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# Diversity of Soil Arthropods in Teak Plantation Forests at Cepu, Blora, Central Java

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***Abstract***

*Insects are the main group of soil arthropod and the most dominant animals in the terrestrial ecosystems. The aims of this study were to get information about soil arthropod diversity in relation to environmental influence at teak plantations at Cepu, Central Java. The sampling plot design was based on forest health monitoring design method. Pitfall trap and Berlese-Tullgren funnel were employed to collect the soil arthropods. The trapped specimens were sorted in the laboratory and then identified up to family or genus. The result of the study revealed that young-age plantation has higher abundance and diversity of arthropod than old-age plantation. Totally we found 3 classes, 11 orders, 29 families, and 714 individuals from young teak plantation, and 3 classes, 11 orders, 25 families, and 397 individuals from the old one. The dominant class was insect and the dominant order of the insects was Hymenoptera. The thickness of the teak litter was the most important factor to the abundance of soil arthropods ($R^2$ = 0.891).*

*Keywords: forest health monitoring, environmental factor, teak litter, pitfall, Berlese-Tullgren funnel*

***Abstrak***

*Serangga merupakan kelompok binatang terbesar dari arthropoda tanah dan paling dominan di ekosistem terestrial. Tujuan penelitian ini adalah untuk mendapatkan informasi hubungan keanekaragaman artropoda tanah dengan pengaruh lingkungan di hutan hutan jati di Cepu, Jawa Tengah. Plot pengamatan dibuat berdasarkan desain forest health monitoring. Metode Pitfall trap dan Corong Berlese-Tullgren digunakan untuk mengoleksi arthropoda tanah. Pemisahan hasil koleksi dilakukan di laboratorium dan kemudian diidentifikasi sampai tingkatan famili atau genus. Hasil penelitian menunjukkan bahwa hutan jati umur muda (kelas umur III) mempunyai kelimpahan dan keanekaragaman arthopoda tanah yang lebih tinggi dibandingkan dengan hutan jati umur tua (kelas umur VI). Secara keseluruhan didapatkan 3 kelas, 11 ordo, 29 famili, dan 714 individu di hutan jati umur muda, sedangkan di hutan jati umur tua didapatkan 3 kelas, 11 ordo, 25 famili, dan 397 individu. Kelas yang dominan dari kelompok arthropoda adalah serangga, sedangkan ordo yang dominan adalah Hymenoptera. Ketebalan serasah merupakan faktor yang penting dalam hubungannya dengan kelimpahan arthropoda tanah ($R^2$=0.891).*

*Kata kunci: forest health monitoring, faktor lingkungan, serasah, pitfall, corong Berlese-Tullgren*

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## Introduction

The great number of species interacted with complexity of food chain are the reason for stable ecosystem because food chain is a complex balance of life. However, in recent years, human activities, like forest logging, conversion of natural forests to a plantations forest, and other disturbance to the forest have caused instability of the ecosystem. The issues of forest destruction, forest fragmentation, biological conservation, and ultimately sustainable management of tropical forest have attracted the attention of biologists all over the world. The great number of species and the value to the biosphere are reason for their fascination to biologists. Forest disturbances cannot be avoided as development requires a certain amount of land clearance. However, there must exist a balance between preservation and utilization of the forest. A concerted effort toward conservation is therefore highly warranted. The critical fauna's habitat such as lowland forest in the tropic is raidly diminishing particularly in the developing country. Thus, a thorough understanding of landscape quality is essential for monitoring forest environmental changes, and that its impact towards animals, expecially soil arthropods are urgently needed.

At the present time many people want to know

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biodiversity that explain the variability of species of the organisms. Biological diversity, very simply, refers to all of the different kinds of life on earth. Diversity is a simple concept. In ecology, it means variety. Biodiversity is used as a synonym for the variety of life. Gaston (1996) defines biodiversity as the structural and functional variety of life forms at genetic, species, population, community, and ecosystem levels.

Soil arthropod is one of the terrestrial organisms. Insects and other arthropods are abundant throughout terrestrial ecosystems. They apparently consumed about 20% of the foliage annually worldwide. They are in association with many other detritivore invertebrates, fungi and bacteria in releasing and recycling the nutrients that are fixed in decaying vegetation (Samways 1994; Abbott *et al*. 2002).

It has been recognized that there are different biodiversity and abundance of organisms among different habitats but the difference has not yet been thoroughly investigated. The abundance of a species is influenced by several environmental (biotic and abiotic) factors (Detsis *et al.* 2000; Jukes *et al.* 2001). It is reasonable to conduct a study to describe species diversity in a certain habitat and try to find out which environmental factors play an important role in determining the abundance of the existing organisms, especially the soil arthropods (Bonham *et al.* 2002; Pflug & Wolters 2002). The objectives of the study were to investigate the difference between soil arthropod diversity living in a younger teak plantation and in an older one in Cepu Forest District and determine the most influencing environmental factor influencing the abundance of soil arthropods. The study is expected to provide a considerable benefit to for stakeholders in the process of monitoring the soil nutrition and in management of teak plantation forest.

**Methods**

The research was conducted at teak forest plantation whitin the forest health monitoring (FHM) plots in Cepu. The sampling plot was located in 2 different age classes of teak plantation. Age class is a distinct aggregation of tress originating from a single natural or regeneration activity, or a grouping of trees, eg. 10-year age class, as used in teak plantation (Helms 1998). The locations of sampling plots were at the compartment 1039 (age class III–young) at Pasarsore Sub Forest District and compartment 4005 (age class VI–old) at Cabak Sub Forest District, Cepu Forest District.

Sampling plots were choosen by referencing to FHM plot (Figure 1). The plots had been pre-prepared by the previous research team. Based on FHM method, the determination of sampling plots was prepared using cluster plot design. One cluster within the sampling plot consisted of 4 sub-plots or annular plots. Every plot had a radius of 7.32 m for a subplot and 17.95 m for annular plot. The center of the subplot 1 was the center for all the plots. The center of subplot 2 lied at the azimuth 360° from the center of subplot 1 and the distance was 36.6 m. The center of subplot 3 lied at the azimuth 120° from the center of subplot 1 and the distance was 36.6 m. The center of subplot 4 lied at the azimuth 240° from the center of subplot 1 and the

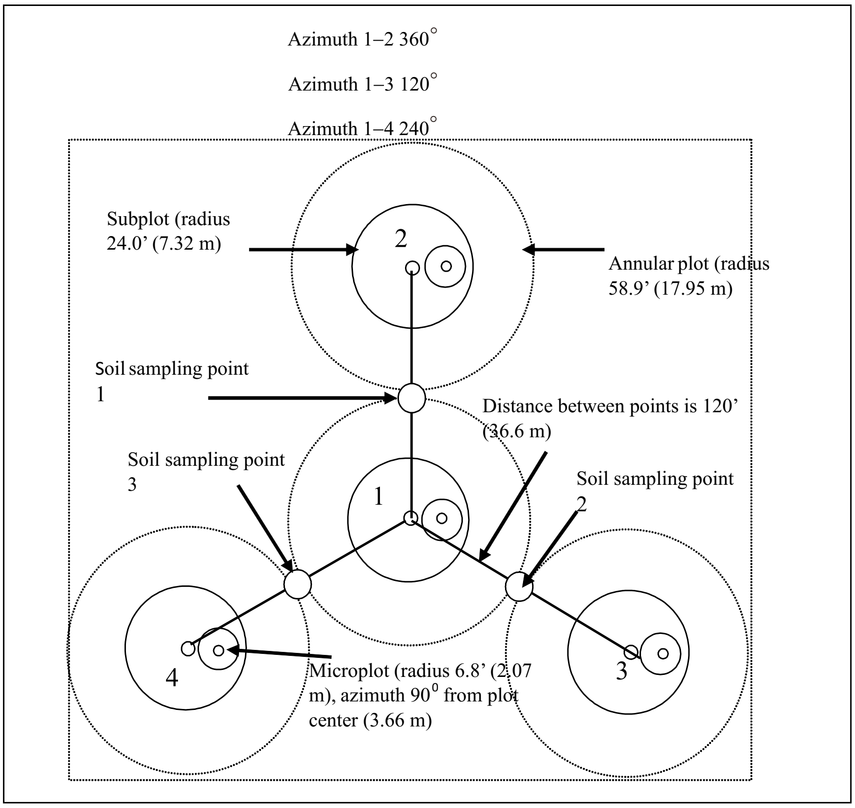


Figure 1 Forest health monitoring (FHM) plot design (●) = Trapping plot of soil arthropod (Alexander 1997).

distance was 36.6 m. Soil samples were taken from 3 points, circular in shape, lied between subplot 1–2, subplot 2–3, and subplot 1–4 with a hole diameter of 16 cm. Observation of soil arthropods was conducted on the holes lying beside soil sample plots. Observation plots for soil arthropods using Berlese-Tullgren funnel were made with the size 50 × 50 cm, 5 cm depth from the litter surface. The dish for pitfall trap method was set at observation plot of 1 × 1 m in size. The trapped soil arthropods were collected placed in alcohol 70% within film tubes and labelled according to the number of observation plots.

This Pitfall trap was employed following Ward *et al*. (2001) with some modification. The Pitfall trap trapped which is a plastic glasses half filled with 70% alcohol was immersed as deep as 1.5–2 cm into the soil with the lips of the glasses were parallel to the soil surface, and left for a week after which specimens were collected and brought back to laboratory. A total of 5 traps were installed per plot with 1 m separating between them.

The Berlese-Tullgren funnel method was used to extract soil arthropods which live in the soil. The method is applied in 2 stages, firstly the separation of the arthropods from the litter layer and secondly the separation of arthropods from the soil layer up to the depth of 0–5 cm. The Barlese-Tullgren funnel method was applied by taking samples of litter and soil and then the samples were placed in funnels. This extractor used a heat source (electric lamp) set on the top of the funnel so that the arthropods would be forced to move downward and fell down to the collection bottle set beneath the extractor.

The environmental factors to be measured were air temperature and humidity, soil pH, cation exchange capacity, abundance of trees and understorey, diversity of trees and understorey, and litter thickness. Soil arthropods were identified based on morphology characters following (Goulet & Huber 1993; Borror *et al*. 1996; Bolton 1997; Deelman-Reinhold 2001; Jocque & Dippenaar-Schoeman 2005).

The data on were analyzed using Species Richness Biodiversity Programme and GW-BASIC 3.20 (Ludwig & Reynolds 1988) to determine richness index, diversity index, and evenness index. Abundance of soil arthropod speciess and environmental factors were analysed using regression analysis on SPSS Program version 13.0.

The formulas to be used were as shown in Equation *[1]*, *[2]*, and *[3]*

Richness index:

$$DMg = \frac{(S-1)}{\ln N} \quad [1]$$

note:
$DMg$ = Margalef's index of richness,
$S$ = number of species found
$N$ = the number of individual of the total species

Dmg value < 3.5 indicated that the species richness is low, DMg value between 3.5–5.0 indicated that the species richness is medium, and DMg value > 5.0 indicated that the species richness is high (Magurran 1988).

Diversity index:

$$H' = -\sum P_i \ln P_i \quad [2]$$

$$P_i = \frac{n_i}{N}$$

note:
$H'$ = Shannon-Weiner's index of diversity
$P_i$ = fraction of the entire population made up of species
$n_i$ = the number of individual of certain ($i^{th}$) species
$N$ = the number of individual of all species

Evenness index:

$$E = \frac{N_2 - 1}{N_1 - 1} \quad [3]$$

note:
$E$ = evennes index
$N_2$ = abundance value
$N_2$ = $e^{H'}$
$N_1$ = the abundance value of the species within the sample

Alatalo (1981) recognized that the E value would approach zero if one species become more dominant in the community.

## Results and Discussion

**Pitfall trap method** The number of individuals of the order *Hymenoptera* was the highest at the 2 study areas (Cepu Age Class III and Cepu Age Class VI) with the number of individuals was 411 and 126, respectively (Figure 2). The *Formicidae* was the most dominant in the order *Hymenoptera*. More clearance for forest age class III may made the number of *Formicidae* collected was higher than the other forest. This may be due to the diversity of understorey plants provides the shelter and food for ants (Maschwitz *et al.* 1996; Bluthgen *et al*. 2000). Change in plant composition in this habitat might initiate ant colonization (Renata & Cerda 2000; Malsch *et al.* 2003). Age class III has abundant understorey because of the high light penetration to the forest floor (Jukes *et al*. 2001). Moreover, Hymenopterans may also more abundant in age class III because they were visiting the numerous existing flowers (Idris & Nor-Zaneedarwarty 2000; Hill *et al*. 2001; Idris & Hainidah 2003).

**Berlese-Tullgren Funnel method** The Berlese-Tullgren funnel also showed that order *Hymenoptera* was the most dominant at the 2 study areas (Cepu Age Class III and Cepu Age Class VI), with number of individuals was 50 and 52, respectively (Figure 3).

**Total soil arthropods** The abundance of all soil arthropods in the young teak plantation (compartment 1039) was higher than that of the old teak plantation (compartment 4005) (Figure 4).

In Cepu Age Class III and Cepu Age Class VI the most abundance anthropods was the hymenopterans with 461 and 178 individual, respectively. In the young teak plantation, the arthropods consisted of 11 order within 3 classes, having the abundance of 714 individuals within 37 families. In old

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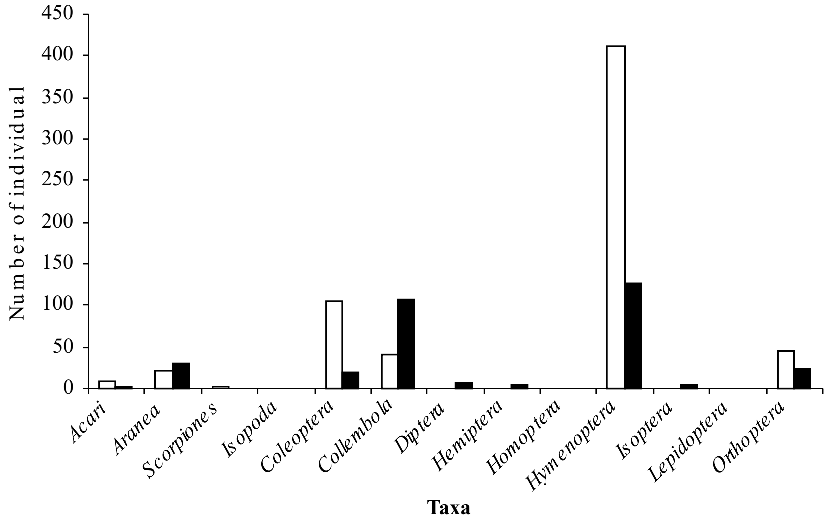


Figure 2 The abundance of soil arthropods using pitfall trap method. Age class III (□), age class VI (■).

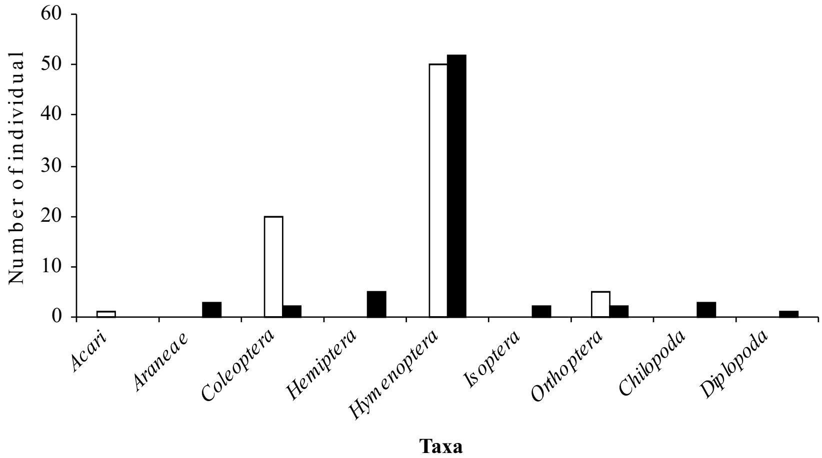


Figure 3 The abundance of soil arthropods using Berlese-Tullgren method. Age class III (□), age class VI (■).

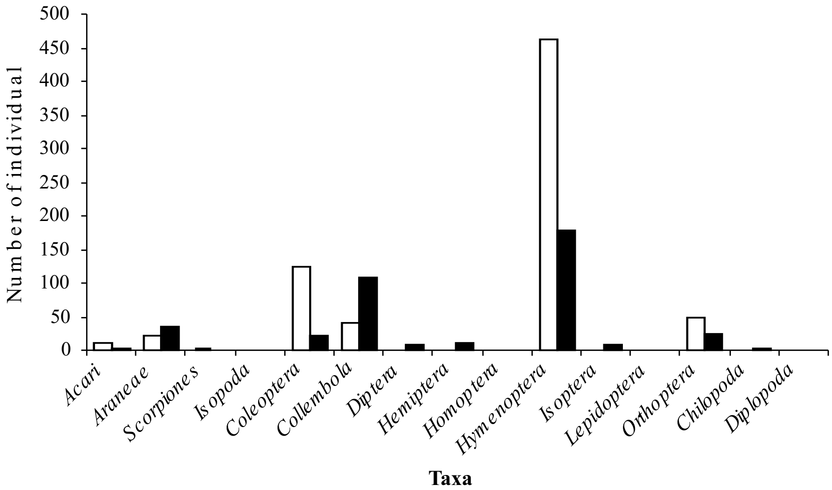


Figure 4 The abundance of all soil arthropods in the 2 study areas. Age class III (□), age class VI (■).

teak plantation, the arthropods consisted of 11 order within 3 classes with 397 individuals within 26 families (Table 1). There was only 1 individual of the *Isopoda*, the order of *Diptera*, *Homoptera*, and *Lepidoptera* belong to the class of *Insecta* (young teak plantation), and the class *Diplopoda* in the old teak plantation). There was only 1 individual of the *Isopoda*, the order of *Diptera*, *Homoptera*, and *Lepidoptera* belong to the class of *Insecta* (young teak plantation), and the class *Diplopoda* in the old teak plantation.

The younger teak plantation had a higher composition

Table 1 The number of individual in family level of insect

| Class | Order | Family | Location | |
|---|---|---|---|---|
| | | | Cepu age class III | Cepu age class VI |
| *Arachnida* | *Acari* | | 10 | 3 |
| | *Araneae* | *Lycosidae* | 3 | 10 |
| | | *Pisauridae* | 14 | 19 |
| | | *Segestriidae* | 5 | 5 |
| | *Scorpiones* | *Scorpionidae* | 2 | 0 |
| *Crustacea* | *Isopoda* | *Trichoniscidae* | 1 | 0 |
| *Hexapoda* | *Coleoptera* | *Carabidae* | 1 | 1 |
| | | *Halticidae* | 8 | 1 |
| | | *Histeridae* | 2 | 0 |
| | | *Lyctidae* | 24 | 0 |
| | | *Mordellidae* | 4 | 0 |
| | | *Mycetophagidae* | 0 | 0 |
| | | *Nitidulidae* | 29 | 2 |
| | | *Phalacridae* | 1 | 0 |
| | | *Salpingidae* | 1 | 0 |
| | | *Scarabaidae* | 36 | 5 |
| | | *Scolytidae* | 6 | 0 |
| | | *Scydmaenidae* | 0 | 1 |
| | | *Staphylinidae* | 12 | 12 |
| | *Collembola* | *Entomobrydae* | 32 | 86 |
| | | *Puduridae* | 2 | 0 |
| | | *Pseudochorutidae* | 7 | 21 |
| | *Diptera* | *Chamaemyiidae* | 0 | 1 |
| | | *Piophilidae* | 1 | 0 |
| | | *Phoridae* | 0 | 4 |
| | | *Sciaridae* | 0 | 2 |
| | *Hemiptera* | *Cimicidae* | 0 | 2 |
| | | *Lygaeidae* | 0 | 3 |
| | | *Reduviidae* | 0 | 5 |
| | | *Thyphlocybinae* | 1 | 0 |
| | *Hymenoptera* | *Formicidae* | 459 | 176 |
| | | *Mymaridae* | 0 | 2 |
| | | *Tiphiidae* | 2 | 0 |
| | *Isoptera* | *Termitidae* | 0 | 7 |
| | *Lepidoptera* | *Larvae* | 1 | 0 |
| | *Orthoptera* | *Acrididae* | 1 | 0 |
| | | *Gryllidae* | 40 | 15 |
| | | *Tetrigidae* | 5 | 0 |
| | | *Grillacrididae* | 4 | 10 |
| *Myriapoda* | *Chilopoda* | *Cryptopidae* | 0 | 3 |
| | *Diplopoda* | *Spirobolidae* | 0 | 1 |

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and abundance of soil arthropods compared to the older teak plantation. This may be due to the availability of food source, in a younger teak plantation are as it has higher tree density, compared to that of the older plantation (Barbosa & Marquet 2002; Warren & Zou 2002). Besides, the monoculture plantation (pure stand) also provided a better condition to support the life of a certain arthropod especially food and habitat (Toft *et al.* 2001; Warren & Zou 2002). This condition was supported by the fact that the arthropods found in the young plantation (compartment 1039) were more abundant than that of the old one (compartment 4005). In the younger plantation the trees consist of only the teak (*Tectona grandis*), and in the older one consisted of teak (*T. grandis*), *ploso* (*Butea monosperma*), and *Dalbergia latifolia*. Simplification of the forest structure and loss of major competitive species have enabled some species to survive and dominant in the disturbed habitat (Majer & Nichols 1998; Strehlow *et al.* 2002).

Beside the environmental factors, the characteristic of arthropod (such as way of life and feeding) also has an important role to the presence of the arthropods in a certain habitat (Pflug & Wolters 2002). In the 2 study areas, the most abundant arthropod was from the order *Hymenoptera*, especially the family *Formicidae* (ant). The teak forest in Cepu Forest District had suffered forest fires. DeBano *et al.* (1998) explained that the ant population on the burnt site would increase due to many seeds to be eaten. *Formicidae* is also a hymenopteran group that easy to find and disperse in large areas (Borror *et al.* 1996; Gandhi *et al.* 2001).

The diversity of arthropods in Cepu Age Class III was higher than that in Cepu Age Class VI (Table 2). The DMg, H' and E values in Cepu Age Class III were 5.479, 2.672, and 0.635, respectively. Generally, the richness, diversity, and evenness indexes were higher in younger plantation than in the older one. This was due to the undergrowth species (Jukes *et al.* 2001). Bird *et al.* (2000) found that species diversity was higher in the first year following removal of trees. Arthropod species richness increased following nitrogen and phosphorus application. This indicates that the arthropod community had responded to fertilizer application with a change in community composition. Finch (2005) also suggested that spider diversity was significantly higher in the spruce forest (55 years old), compared to the beech (170 years old) and pine stand (110 years old), respectively.

The arthropod species in compartment 1039 and 4005 distributed evenly throughout the area. This was indicated by the evenness index in each study area which was higher than zero. The evenness of the species was supported by the condition of habitat in each area for example (the availability of food sources for the arthropods life) (Detsis *et al.* 2000; Manh & Nguyen 2000; Magura 2002) and the characteristic of the arthropods themselves (such as life style and feeding).

The evenness index in the younger plantation was higher than that in the older one. This was due to the occurrence of forest disturbances in each location (such as forest fires and human activities), which could make one species of arthropod in a location is more dominant than the others (Orendt 2000; Zhu *et al.* 2000; Dombos 2001; Siira-Pietikainenm *et al.* 2001; Strehlow 2002; Siira-Pietikainenm *et al.* 2003).

**Relation between arthropods abundance and environmental factors** Regression analyses showed that among the environmental factors measured, the litter thickness was found to be the most significant factor ($F$ = 57.35, $r$ = 0.89, $df$ = 1&7, $P$ < 0.01) influencing the number of arthopods collected than due to other factor (number of tree species diversity and the number and diversity of undergrowth) (Table 3).

So, it could be concluded that food (litter) was the

Table 2 Diversity index, richness index, and evenness index of soil arthropods in the 2 study areas

| Parameter | Location | |
|---|---|---|
| | Cepu age class III | Cepu age class VI |
| DMg | 5.479[t] | 5.203[t] |
| H’ | 2.672 | 2.552 |
| E | 0.635[td] | 0.604[td] |

t = high, td = no species dominated, H’= Shannon-Wiener’s index of diversity, DMg = Margalef’s richness index and E= modified evenness index (Hill’s ratio)

Table 3 Environmental condition in Cepu teak plantation

| Variab le of environmental factors | Location | |
|---|---|---|
| | Cepu age class III | Cepu age class VI |
| Temperature ($^o$C) | 28.40 | 28.40 |
| Relatif humidity (%) | 70.30 | 71.80 |
| pH | 6.60 | 7.10 |
| Cation exchange capacity (me $100g^{-1}$) | 16.66 | 33.31 |
| Litter depth (cm) | 6.55 | 6.90 |
| Σ tree (individual) | 39.00 | 15.00 |
| Σ understorey plant (individual) | 37.00 | 120.00 |
| Diversity of tree | 0.00 | 0.22 |
| Diversity of understorey plant | 1.93 | 1.20 |

determining factor to the soil arthropods diversity and abundance (Bird *et al.* 2000; Bird *et al.* 2004). Forest litter in teak forest composed of dead plant part, including twigs and leafs. Wallwork (1976) stated that the thicker the litter, the more the food available for the arthropods. Litter quality is closely related with soil moisture to influence the soil arthropods (Costa *et al.* 2002). The litter with higher ratios of lignin/nitrogen and C/N had higher diversity of Collembola (Pflug & Wolters 2001). The thick litter could reflect a slower decomposition of leaves by microorganisms, which make large contributions to arthropods diets (Cortet & Poinsot-Balaguer 1998).

**Conclusion**

The H' of soil arthropods in the younger forest plantation was higher than that in the older one. This was attributed of high E and R indexs in young teak forest than the old one. The thickness of the litter of the young forest influenced the abundance of soil arthropods since the litter was the very important food source for survival of the soil arthropods. This study indicates that diversity of soil arthropods could be used as a preliminary information to understand the changes in the presence and abundance of the soil arthropods in the disturbed and virgin forest.

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