, Seoul, Korea.

Atkin, L. and J. Proctor. 1988. Invertebrates in the litter and soil on Volcan Barva, Costa Rica. J. Trop. Ecol. 4:307–310.

Barrocas, H.M., M.M.da Gama, J.P. Sousa, and C.S. Ferreira. 1998. Impact of reafforestation with Eucalyptus globulus Labill. on the edaphic collembolan fauna of Serra de Monchique (Algarve, Portugal). Misc. Zool. 21:9–23.

Barros, E., E. Neves, E. Blanchart, E.C.M. Fernandez, E. Wandelli and P. Lavelle. 2003. Development of the soil macrofauna community under silvipastoral and agrisilvicultural systems in Amazonia. Pedobiologia (Jena) 47:273-280.

Barros, E., M. Grimaldi, A. Sarrazin, D. Chauvel, T. Mitja, Desjardins and P. Lavelle. 2004. Soil physical degradation and changes in macrofaunal communities in Central Amazon. Appl Soil Ecol 26:157–168.

Bedano, J.C., M.P. Cantu and M.E. Doucet. 2005. Abundance of soil mites (Arachnida: Acari) in a natural soil of central Argentina. Zoological Studies 44(4):505-512.

Benito, J.C.S. and M.J.L. Sanchez. 2000. Ecology of soil springtails (Collembola: Insecta) from pine woods and Rhododendron shrublands in the Central and Eastern Pyrenees (North Spain). Pedobiologia 44:430-441.

Brown, G.G., J. Rombke, H. Hofer, M. Verhaagh, K.D. Sautter and D.L.Q. Santana. 2006. Biodiversity and function of soil animals in Brazilian agroforestry systems. In: A.C. Gama-Rodriguez, N.F. Barros, E.F. Gama-Rodriguez, M.S.M. Freitas, A.P. Viana, J.M. Jasmin, C.R. Mercado and J.G.A. Carneiro (eds), Sistemas Agroflorestais: Bases Cientificas para o desenvolvimento sustentavel. UENF Campos dos Goytacazes. pp. 217-242.

Bruyn, L.A. 1997. Status of soil microfauna as indicator of soil health to monitor the sustainability of Australian soil. Ecological Economics Amsterdam 23:167-178.

Burgess, N.D., K.L. Ponder and J. Goddard. 1999. Surface and leaf-litter arthropods in the coastal forests of Tanzania. Afr. J. Ecol. 37:355–365.

Chagnon, M., D. Pare, C. Hebert, and C. Camire, C. 2001 Effects of experimental liming on collembolan communities and soil microbial biomass in a southern Quebec sugar maple (Acer saccharum Marsh) stand. Appl. Soil Ecol. 17:81–90.

Chazdon, R.L. and T.C. Whitmore. 2002. Foundations of Tropical Forest Biology. University of Chicago, Chicago.

Connell, J.H. 1978. Diversity in tropical rain forests and coral reefs. Science 199: 1302-1310.

Cortet, J. and N. Poinsot-Balaguer. 1998. Collembola populations under sclerophyllous coppices in Provence (France): comparison between two types of vegetation, Quecus ilex L. and Quecus coccifera L. Acta Oecol. Int. J. Ecol. 19:12.

Dekkers, T.B.M., P.A. van der Werff, and P.A.M. van Amelsvoort. 1994. Soil Collembola and Acari related to farming systems and crop rotations in organic farming. Acta Zool. Fenn. 195:28-31.

Deharveng, L. 1996. Soil collembola diversity, endemism and reforestation: a case study in Pyrenees (France). Conserv. Biol. 10:74–84.

Detsis, V., J. Diamantopoulos, and C. Kosmas. 2000. Collembolan assemblages in Lesvos, Greece. Effects of differences in vegetation and precipitation. Acta Oecol. 21:149-159.

Emberton, K.C. 1996. Conservation priorities for forest-floor invertebrates of the southeastern half of Madagascar: evidence from two land-snail clades. Biodiversity and Conservation 5:729-741.

FAO (Food and Agriculture Organization). 2006. Global Forest Resources Assessment 2005: Progress Towards Sustainable Forest Management. Food and Agriculture Organization (United Nations), Rome, Italy. FAO Forestry Paper 147. 352 pp.

Fernando, E.S., B.Y. Sun, M.H. Suh, H.Y. Kong, and K.S. Koh. 2004. Flowering Plants and Ferns of Mt. Makiling. ASEAN-Korea Environmental Cooperation Unit (AKECU), National Instrumentation Center for Environmental Management, College of Agriculture and Life Sciences, Seoul National University, Korea

Ferris, V.R. and J.C. Ferris. 1974. Inter-relationships between nematode and plant communities in agricultural ecosystems. Agro-Ecosystems 1: 275–299

Filser, J., H. Fromm, R.F. Nagel, and K. Winter. 1995. Effects of previous intensive agricultural management on microorganisms and the biodiversity of soil fauna. Plant Soil 170:123-129.

Fitter, A.H., C.A. Gilligan, K. Hollingworth, A. Kleczkowski, R.M. Twyman, J.W. Pitchford, The members of the NERC Soil Biodiversity Programme. 2005. Biodiversity and ecosystem function in soil. Functional Ecology 19:369–377.

Franklin, E.N., J.W. Morais, and E.M.R. dos Santos. 2001. Density and biomass of Acari and Collembola in primary forest, secondary regrowth and polyculture in central Amazonia. Andrias 15:141-153.

Frampton, G.K. 2000. Recovery responses of soil surface Collembola after spatial and temporal changes in long-term regimes of pesticide use. Pedobiologia 44:489-501.

Freckman, D.W. and C.H. Ettema. 1993. Assessing nematode communities in agroecosystems of varying human intervention. Agriculture, Ecosystems and Environment 45:239–261

Gama, M.M. da., T.M. Vasconcelos, and J.P. Sousa. 1994. Collembola diversity in Portuguese autochthonous and allochthonous forests. Acta. Zool. Fenn. 195:44–47.

Gardi, C., M. Tomaselli, V. Parisi, A. Petraglia, and C. Santini. 2002. Soil quality indicators and biodiversity in northern Italian permanent grasslands. Eur. J. Soil Biol. 103-110.

Geist, H. J. and E.F. Lambin. 2002. Proximate causes and underlying driving forces of tropical deforestation. BioScience 52:143–150.

Gergócs, V. and L. Hufnagel. 2009. Application of oribatid mites as indicators (Review). Applied Ecology and Environmental Research 7(1):79-98.

Giller, K.E., D. Bignell, P. Lavelle, M. Swift, E. Barrios, F. Moreira, M. van Norrdwijk, I. Barios, N. Karanja, and J. Huising. 2005. Soil Biodiversity in Rapidly Changing Tropical Landscapes: Scaling Down and Scaling up. In: R.D. Bargett, M.B. Usher, and D.W. Hopkins (eds.), Biological Diversity and Function in Soils. Cambridge University Press, Cambridge. pp. 295-318.

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

Goehring, D.M., G.C. Daily and C.H. Sekrcioğlu. 2002. Distribution of ground-dwelling arthropods in tropical countryside habitats. J. Ins. Conserv. 6:83–91.

Hagvar, S. 1982. Collembola in Norwegian coniferous forest soil. I. Relations to plant communities and soil fertility. Pedobiologia 24:255-296.

Hasegawa, M. 2002. The response of collembolan community and composition of organic matter of a forest floor. Pedobiologia 46:353-364.

Hedlund, K., B. Griffiths, S. Christensen, S. Scheu, H. Setälä, T. Tscharntke, and H. Verhoef. 2004. Trophic interactions in changing landscapes: responses of soil food webs. Basic and Applied Ecology 5(6): 495-503.

Heneghan, L. and T. Bolger. 1998. Soil microarthropod contribution to forest ecosystem processes: the importance of observational scale. Plant and Soil 205:113–124.

Heneghan, L., D.C. Coleman, X. Zou, D.A. Crossley and B.L. Haines. 1999. Soil microarthropod contribution to decomposition: tropical-temperate comparisons of a single substraste. Ecology 80:1873-1882.

Hobbs, R.J. and L.F. Huenneke. 1992. Disturbance, diversity and invasion: implications for conservation. Conservation Biology 6:324-337.

Hobbs, R.J., R. Floyd, S. Cunningham, P. Catling, and J. Ive. 2002. Hardwood plantations: quantifying conservation and environmental service benefits. Report to the Joint-Venture Agroforestry Program, Project CSW-32A. Rural Industries Research and Development Corporation, Canberra.

Höffer, H., W. Hanagarth, M. Garcia, C. Martius, E. Franklin, J. Römbke and L. Beck. 2001. Structure and function of soil fauna communities in Amazonian anthropogenic and natural ecosystems. Eur J Soil Biol 37:229–235.

Huhta, V. 2007. The role of soil fauna in ecosystems: a historical review. Pedobiologia (Jena) 50:489–495.

Kaspari, M. 1996. Litter ant patchiness at the 1-m^2 scale: disturbance dynamics in three Neotropical forests. Oecologia 107:265-273.

Kattan, G.H., D. Correa, F. Escobar and C. Medina. 2006. Leaf-litter arthropods in restored forests in the Columbian Andes: a comparison between secondary forest and tree plantations. Ecology 14(1):95-102.

Kelly, J.A. and M.J. Samways. 2003. Diversity and conservation of forest-floor arthropods on a small Seychelles island. Biodiv. Conserv. 12:1793-1813.

Kouadio, K.D., M. Doumbia, K. Jan, M. Dagnogo and D. Aidara. 2009. Soil/litter beetle abundance and diversity along a land use gradient in tropical Africa (Oumé, Ivory Coast). Sciences and Nature 6(2):139-147.

Lavelle, P., D. Bignell, M. Lepage, V. Wolters, P. Roger, P. Ineson, O.W. Heal and S. Dhillion. 1997. Soil function in a changing world: the role of invertebrate ecosystem engineers. Eur. J. Soil Biol. 33(4):159-193.

Lavelle, P., E. Barros, E. Blanchart, G. Brown, T. Desjardins, L. Mariani, and J.-P. Rossi. 2001. SOM management in the tropics: why feeding the soil macrofauna? Nutr Cycl Agroecosyst 61:53–61.

Lindenmayer, D.B., R.J. Hobbs, and D. Salt. 2002. Plantation forests and biodiversity conservation. Australian Forestry 66(1):62-66.

Lindo, Z. and S. Visser. 2004. Forest floor microarthropod abundance and oribatid mite (Acari: Oribatida) composition following partial and clear-cut harvesting in the mixedwood boreal forest. Canadian Journal of Forest Research-Revue Canadienne de Recherche Forestiere 34(5):998-1006.

Lopez-Hernandez, D., Y. Araujo, A. Lopez, I. Hernandez-Valencia, and C. Hernandez. 2004. Changes in soil properties and earthworm populations induced by long-term organic fertilization of the sandy soil in the Venezuelan Amazonian. Soil Sci. 169:188–194.

Loranger, G., J.-F. Ponge, E. Blanchart, and P. Lavelle. 1999. Influence of agricultural practices on arthropod communities in a vertisol (Martinique). Eur. J. Soil. Biol. 34:157-165.

Luna, A.C., K. Osumi, A.F. Gascon, R.D. Lasco, A.M. Palijon and M.L. Castillo. 1999. The community structure of a logged-over tropical rain forest in Mt. Makiling forest reserve, Philippines. J. Trop. Forest Sci. 11:446-458.

Marra, J.L. and R.L. Edmonds. 1998. Effects of coarse woody debris and soil depth on the density and diversity of soil invertebrates on clearcut and forested sites on the Olympic Peninsula, Washington. Environ. Entomol. 27(5):1111-1124.

Martius, C., H. Tiessen, and P.L.G. Vlek. 2001. The management of organic matter in tropical soils: what are the priorities? Nutrient Cycling Agroecosystems 6:1-6.

Martius, C., H. Höfer, M.V.B. Garcia, J. Römbke, B. Forster and W. Hanagarth. 2004. Microclimate in agroforestry systems in Central Amazonia: does canopy closure matter to soil organisms? Agrofor. Sys. 60:291-304.

Mayaux, P., P. Holmgren, F. Achard, H. Eva, H.-J. Stibig and A. Branthomme. 2005. Tropical forest cover change in the 1990s and options for future monitoring. Phil. Trans. R. Soc. B 360:373–384.

McNeely, J.A., K.R. Miller, W.V. Reid, R.A. Mittermeier, T.B. Werner. 1990. Conserving the World's Biological Diversity. IUCN, Gland, Switzerland.

Mermut A.R. 1985. Faunal influence on soil microfabrics and other soil properties. Quaest Entomol 21:523-542.

Millenium Ecosystem Assessment. 2005. Ecosystem and Human Well-Being: Synthesis. Island Press, Washington D.C.

Mittermeier, R.A., P. Robles and C.G. Mittermeier. 1997. Mediversity, Earth's Biologically Wealthiest Nations. CEMEX, Monterrey, Mexico. 501 pp.

Myers, N., R.A. Mittermeier, C.G. Mittermeier, G.A.B. da Fonseca and J. Kent. 2000. Biodiversity hotspots for conservation priorities. Nature 403:853-858.

Nakamura, V. 1988. The effect of soil management on the soil fauna make up of a cropped andosol in Central Japan. Soil Till. Res. 12:177-186.

Neher, D.A. and C.L. Campbell. 1994. Nematode communities and microbial biomass in soils with annual and perennial crops. Applied Soil Ecology 1:17–28.

Noti, M.I., H.M. Andre, X. Ducarme and P. Lebrun. 2003. Diversity of soil oribatid mites (Acari: Oribatida) from high Katanga (Democratic Republic of Congo): a multiscale and multifactor approach. Biodiv. Conserv. 12:767-785.

Pflug, A and V. Wolters. 2001. Influence of drought and litter age on Collembola communities. Eur. J. Soil Biol. 37:305-308.

Pickett, S.T.A. and P.S. White. 1985. The ecology of natural disturbance and patch dynamics. New York, NY: Academic Press, Inc.

Pimm, S.L. and R.A. Askins. 1995. Forest losses predict bird extinctions in eastern North America. Proceedings of the National Academy of Sciences USA 92:9343–9347.

Pimm, S.L. and P. Raven. 2000. Biodiversity: extinction by numbers. Nature 403:843–845.

Pinto, C., J.P. Sousa, M.A.S. Graca, and M.M.da Gama. 1997. Forest soil Collembola. Does tree introductions make a difference? Pedobiologia 41:131–138.

Ponge, J.F. 1993. Biocenoses of Collembola in atlantic temperate grass-woodland ecosystems. Pedobiologia. 87:223-244.

Ponge, J.F., S. Gillet, F. Dubs, E. Fedoroff, L. Haese, J.P. Sousa, and P. Lavelle. 2003. Collembola communities as bioindicators of land use intensification. Soil Biology and Biochemistry 35:813-826.

Pozo, J., D. Selga, and J.C. Simon. 1986. Studies on the collembolan populations of several plant communities of the Basque County (Spain). Rev. Ecol. Biol. Sol. 23:215-232.

Primack, R. and R. Corlett. 2005. Tropical Rain Forests: An Ecological and Biogeographical Comparison. Blackwell, Malden.

Raceles, E.L., W.M. Carandang, R.D. Lasco, D.A. Raceles, A.S.A. Castillo and J.M. Pulhin. 2008. Assessing the carbon budgets of large leaf mahogany (Swietenia macrophylla King) and dipterocarp plantations in the Mt. Makiling Reserve, Philippines. J. Env. Sci. and Mgt. 11(1):40-55.

Reddy, V.S., M.V. Reddy, K.K. Lee, K.P.C. Rao, and S.T. Sinivasan. 1996. Response of some soil meso- and macro-fauna populations to soil management during crop and fallow period on a semi-arid alfisol (India). Eur. J. Soil Biol. 32:123-129.

Richardson, B.A., M.J. Richardson, and F.N. Soto-Adames. 2005. Separating the effects of forest type and elevation on the diversity of litter invertebrate communities in a humid tropical forest in Puerto Rico. J. Animal Ecol. 74:926-936.

Ruiter, P.C. de, B. Griffiths, and J.C. Moore. 2002. Biodiversity and stability in soil ecosystems: patterns, processes and the effects of disturbance. In: M. Loreau, S. Naeem, and P. Inchausti (eds.), Biodiversity and ecosystem functioning. Synthesis and perspectives. Oxford University Press, Oxford. pp 102–113.

Samways, M.I., P.M. Caldwell, and R. Osborn. 1996. Ground-living invertebrate assemblages in native, planted and invasive vegetation in South Africa. Agri., Ecos. and Env. 59:19-32.

Setälä, H. 2005. Does biological complexity relate to functional attributes of soil food webs? In: P. De Ruiter, V. Wolters, and J.C. Moore (eds.), Dynamic food webs: multispecies assemblages, ecosystem development, and environmental change. Elsevier, Amsterdam. pp 308–320.

Setälä, H., V.G. Marshall, and J.A. Trofymow. 1995. The influence of micro- and macro-habitat factors on collembolan communities in douglar-fir stumps during forest succession. Appl. Soil Ecol. 2:227-242.

Sheil, D. and D.F.R.P. Burslem. 2003. Disturbing hypotheses in tropical forests. Trends Ecol. Evol. 18:18-26.

Sousa, J.P., J.V. Vingada, H. Barrocas, and M.M.da Gama. 1997. Effects of introduced exotic tree species on Collembola communities: the importance of management techniques. Pedobiologia 41, 145–153.

Sousa, J.P., M.M.da Gama, C. Ferreira, and H. Barrocas. 2000. Effect of eucalyptus plantations on Collembola communities in Portugal: a review. Belg. J. Entomol. 2: 187–201.

Tian, G., L. Brussaard, and B.T. Kong. 1993. Biological effect of plant residues with contrasting chemical compositions under humid tropical conditions – effects on soil fauna. Soil Biol. Biochem. 25:731-737.

Tsukamoto, J. And J. Sabang. 2005. Soil macro-fauna in an Acacia mangium plantation in comparison to that in a primary mixed dipterocarp forest in the lowland of Sarawak, Malaysia. Pedobiologia 49:69-80.

Vasconcelos, H.L. and W.F. Laurance. 2005. Influence of habitat, litter type, and soil invertebrates on leaf-litter decomposition in a fragmented Amazonian landscape. Oecologia 144:456-462.

Verhoef, H.A. and A.J. van Selm. 1983. Distribution and population dynamics of Collembola in relation to soil moisture. Holarct. Ecol. 6:387-394.

Vohland, K. and G. Schroth. 1999. Distribution patterns of the litter macrofauna in agroforestry and monoculture plantations in the Amazonian central affected by plant species and management. Appl. Soil Ecol. 13:57-68.

Wardle, D.A., H.A. Verhoef, M. Clarholm. 1998. Trophic relationships in the soil microfood-web: predicting the responses to a changing global environmental. Glob Chang Biol 4:71–727.

Wasilewska, L. 1979. The structure and function of soil nematode communities in natural ecosystems and agrocenoses. Polish Ecological Studies 5:97–145.

Watt, A.D., N.E. Stork and B. Boltron. 2002. The diversity and abundance of ants in relation to forest disturbance and plantation establishment in southern Cameroon. J. Appl. Ecol. 39:18-40.

Whitmore, T.C. 1998. An Introduction to Tropical Rain Forests (2nd. ed.). Oxford University Press, Oxford.

Wilson, J. B. 1994. The 'intermediate disturbance hypothesis' of species coexistence is based on patch dynamics. N.Z. J. Ecol. 18: 176-181.

Wiwatwitaya, D. and H. Takeda. 2005. Seasonal changes in soil arthropod abundance in the dry evergreen forest of north–east Thailand, with special reference to collembolan communities. Ecol. Res. 20:59–70.

Wolters, V. 2001. Biodiversity of soil animal and its function. Eur. J. Soil Biol. 37:221–227.

Yang, X., M. Warren and X. Zou. 2007. Fertilization responses of soil-litter fauna and litter quantity, quality and turnover in low and high elevation forests of Puerto Rico. Appl. Soil Ecol. 37:63–71.

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