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LITTER AND SOIL ARTHROPOD COMMUNITY ASSEMBLAGE IN ENVIRONMENTALLY CRITICAL AREAS NETWORK OF PALAWAN ISLAND, PHILIPPINES

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ABSTRACT – The Environmentally Critical Areas Network (ECAN) is a graded system of protection and development control adopted in Palawan through the Republic Act 7611. It divided the province's terrestrial component into Core Zone (CZ), Buffer Zone (subdivided into Restricted Use Area [RUA], Controlled Use Area [CUA], Traditional Use Area [TUA]), and Multiple Use Zone (MUZ). The assemblage (abundance, species richness, diversity, evenness and composition) of litter and soil arthropods across land use types (LUT) under ECAN was investigated to determine their conformity with the expected pattern (CZ ≥ RUA > CUA > TUA > MUZ) and the potential indicator groups. A representative LUT of each ECAN zone (grassland for MUZ, marginal forest for CUA, residual forest for RUA, coffee plantation for TUA, and primary forest for CZ) was selected where litter and soil samples were collected to extract the arthropods and sorted by class, order and further assigned to morphospecies. None of the overall assemblage variables of litter and soil arthropods conformed the expected pattern of ECAN zoning but they appeared to be affected by unwanted human disturbance. The overall abundance and species richness of litter and soil arthropods significantly discriminated the ECAN sites. The species composition and abundance structure of both litter and soil arthropods were distinct across ECAN sites and conformed the ECAN zoning except for the abundance structure of soil arthropods. Of the arthropod taxa, the abundance and species richness of litter and soil Acari and Coleoptera significantly differ among the sites and more or less conformed the ECAN zoning, making them the potential indicator groups. Strict implementation of the law through close monitoring of human activities in each ECAN zone is recommended to avoid faunal collapse.

Key words: soil and litter arthropods, community assemblage, land use, Palawan

INTRODUCTION

In 1992, Palawan adopted the Republic Act (RA) 7611, otherwise known as the Strategic Environmental Plan (SEP) for Palawan to govern its mode of development (PCSDS, 2005). It is a comprehensive framework for sustainable development of the province compatible with protecting and

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enhancing the natural resources and endangered environment (Sec. 4, RA 7611). The law provides for a strategy called the Environmentally Critical Areas Network (ECAN), which is designed to protect critical ecosystems and habitats allowing sustainable development to take place and mandates ECAN implementation to ensure forest conservation and protection, protection of watersheds, preservation of biological diversity, and protection of rare and endangered species and their habitat, among others (Sec. 7, RA 7611).

ECAN, which classified Palawan into three main components: terrestrial, coastal/marine and tribal ancestral lands, is a graded system of protection and development control over the whole province (Sandalo and Baltazar, 1997). The terrestrial component covers mountains, ecologically important low hills and lowland areas in the province and is subdivided into smaller management components, which include core zone, buffer zone (further divided into Restricted Use Area [RUA], Controlled Use Area [CUA] and Traditional Use Area [TUA]) and Multiple Use Zone (MUZ) for a more efficient supervision. Certain land uses are assigned to each zone with full protection in the CZ (RA 7611).

While the terrestrial areas of Palawan have been classified into ECAN zones based on the criteria set by SEP and ECAN guidelines, zone delineation was merely based on elevation, slope, and vegetation cover, but the required biological surveys to determine the relationship between fauna and ECAN zones were insufficient, if not lacking. Identification of the ECAN zones is not only the assignment of uses but also the requirement of biological and ecological justification for effective management. On the other hand, environmental research and monitoring are the two essential components set forth in the SEP for Palawan that are closely linked to the ECAN (Sandalo and Baltazar, 1997). Changes occurring in the ECAN zones are the main subjects for environmental monitoring. However, biological and ecological studies in these areas are negligible (Sandalo and Baltazar, 1997) or insufficient, thus monitoring the changes, particularly in terrestrial ECAN zones, is impossible in the absence of baseline data and appropriate indicators.

In terrestrial ecosystems, soil shelters among the most diverse biological communities on the planet (Jimenez *et al*., 2001; Wolters, 2001) with extremely rich biodiversity, and thus, often considered as 'the poor man's tropical rainforests' (Giller, 1996). Without these organisms, soil cannot perform ecosystem services like decomposition and nutrient cycling (Tripathi *et al*., 2010). Despite their inconspicuous nature, litter and soil arthropods are one of the most prominent components of ecological communities of both abundance and diversity in terrestrial habitats (Baloph, 1970; Ghilarov, 1977; Wilson, 1987; Andre *et al*., 1994). About 70% of all arthropods inhabit the soil and leaf litter in the rainforest ecosystem in Southeast Asia (Stork and Brendell, 1990). Litter and soil arthropods are also known to play an essential role in many ecological processes (e.g. predation, parasitism, herbivory, soil formation, decomposition), thus their presence or absence may be a useful indicator of the development of these processes in terrestrial habitats (Majer, 1989; Curry and Good, 1992; Lavelle *et al*., 2006). On the other hand, because many litter and soil arthropods are habitat specialists with short generation times and sedentary natures, they may reflect local habitat conditions better than other long lived, highly mobile organisms, such as vertebrates and flying invertebrates (van Straalen, 1997, 1998; Hilty and Merenlender, 2000). Therefore, these organisms provide the best reflection of the soil system, ecological services and ecosystem functioning therein (Mulder, 2006) and may represent the best choice organisms in investigating the relationship between fauna and the terrestrial ECAN zones in Palawan.

Arthropod assemblages are often studied to describe community succession and restoration (Pik *et al*., 2002; Longcore, 2003; Schnell *et al*., 2003), evaluate conservation status (Ribeiro *et al*., 1998; Barrow, Parr and Kohena., 2007), and address the distribution of species along environmental (Bach, 1993; Antvogel and Bonn, 2001; Davis and Scholtz, 2004) and disturbance (Lawton *et al*., 1998; Eggleton *et al*., 2002) gradients. In this study, the litter and soil arthropod assemblage variables that include abundance, species richness, composition (Grimbacher *et al*., 2007) and diversity among ECAN sites in Palawan were investigated to 1) determine their patterns, 2) the conformity of these patterns with ECAN zoning, and 3) the potential indicator groups.

Since ECAN is a graded system of protection, it is assumed that there is a gradient of anthropogenic disturbance and, consequently, environmental conditions, across the delineated zones after 23 years of implementation. Logically, we expected the following assemblage pattern of litter and soil arthropod assemblage across the sites: CZ ≥ RUA > CUA > TUA > MUZ.

MATERIALS AND METHODS

sThe Study Area

This study was conducted in the Municipality of Aborlan, which is situated at the central portion of Palawan Island, about 70 km southeast of Puerto Princesa City (Fig. 1). Located at 118°32' 53" North longitude and 9°26' East latitude, Aborlan is bounded by Puerto Princesa City in the north, Narra Municipality in the south, Quezon Municipality in the southwest, and Sulu Sea and south China Sea in the east and west, respectively.

Aborlan falls under two climate types: type III in the eastern side wherein there is no pronounced dry and wet season but relatively dry from November to April and wet during the rest of the year; and type I in the western side of the municipality wherein there is pronounced dry (from November to April) and wet (the rest of the year) seasons.

Generally, the soil of Aborlan can be classified into rough mountain soil type which is suitable for forest growth and preservation purposes comprising about 57% of its total land area, and clay loam which is suitable for agriculture comprising about 40%. Hydrosol and beach sand are also present in the municipality. The topography ranges from flat near the shore of the eastern and western part to rugged mountainous in the central and southwestern portion of the municipality.

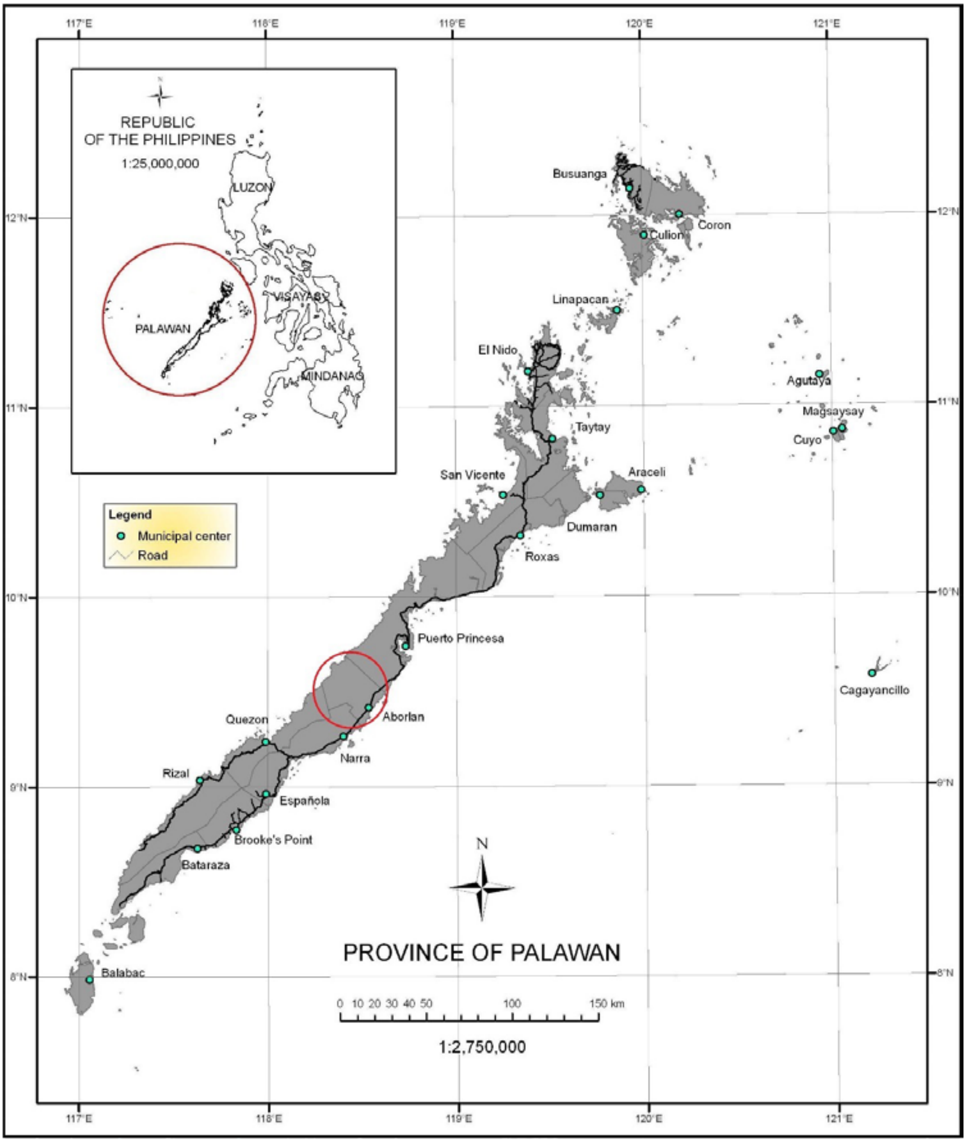

Figure 1. Map of Palawan Island showing the study area. (Source: PCSDS, 2015)

The total land area of c. 80,733 ha is covered with different land use types (Table 1) of which about 54.8% is forest. The whole Aborlan Municipality, which is composed of 19 barangays, is divided into different zones of Environmentally Critical Areas Network (ECAN) (Table 2).

The Sampling Sites

Sampling sites were identified based on ECAN and land cover maps of Aborlan, Palawan. One representative site from each ECAN zone (Fig. 2) comprising a land use type was selected. These sampling sites were the following:

1. ***Primary forest***. Found in the Core Zone (CZ) of Brgy. Sagpangan, this site (Fig. 3) is a huge forest located at 9º 34' 18.5" North longitude and 118º 31' 6.49" East latitude about 600 m elevation. The terrain is generally rugged with at least 50% slope with intermittent rolling to flat areas. The ground flora consisted mainly of tree seedlings including rattan species. Some of the tree species found in the area are *Agathis celebica*, *Quercus* sp., and *Nephelium* sp. The only destructive activity observed was the improper almaciga resin tapping that seems to have promoted the attack of termites (Fig. 4). Accordingly, there is decreasing number of almaciga trees due to this method of resin tapping.

Table 1. Land cover (1992 and 1998) of Aborlan Municipality.

LAND COVER	AREA (ha)	
	1992	1998
Forest	46,395	44,255
Primary forest	21,008	27,178
Mossy forest	4,924	-
Residual forest	18,260	14,961
Marginal forest	2,203	2,112
Karst/Limestone	-	4
Mangrove	1,183	1,391
Brushland	8,920	9,472
Coconut plantation	1,235	3,407
Other plantations	-	2,631
Grassland	11,159	3,614
Paddy field	3,764	5,841
Cropland	421	1,625
Bare/rocky areas	55	326
Built-up area	-	239
Fishpond	-	78
Lakes/water body	-	96
Clouds/shadow	956	

Source: PCSDS (2005)

Table 2. Land area of terrestrial ECAN zones of Aborlan Municipality.

TERRESTRIAL ECAN ZONE	AREA (ha)	% OF TOTAL AREA
Core Zone	27,152	33.63
Buffer Zone		
Restricted Use Area	2,432	3.01
Controlled Use Area	21,986	27.23
Traditional Use Area	983	1.22
Multiple/Manipulative Use Zone	26,514	32.84

Source: MPDO Data Bank

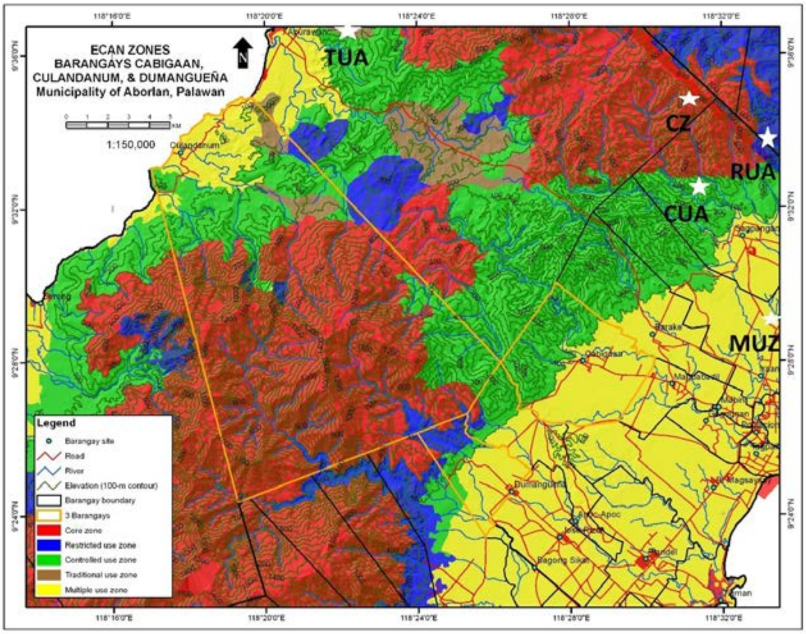

Figure 2. ECAN map of Aborlan, Palawan showing the sampling sites (CZ = Core Zone, RUA = Restricted Use Area, CUA = Controlled Use Area, TUA = Traditional Use Area, MUZ = Multiple Use Zone).

Figure 3. Primary forest in the Core Use Zone of ECAN.

Figure 4. Almaciga tree attacked by termites in primary forest in the Core Use Zone of ECAN.

2. ***Residual forest***. This sampling site (Fig. 5) has been subjected to timber extraction and covers an estimated area of about 30 ha. It is part of the Restricted Use Area (RUA) of ECAN in Brgy. Sagpangan

found at 09º 33’ 56.9” North longitude and 118º 32’ 6.35” East latitude about 420 m above sea level (asl). The slope ranged from 39% to 44% and some portions are rolling to flat. Logging is very evident in the premises of this sampling site (Fig. 6). The ground flora composed mainly of tree seedlings. Some of the tree species found in the area are *Koordersiodendron pinnatum*, some unidentified species of Moraceae and *Pterospermum diversifolum*.

Figure 5. Residual forest in the Restricted Use Area of ECAN.

Figure 6. A tree logged using a chain saw in the Restricted Use Area of ECAN

3. ***Marginal forest***. This sampling site is an open, denuded forest (Fig. 7) located at 09º 32' 6.57" North longitude and 118º 32' 15.5" East latitude about 250 m asl. It is part of the Controlled Use Area (CUA) of the ECAN under the jurisdiction of Brgy. Sagpangan of Aborlan Municipality. It is a fallow area after about 10 years or more of "kaingin" system of farming (swidden agriculture). The area covers about 30 ha with slope ranging from 27% to 35%. There are portions planted to *Gmelina* and cassava. The northwest side of this area is planted to upland rice. *Chromolaena odorata* dominated the ground flora in this site. *Paspalum conjugatum* and *Ixora* sp. are among the plant species growing in this site. The few tree species are composed mainly by *Acacia mangium* and *Antidesma* sp.

Figure 7. Marginal forest in the Controlled Use Zone of ECAN.

4. ***Coffee plantation***. This study site (Fig. 8) is within the Traditional Use Area (TUA) in Brgy. Apurawan of the western side of Aborlan Municipality. Geographically located at 09º 36' 51.2" North longitude and 118º 22' 48.6" East latitude, the slope ranged from 30-40% with ridge tops gently sloping to flat. It is a forest newly cleared of small trees, underbrushed, burned and planted to coffee (Fig. 9). Coffee, *Lygodium* sp. *Borreria* sp., *Cyperus* sp., tree seedling species and *Ixora* sp were the few ground flora species observed. Some tree species found in this site are *Brackenridgia* sp., *Myristica* sp., *Dipterocarpus* sp., and a species of Fagaceae (probably new species).

5. ***Grassland***. Located in the Multiple Use Zone (MUZ) of ECAN at 09º 29' 27.1" North longitude and 118º 33' 29.9" East latitude about 40 m asl, this sampling site (Fig. 10) is a privately-owned lot covering an area of c. 140 ha. It is situated beside the highway in Sitio Mailigan, Brgy. Iraan of Aborlan Municipality. The area is flat to rolling of about 17%. A grass species (Fig. 11) dominates

the area. Other plant species present in the area are *Ageratum conyzoides*, *Pueraria montana*, *Cyperus rotundus*, *Paspalum conjugatum, Melastoma malabathricum, Lygodium* sp., *Sida* sp., *Chromolaena odorata*, and *Pterogramma* sp. Very few trees and shrubs are present in the area, of which a small portion is planted to *Acacia mangium*.

Figure 8. New coffee plantation in the Traditional Use Area of ECAN.

Figure 9. Coffee seedling planted at the sampling site in the Traditional Use Zone of ECAN

Figure 10. Grassland in the Multiple Use Zone of ECAN.

Figure 11. The dominant grass species in the sampling site of Multiple Use Zone of ECAN.

Sampling of Litter and Soil Arthropods

At each sampling site, a 2-km transect line was randomly laid out and was divided into three (3) plots at c. 500 m distance. At each plot, litter arthropods were sampled by collecting c. 2 li of litter (leaves, reproductive litter, twigs <1cm diameter) while soil arthropods were sampled by collecting a block of soil using a 10 cm x 10 cm frame up to 5 cm depth. Litter and soil samples were placed in a Berlese-Tullgren funnel (28 cm diameter, 51 cm height, 100W incandescent bulb) for 72 h to extract the arthropods. Arthropods were sorted by class, order (Yang and Chen, 2009; Nakamura *et al*., 2009) and whenever possible, family (for insects) and further assigned to morphospecies (Oliver and Beattie, 1993; 1996; Longcore, 2003; Grimbacher *et al*., 2007).

Ecological Indices

The following ecological indices were used to describe the assemblages of soil and litter arthropod communities of each ECAN sites, as recommended by Ludwig and Reynolds (1988):

1. ***Species richness and diversity***. The Hill's numbers (N0, N1, N2; Hill, 1973) were calculated to express different aspects of species diversity. Since these three indices are expressed in the same units (number of species), the results are easily interpreted and compared (Ludwig and Reynolds, 1988; Addison *et al*., 2003). N0, the mean number of species in a site, represents species richness, while N1 ($e^{H'}$) and N2 ($1/\lambda$) incorporate both species richness and species equitability and, respectively, express the number of abundant, and very abundant species in the samples.

2. ***Species evenness***. For species evenness, the modified Hill's ratio (E5) was used because it is least ambiguous, most interpretable, and relatively unaffected by species richness (Ludwig and Reynolds, 1988). The E5 value approaches zero as a single species becomes more and more dominant in the community (Alatalo and Alatalo, 1977) and is computed as:

$$E5 = \frac{(1/\lambda)-1}{e^{H'}-1} = \frac{N2 - 1}{N1 - 1}$$

3. ***Community resemblance***. The resemblance of the soil and litter arthropod community among ECAN sites was compared using the Jaccard Index (JI), a similarity coefficient, and Chord Distance (CRD), a distance coefficient. Using the absence and presence data of the species, JI is simple and easy to understand (Ludwig and Reynolds, 1988). JI value approaches 1 as the species composition of a pair of sites becomes more similar. It is calculated as:

$$JI_{1,2} = \frac{a}{a + b + c}$$

where: a = number of species found in sites 1 and 2

b = number of species found only in site 1

c = number of species found only in site 2

CRD is the distance between sample unit j (SUj) and sample unit k (SUk). It puts greater importance on the relative proportions of species in sampling unit and correspondingly, less importance on their absolute quantities, and performs very satisfactorily over a diverse set of ecological data (Ludwig and Reynolds, 1988). CRD value ranges from 0 to and approaches 0 as the proportions of species of a pair of sites becomes more similar. CRD is obtained using:

$$CRD_{jk} = \sqrt{2(1 - ccos_{jk})},$$ ccos is chord cosine and is computed as:

$\sqrt{2}$

$$\cos = \frac{\Sigma (X_{ij} \,.\, Y_{ij})}{\Sigma X^2_{ij} \,.\, \Sigma Y^2_{ij}}$$

where:

X_{ij} = the number of individuals of the ith species of sample unit j

Y_{ij} = the number of individuals of the ith species of sample unit k

s = the number of species

Data Analysis

The data sets (means) on different variables were subjected to test for normality (Shapiro-Wilk's test) and homogeneity of variance (Levene's test). Transformation (x' = log [x + 1]) was done when data departed from the assumptions of normality and homogeneity. Analysis of variance (ANOVA) was carried out to test the significant difference of assemblage variables across the ECAN sites. For taxonomic groups as potential indicator, we limited our analysis with abundance and species richness. Least significant difference (LSD) was used to compare means among the sites. If transformed data still did not meet the assumptions of normality and homogeneity, nonparametric tests were employed: the Kruskal-Wallis instead of ANOVA and Mann-Whitney U instead of LSD. Cluster analysis for Jaccard Index of Similarity and Chord Distance values was performed using PAST3 software.

RESULTS

The entire study collected 3,724 litter arthropods, representing 17 taxonomic groups (mainly orders) and 194 morphospecies. At least 13 litter arthropod groups were recorded in the CZ and TUA, 12 in MUZ, 11 in RUA, and 8 in CUA. From soil samples, a total of 2,278 arthropod specimens were collected, representing 20 higher taxa (i.e., mainly orders) and 175 morphospecies. At least 15, 14, 12, 10 and 9 soil arthropod groups were recorded in RUA, TUA, CZ, CUA and MUZ, respectively.

Litter arthropods

Significant differences were obtained for overall mean litter arthropod abundance ($F_{[4,10]}$=12.660, P=0.001), species richness ($F_{[4,10]}$=17.703, P<0.001), N2 diversity index ($F_{[4,10]}$=5.270, P=0.015), and evenness ($F_{[4,10]}$=15.066, P<0.001) but not N1 diversity index ($F_{[4,10]}$=1.244, P=0.353) (Table 3).

MUZ and CZ were statistically similar in litter arthropod abundance and species richness and were highest among the sites. TUA was lowest in abundance but was not significantly different from CUA, which was lowest in species richness. N2 diversity index of TUA was higher than the other sites. E5 evenness index for litter arthropods followed a trend similar with that of N2.

The abundance of taxonomic groups of litter arthropods of ECAN sites is presented in Table 4. Acari were the most abundant in CZ (32.21%) and RUA (49.17%) while Hymenoptera (45.55%) predominated in CUA. Collembola (31.46%) was the dominant group in TUA; Diptera (51.31%) in MUZ. Hemiptera (Heteroptera), Hemiptera (non-Heteroptera), Coleoptera, Diptera and Hymenoptera were well represented in all ECAN sites. Their abundances were significantly different except for Hemiptera (non-Heteroptera) ($F_{[4,10]}$=1.446, P=0.289). Some groups were not represented in some sites while others were rare.

Out of 17 taxonomic groups of litter arthropods, only eight showed significant differences in species richness across ECAN sites (Table 5). Coleoptera contributed most of the species in CZ; Acari in RUA. Likewise, Coleoptera had the highest species richness in CUA while Hemiptera (non-Heteroptera) occupied this rank in TUA. Most of the species in MUZ were contributed by Diptera. Coleoptera was the taxonomic group that contributed substantially to the species richness in all ECAN sites. Some groups had very few species in some sites.

The dendrograms that resulted from cluster analysis using Jaccard Index (JI) of similarity and Chord Distance (CRD) index for litter arthropods are presented in Figure 12. CUA, TUA and MUZ were separated from each other and from other sites (Fig. 12a). RUA and CZ clustered together suggesting a closer resemblance of their litter arthropod species composition. The dendrogram of Chord Distance index (Fig 12b) showed a similar pattern.

Soil Arthropods

Significant differences were also obtained on overall mean soil arthropod abundance ($F_{[4,10]}$=12.178, P=0.001), species richness ($F_{[4,10]}$=4.317, P=0.028) and evenness ($F_{[4,10]}$=6.701, P=0.007) but none with N1 ($F_{[4,10]}$=0.337, P=0.847) and N2 ($F_{[4,10]}$=1.988, P=0.172) diversity indices (Table 6).

Soil arthropod abundance and richness were significantly highest in MUZ and RUA but lowest in CUA and TUA together with CZ. No statistical differences were obtained among the soil arthropod species richness values in CZ, CUA and TUA together with RUA, which were significantly lower than MUA. For evenness index (E5), TUA and CUA were not significantly different and were highest among the sites followed by CZ. RUA was lowest in E5 and not statistically different from MUZ.

The abundance of taxonomic groups of soil arthropods across ECAN sites is presented in Table 7. Hemiptera (non-Heteroptera) (33.45%) contributed the highest percentage of soil arthropod abundance in CZ and so did Blattodea (Isoptera) (35.22%) in RUA. Diptera was the predominant group (36.24%) in CUA and Hemiptera (non-Heteroptera) (58.04%) in TUA. Acari predominated (30.84%) the soil arthropods of MUZ. The common taxonomic groups of soil arthropods across the ECAN sites were Acari, Hemiptera (Heteroptera), Hemiptera (non-Heteroptera), Coleoptera and Diptera. Their abundances were significantly different except for Hemiptera (Heteroptera) ($F_{[4,10]}$=1.381, P=0.308) and Hemiptera (non-Heteroptera) ($F_{[4,10]}$=0.282, P=0.883).

Only four taxonomic groups of soil arthropods showed significant difference in species richness among ECAN sites (Table 8). Diptera and Coleoptera contributed most of the species in CZ and in RUA, respectively. Diptera had highest species richness in CUA but was not statistically different from other sites. Likewise, Diptera was highest in species richness in TUA and in MUZ. The order Diptera contributed a substantial number of species in all ECAN sites.

Cluster analysis using Jaccard Index (Fig. 13a) showed that CZ and RUA were more similar in soil arthropod species composition, far from MUZ and CUA, which were numerically closer to each other. TUA was different in soil arthropod species composition from other sites. Dendrogram for Chord distance index (Fig. 13b) showed closer similarity of soil arthropod structure (abundance) between CUA and CZ as compared to other sites, which were more distinct.

Table 3. Comparison of abundance and diversity indices of litter arthropods across ECAN sites.

SITES	ABUNDANCE		SPECIES RICHNESS		DIVERSITY				SPECIES EVENNESS	
	N	SE	N0	SE	N1	SE	N2	SE	E5	SE
CZ	84.0	± 26.4bc	25.3	± 4.8b	19.2	± 0.4	15.3	± 2.8	0.78	± 0.15ab
RUA	229.0	± 49.5a	37.3	± 9.0ab	15.7	± 4.5	7.5	± 2.5	0.42	± 0.04c
CUA	57.3	± 14.4c	21.7	± 4.0b	16.7	± 1.2	17.4	± 1.0	1.06	± 0.13a
TUA	69.0	± 23.4c	17.3	± 3.2b	15.9	± 1.2	12.7	± 1.4	0.79	± 0.08a
MUZ	314.7	± 39.8a	43.7	± 6.9a	20.3	± 6.3	11.2	± 4.4	0.50	± 0.05bc

Means (± SE) in a row with common letter are not significantly different using LSD (P<0.05).

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Table 4. Abundance of taxonomic groups of litter arthropods across ECAN sites.

TAXONOMIC GROUPS	CZ Mean SE	CZ %	RUA Mean SE	RUA %	CUA Mean SE	CUA %	TUA Mean SE	TUA %	MUZ Mean SE	MUZ %
Class Arachnida										
Acari	120.3 ± 58.4a	32.21	126.7 ± 41.7a	49.17	-	-	4.7 ± 3.3c	6.94	54.3 ± 2.3b	12.80
Araneae	1.3 ± 1.3	0.35	2.0 ± 2.0	0.78	4.0 ± 2.3	3.29	1.7 ± 0.9	2.51	-	-
Pseudoscorpiones	2.3 ± 0.3a	0.62	0.3 ± 0.3bc	0.12	-	-	1.0 ± 0.6b	1.48	-	-
Class Diplopoda	-	-	0.3 ± 0.3	0.12	0.7 ± 0.7	0.58	-	-	-	-
Class Insects										
Coleoptera	37.3 ± 7.7ab	9.99	16.0 ± 3.2b	6.21	9.7 ± 2.8bc	7.99	6.3 ± 1.9cd	9.31	52.7 ± 19.1a	12.42
Collembola	8.0 ± 1.5bc	2.14	-	-	-	-	21.3 ± 5.0a	31.46	3.3 ± 0.3c	0.78
Dermaptera	-	-	0.3 ± 0.3	0.12	-	-	0.7 ± 0.7	1.03	-	-
Diplura	-	-	-	-	-	-	-	-	1.3 ± 0.9	0.31
Diptera	37.3 ± 4.7b	9.99	26.7 ±4.2b	10.36	20.0 ± 3.0b	16.47	8.0 ± 2.0b	11.82	217.7 ± 25.4a	51.31
Hemiptera (Heteroptera)	29.0 ± 3.2a	7.76	22.7 ± 11.7a	8.81	8.7 ± 5.0bc	7.17	1.3 ± 1.3c	1.92	15.0 ± 3.5ab	3.54
Hemiptera (non-Heteroptera)	43.3 ± 16.0	11.59	45.7 ± 12.4	17.73	22.3 ± 10.0	18.37	12.7 ± 4.3	18.76	24.0 ± 13.4	5.66
Hymenoptera	89.3 ± 29.7a	23.91	16.3 ± 10.3c	6.33	55.3 ± 23.4b	45.55	5.0 ± 0.6d	7.39	45.0 ± 24.4b	10.61
Lepidoptera	2.7 ± 0.7b	0.72	-	-	0.7 ± 0.7bc	0.58	1.3 ± 0.9b	1.92	5.7 ± 0.9a	1.34
Orthoptera	-	-	-	-	-	-	0.7 ± 0.7	1.03	1.3 ± 0.9	0.31
Strepsiptera	0.3 ± 0.3	0.08	0.7 ± 0.7	0.27	-	-	03 ± 0.3	4.43	0.7 ± 0.7	0.16
Thysanoptera	0.7 ± 0.3	0.19	-	-	-	-	-	-	3.3 ± 3.5	0.78
Class Malacostraca										
Isopoda	1.7 ± 1.2	0.46	-	-	-	-	-	-	-	-

Means (± SE) in a row with common letters are not significantly different using LSD (P<0.05).

Table 5. Species richness of taxonomic groups of litter arthropods across the ECAN sites.

TAXONOMIC GROUPS	CZ	RUA	CUA	TUA	MUZ
	Mean SE	Mean SE	Mean SE	Mean SE	Mean SE
Class Arachnida					
Acari	11.0 ± 3.1a	11.7 ± 1.3a	-	2.3 ± 1.2b	1.0 ± 0.0b
Araneae	1.3 ± 1.3	1.0 ± 1.0	3.7 ± 2.0	0.7 ± 0.3	-
Pseudoscorpiones	1.3 ± 0.3a	0.3 ± 0.3b	-	0.7 ± 0.3b	-
Class Diplopoda	-	0.3 ± 0.3	0.3 ± 0.3	-	-
Class Insecta					
Coleoptera	16.0 ± 3.2a	9.0 ± 1.2b	6.0 ± 1.5c	4.0 ± 1.0c	15.3 ± 2.8a
Collembola	2.7 ± 0.3	-	-	6.0 ± 1.0a	2.3 ± 0.3c
Dermaptera	-	0.3 ± 0.3	-	0.3 ± 0.3	-
Diplura	-	-	-	-	0.7 ± 0.3
Diptera	9.0 ± 2.4b	9.0 ± 2.1b	6.7 ± 0.9b	4.3 ± 1.0b	19.0 ± 4.0a
Hemiptera (Heteroptera)	5.0 ± 0.0a	3.0 ± 0.6b	2.7 ± 1.2bc	0.7 ± 0.7c	4.7 ± 0.7a
Hemiptera (non-Heteroptera)	4.0 ± 1.0	2.7 ± 0.7	4.0 ± 0.6	4.7 ± 0.7	3.7 ± 2.1
Hymenoptera	4.7 ± 0.7b	3.7 ± 1.2b	4.3 ± 0.3b	3.3 ± 0.3b	10.3 ± 2.0a
Lepidoptera	1.0 ± 0.0b		0.3 ± 0.3bc	1.3 ± 0.9ab	1.7 ± 0.3a
Orthoptera	-	-	-	0.3 ± 0.3	-
Strepsiptera	0.3 ± 0.3	0.3 ± 0.3	-	0.3 ± 0.3	0.7 ± 0.3
Thysanoptera	0.7 ± 0.3	-	-	-	0.7 ± 0.3
Class Malacostraca					
Isopoda	0.7 ± 0.3	-	-	-	-

Means (± SE) in a row with common letters are not significantly different using LSD ($P<0.05$).

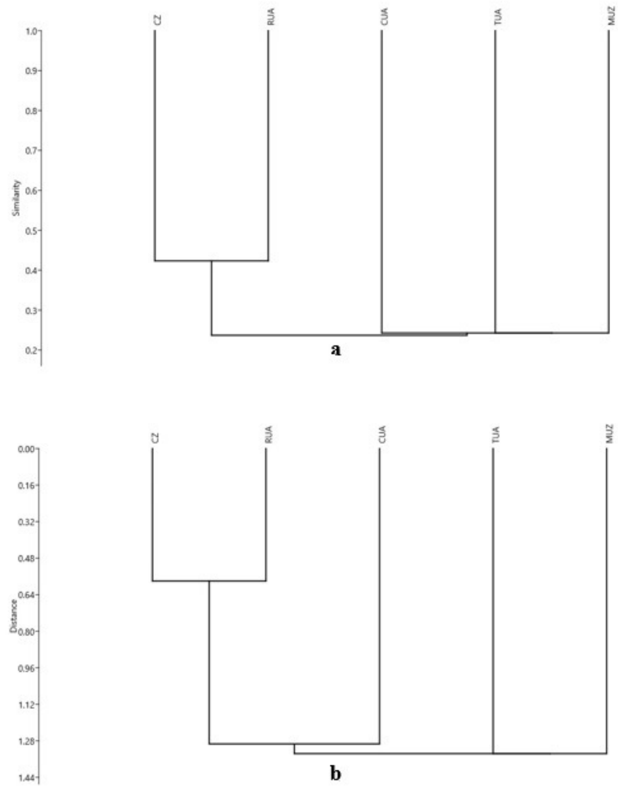

Figure 12. Cluster analysis of litter arthropods using (a) Jaccard Index of Similarity (Cophen Corr: 0.89) and (b) Chord Distance (Cophen corr.= 0.99).

Table 6. Comparison of abundance and diversity indices for soil arthropods in across ECAN sites.

SITES	ABUNDANCE		SPECIES RICHNESS		DIVERSITY				SPECIES EVENNESS	
	N	SE	N0	SE	N1	SE	N2	SE	E5	SE
CZ	84.0	± 26.4bc	25.3	± 4.8b	19.2	± 0.4	15.3	± 2.8	0.78	± 0.15ab
RUA	229.0	± 49.5a	37.3	± 9.0ab	15.7	± 4.5	7.5	± 2.5	0.42	± 0.04c
TUA	69.0	± 23.4c	17.3	± 3.2b	15.9	± 1.2	12.7	± 1.4	0.79	± 0.08a
CUA	57.3	± 14.4c	21.7	± 4.0b	16.7	± 1.2	17.4	± 1.0	1.06	± 0.13a
MUZ	314.7	± 39.8a	43.7	± 6.9a	20.3	± 6.3	11.2	± 4.4	0.50	± 0.05bc

Means (± SE) in a row with common letter are not significantly different using LSD (P<0.05).

Table 7. Abundance of taxonomic groups of soil arthropods across the ECAN sites.

	CZ		RUA		CUA		TUA		MUZ	
	Mean SE	%	Mean SE	%	Mean SE	%	Mean SE	%	Mean SE	%
Class Arachnida										
Acari	6.7 ± 0.3b	7.81	7.3 ± 0.9b	3.41	7.3 ± 2.3b	11.16	1.0 ± 1.0c	1.49	96.0 ± 16.9a	30.84
Araneae	0.3 ± 0.3b	0.35	3.7 ± 1.2a	1.73	-	-	0.3 ± 0.3b	0.45	-	-
Pseudoscorpiones	-	-	1.0 ± 0.6	0.47	1.7 ± 0.9	2.60	1.0 ± 0.6	1.49	1.0 ± 0.6	0.32
Schizomida	2.0 ± 2.0	2.33	-	-	-	-	-	-	-	-
Class Chilopoda	1.7 ± 1.7	1.98	3.3 ± 1.8	1.54	0.3 ± 0.3	0.46	-	-	-	-
Class Diplopoda	-	-	1.0 ± 0.0	0.47	0.7 ± 0.7	1.07	-	-	-	-
Class Insecta										
Blattodea (Isoptera)	-	-	75.3 ± 3.2a	35.22	-	-	0.3 ± 0.3b	0.45	-	-
Coleoptera	14.7 ± 5.0b	17.13	21.0 ± 6.7b	9.82	9.7 ± 4.2bc	14.83	3.3 ± 0.3c	4.91	37.0 ± 3.2a	11.89
Collembola	-	-	16.7 ± 2.6a	7.81	3.3 ± 0.3b	5.05	-	-	-	-
Diplura	2.0 ± 2.0	2.33	3.3 ± 2.4	1.54	-	-	0.7 ± 0.7	1.04	-	-
Diptera	16.0 ± 2.6b	18.65	24.3 ± 8.2a	11.37	23.7 ± 8.7ab	36.24	12.0 ± 1.2b	17.86	45.7 ± 11.8a	14.68
Hemiptera (Heteroptera)	7.7 ± 0.3	8.97	16.0 ± 11.2	7.48	1.7 ± 1.2	2.60	1.2 ± 0.7	1.79	8.3 ± 1.3	2.67
Hemiptera (non-Heteroptera)	28.7 ± 16.5	33.45	35.0 ± 20.2	16.37	16.7 ± 8.5	25.54	39.0 ± 20.0	58.04	33.3 ± 12.5	10.70
Hymenoptera	5.0 ± 1.0b	5.83	5.3 ± 1.2b	2.48	-	-	5.7 ± 1.2b	8.48	87.3 ± 30.7a	28.04
Orthoptera	-	-	-	-	-	-	-	-	1.0 ± 1.0	0.32
Psocoptera	-	-	-	-	-	-	0.7 ± 0.7	1.04	1.7 ± 0.9	0.55
Strepsiptera	-	-	0.3 ± 0.3	0.14	0.3 ± 0.3	0.46	0.3 ± 0.3	0.45	-	-
Thysanoptera	-	-	0.3 ± 0.3	0.14	-	-	1.0 ± 1.0	1.49	-	-
Class Malacostraca										
Isopoda	0.7 ± 0.7	0.82	-	-	-	-	-	-	-	-
Class Symphyla	0.3 ± 0.3	0.35	-	-	-	-	0.7 ± 0.7	1.04	-	-

Means (± SE) in a row with common letters are not significantly different using LSD ($P<0.05$).

Table 8. Species richness of taxonomic groups of soil arthropods across the ECAN sites.

TAXONOMIC GROUPS	CZ	RUA	CUA	TUA	MUZ
	Mean SE	Mean SE	Mean SE	Mean SE	Mean SE
Class Arachnida					
Araneae	0.3 ± 0.3	2.3 ± 0.3	-	0.3 ± 0.3	-
Schizomida	1.0 ± 1.0	-	-	-	-
Acari	5.0 ± 0.6a	4.0 ± 0.6a	2.0 ± 0.0b	0.3 ± 0.3c	4.7 ± 0.3a
Pseudoscorpiones	-	0.7 ± 0.3	1.3 ± 0.3	0.7 ± 0.3	0.7 ± 0.3
Class Chilopoda	0.7 ± 0.7	1.7 ± 0.9	0.3 ± 0.3	-	-
Class Diplopoda	-	1.0 ± 0.6	0.3 ± 0.3	-	-
Class Insecta					
Blattodea (Isoptera)	-	1.0 ± 0.0	-	0.3 ± 0.3	-
Coleoptera	6.3 ± 1.2b	11.3 ± 2.2a	6.3 ± 1.9b	2.3 ± 0.3b	12.0 ± 0.6a
Collembola	-	3.0 ± 0.0	2.0 ± 0.0	-	-
Diplura	1.0 ± 1.0	1.0 ± 0.6	-	0.7 ± 0.7	-
Diptera	8.0 ± 0.6	5.3 ± 0.7	9.0 ± 0.6	7.7 ± 0.7	14.3 ± 5.8
Hemiptera (Heteroptera)	2.0 ± 0.0ab	3.0 ± 1.2a	0.7 ± 0.3b	1.0 ± 0.6b	3.8 ± 0.4a
Hemiptera (non-Heteroptera)	3.7 ± 0.9	3.3 ± 2.0	3.0 ± 1.5	5.0 ± 2.6	5.3 ± 1.2
Hymenoptera	3.0 ± 0.6b	3.3 ± 0.7b	-	3.3 ± 0.3b	6.7 ± 1.8a
Orthoptera	-	-	-	-	0.7 ± 0.7
Psocoptera	-	-	-	0.3 ± 0.3	1.3 ± 0.9
Strepsiptera		0.3 ± 0.3	0.3 ± 0.3	0.3 ± 0.3	-
Thysanoptera	-	-	-	0.3 ± 0.3	
Class Malacostraca					
Isopoda	0.7 ± 0.7	-	0.3 ± 0.3	-	-
Class Symphyla	-	-	-	0.3 ± 0.3	-

Means (± SE) in a row with common letters are not significantly different using LSD (P<0.05).

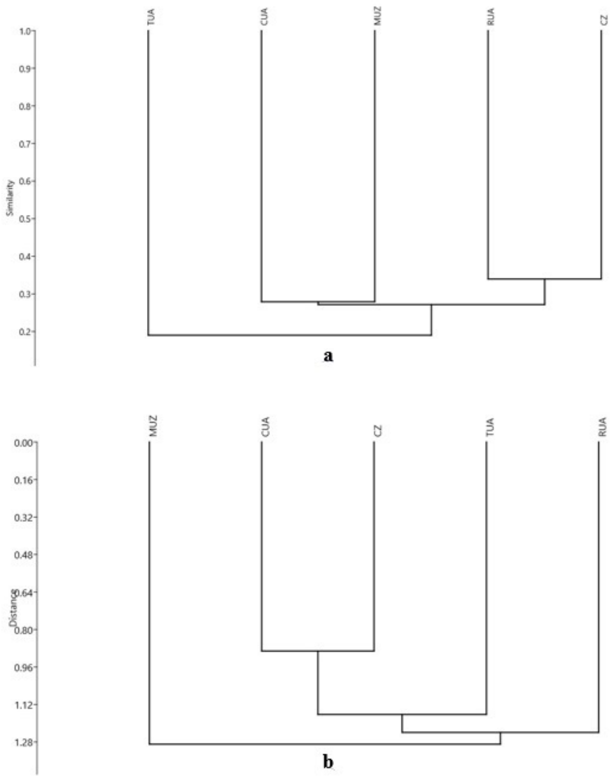

Figure 13. Cluster analysis of soil arthropods using (a) Jaccard Index of Similarity (Cophen Corr: 0.83) and (b) Chord Distance (Cophen corr.= 0.90).

DISCUSSION

Pattern of Litter and Soil Arthropod Assemblages

Litter arthropods. Overall assemblage measures of litter arthropods did not conform with the expected pattern across ECAN sites (Table 3). It is suspected that this is due to the occurrence of prohibited human activities in these areas. For instance, timber extraction is not allowed but currently going on in RUA (Fig. 6). TUA is supposedly for material and cultural needs of indigenous people but the site was burnt and converted to coffee plantation (Figs. 8 and 9). CUA is intended for utilization of minor forest products and logging is supposedly controlled but the site is already devoid of big trees, being subjected to kaingin (Fig. 7). According to Lavelle *et al.* (1994), disturbances linked to land use practices severely affect the species richness of soil invertebrate communities.

However, the overall abundance and species richness of litter arthropods showed significant difference among ECAN sites (Table 3). It was observed that CZ had complex vegetation structure having tree, shrub and herb strata and had highest litter quantity, which may explain the highest abundance and species richness of litter arthropods. MUZ (a grassland) had simple vegetation structure with the least litter cover and depth. Thus, its comparable abundance and species richness with CZ was unexpected but agrees with Muchane *et al.* (2002) who found highest density of total soil macrofauna in grassland and woodland. They also found an increase in soil macrofaunal density and species richness due to disturbance. The intermediate disturbance hypothesis may, therefore, be invoked as a possible explanation to these findings. The said hypothesis states that species richness and diversity are highest at intermediate frequency or intensity of disturbance because both rapid colonizers and more competitive species do occur (Connel, 1978; Pickett and White, 1985; Wilson, 1994). In MUZ, fire usually occurs during the dry months (March to May) and it occurred in this sampling site as evidenced by blackish soil and remnants of burned leaf litter in the sampling plots.

Non-significant differences in N1 diversity indices imply that all ECAN sites have more or less similar number of abundant species of litter arthropods. Likewise, the sites have relatively similar number of very abundant species of litter arthropods since their N2 diversity indices were not significantly different resulting to comparable species evenness except for TUA. Higher species evenness in TUA is expected because of low abundance although its N2 diversity index was higher than those of other sites.

Soil arthropods. Similarly, the overall assemblage measures of soil arthropods did not conform with the expected pattern across ECAN sites (Table 6). The same reason given for litter arthropods is offered here. Unlike litter arthropods, the abundance and species richness of soil arthropods in MUZ became at par with that of RUA. The intermediate disturbance hypothesis may also have work for soil arthropods in RUA. Being a natural ecosystem relatively free of disturbance, the complex interrelationships among functional groups of soil arthropods and other organisms may have stabilized the abundance and species richness in CZ, making them comparable with CUA and TUA (Table 6).

Non-significant difference in N1 and N2 diversity indices implies that all ECAN sites have more or less similar number of abundant and very abundant species of soil arthropods, respectively. The lowest evenness in MUZ and RUA indicates that there are soil arthropod species that are very abundant although the N2 diversity index was not significantly different among the ECAN sites.

Arthropod Community Resemblance

Results from cluster analysis revealed that ECAN sites sustained highly dissimilar arthropod assemblage both in composition and structure (relative proportion of species abundance) both in litter and soil (Figs. 12 and 13). Sopsop and Lit (2014) found dissimilarity in species composition between dipterocarp forest and mahogany plantation. Beiroz *et al.* (2014) also reported dissimilarity in edaphic arthropod communities both in structure and species composition between *Eucalyptus* and pasture. Loyola *et al.* (2006) found this same pattern when studying the invertebrate community in areas of forest and pasture in Pantanal wetlands. Ferreira and Marques (1998) verified low similarity between litter arthropod communities of secondary forest and *Eucalyptus* monoculture, as well as, arthropod richness and diversity of secondary forest and *Eucalyptus* monoculture.

For litter arthropods, the pattern of species composition resemblance across ECAN sites (Fig. 12a) mirrored that of species abundance (Fig. 12b). Among the sites, CUA, TUA and MUZ appeared to be more distinct in their species composition and abundance structure as shown by the distance in the dendrogram (Fig, 12) compared with CZ and RUA. Vegetation structure and litter quantity possibly explain these results. Wardle *et al.*, (2006) stated that at the landscape scale, the vegetation composition, plant species diversity, mixing of plant litter types, and aboveground trophic interaction, all impact on soil faunal diversity and in this case, the litter arthropods. Furthermore, the closer resemblance in species composition and structure of litter arthropods between CZ and RUA than other ECAN sites could also be explained by vegetation structure and litter quantity. The results suggest that vegetation affects the species assemblage of litter arthropods.

There was no consistent pattern of relationship between the species composition resemblance (Fig. 13a) and abundance structure (Fig. 13b) of soil arthropods across ECAN sites, indicating that they are distinct from each other. However, species composition resemblance of soil arthropods followed a pattern similar with that of litter arthropods, suggesting that vegetation and litter quantity also affects species resemblance of soil arthropods. For abundance structure of soil arthropod species (Fig. 13b), CZ and CUA appear to have closer resemblance than other sites, which can be explained by the non-significant difference of their species evenness (Table 6).

Potential Indicator Arthropod Group

Of the hemiedaphon (organisms that live within the litter/humus boundary) and euedaphon (those live lower in the soil profile) (Eisenbeis and Wichard, 1987), five groups are chiefly represented: Isopoda, Myriapoda, Insecta, Acari, and Collembola, the latter two being by far the most abundant and diverse (Culliney, 2013). These groups were represented at least in one ECAN site in Aborlan, Palawan (Tables 4 and 7). Contrary to being the most abundant, Collembola was consistently low in number of individuals in most sites even in CZ (primary forest). This is an interesting area for investigation.

Out of 17 litter arthropod taxa, only eight and seven showed significant differences in abundance (Table 5) and species richness (Table 6), respectively. Out of these, only Acari, Hemiptera and Coleoptera showed a trend in abundance and species richness that more or less conformed with the expected pattern across ECAN sites although the latter two had abundance and species richness at par to those in CZ. These litter arthropod groups could be potential indicators as their abundances and species richness are able to relatively discriminate the five ECAN sites.

Only five and four taxonomic groups of soil arthropods showed significant differences in abundance (Table 7) and species richness (Table 8), respectively. None of these groups showed a pattern that conforms with the expected trend across ECAN sites except for Coleoptera and Acari.

CONCLUSION AND RECOMMENDATIONS

In this study, it was hypothesized that the community assemblage of litter and soil arthropods in terms abundance, species richness, diversity, evenness and composition differs across land use types of ECAN zones through the influence of vegetation, litter and soil characteristics, and their pattern across land use types conforms the ECAN zoning. The results, however, showed varying responses of litter and soil arthropods in terms of general (overall) and specific (taxonomic, mostly orders) assemblage measures across ECAN sites.

Among the overall assemblage measures, only the abundance and species richness of litter and soil arthropods showed distinction among the ECAN sites as they were significantly different. Contrary to the hypothesis, the overall assemblage measures of litter and soil arthropods did not conform with the expected pattern of ECAN zoning but appeared to be affected by unwanted human disturbance. Of the litter arthropod taxa, the abundance and species richness of Acari, Hemiptera (Heteroptera) and Coleoptera, which significantly differ among the sites, more or less conformed with the ECAN zoning. For soil arthropods, the abundance of Coleoptera and Acari differ significantly among the sites and their pattern conformed with the ECAN zoning. The species composition and abundance structure of both litter and soil arthropods were distinct across ECAN sites and conformed with the ECAN zoning except for the abundance structure of soil arthropods.

The overall results suggest that the ECAN sites sustain different assemblages of litter and soil arthropods and are affected by human disturbance through changing the vegetation. Species composition and abundance structure of both litter and soil arthropods are distinct among ECAN sites. Species composition and abundance structure as well as abundance and species richness of specific taxa such as Acari and Coleoptera performed better in discriminating the ECAN sites than the overall assemblage measures. Acari and Coleoptera are potential candidates as bioindicators for monitoring the conditions of the ECAN zones.

The main objective of the SEP law for Palawan (RA 7611) is sustainable development. To attain sustainable development, ecosystem processes must be maintained in order to continually provide ecosystem services. ECAN is the strategy adopted by SEP law to attain sustainable development in Palawan. However, the results of this study indicate that the prohibited human activities in ECAN zones have affected the soil fauna particularly the litter and soil arthropods which are vital for nutrient cycling and soil productivity. It is, therefore, recommended to strictly enforce the law and strengthen the implementation of ECAN through close monitoring of human and activities in each ECAN zone. The local residents can be empowered to do the job. Continuous uncontrolled destructive activities particularly in Restricted Use Area may cause faunal collapse not only of soil invertebrates but also the higher vertebrates.

Many municipalities particularly in southern Palawan have been planning to amend the existing ECAN zoning for whatever reasons. Studies such as of this kind are recommended to be conducted before amending and/or downgrading a certain ECAN zone into a lower level (e.g. changing the Core Zone into Controlled Use Area) before pursuing the amendment, so as not to jeopardize the sustainable development objective of the province as explicitly stated in the SEP law. Each ECAN zone contains distinct assemblage of arthropod fauna which may be severely affected after the amendment.

Presently, there is an urgent need to monitor the conditions of ECAN zones but such cannot be done in the absence of appropriate indicator(s). Follow-up studies on the potential candidates for bioindicators of ECAN zones particularly the Acari and Coleoptera are recommended. This must include among others, the sampling and analysis protocols simple enough to be executed by a non-technical individual but robust enough to reflect the conditions in zones and discriminate these areas. Related to this is the detailed comparison between the use of species composition (e.g. morphospecies), abundance, and diversity indices across space and time. Further, studies on other invertebrate groups are also recommended to complement the findings of the present study and/or provide very useful results for future management strategies of ECAN.

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