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**Research Article**

# Soil macrofauna diversity and structure under different management of pine-coffee agroforestry system

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**Abstract:** The role of tropical forests for maintaining environmental functions is decreasing due to the rapid changes to agricultural purposes. Agroforestry system is assumed to be an alternative system which reduces the negative impact of the conversion in term of maintaining the level of soil macrofauna diversity. This study was conducted at UB Forest within the period November 2017 to February 2018 by collecting soil macrofauna from 9 different land use types using hand sorting along with pitfall sampling for comparison. ANOVA and various diversity indexes were used (Shannon index, Pielu index, etc) to determine macrofauna structure and communities. Total soil C was examined using Walkley and Black method along with Particulate Organic Matter (POM) C fractionation approaches. Litter inputs were collected using a litter trap method, while in-situ litter were determined using destructive methods. Biplot and CVA multivariate analyses were adopted to determine the impact of different management on soil macrofauna diversity and structure. The result showed that conversion to agriculture practices reduced the structure, population and abundance of soil macrofauna as litter production, organic matter and soil C content decreased. The lowest abundance of individual soil macrofauna at monoculture system (PM) was reduced to 45 morphospecies compared to pine coffee agroforestry at the age of 4 (PK4:20 years after planting) system as much as 104 morphospecies. There was a strong relationship between litter thickness and the abundance of soil macrofauna. Both methods (Hand sorting vs Pitfalls traps), had a different ability for collecting soil macrofauna communities. Species occurs at rich or low organic matter input can be adopted as soil macrofauna bioindicator of changes on an ecosystem. Biplot and CVA methods can be used to distinguish and to cluster the impact of different management at various agroforestry systems.

***Keywords**: agroforestry, biodiversity, land management, land use, soil invertebrates*

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## Introduction

In the tropics, deforestation for agricultural expansion is the primary cause for biodiversity extinctions, but the agroforestry system plays important roles in reducing the rapid loss of species and plants. It can be used as a complementary land use strategy for combating rapid developing areas; this system provides conservation benefits for the rich diversity fragile ecosystem (Sistla et al., 2016). As one of the tropical regions, Indonesia is the country that has been named the biggest Mega Biodiversity after Brazil and Madagascar. Indonesia has, for example, the second highest number of indigenous medicinal plants, after the Amazon rain forests (Elfahmi et al., 2014), 10% of the world's flowering plant species, about 12% of the world's mammals, about 16% of the world's reptiles and 17% of the total species of birds. (von Rintelen et al., 2017). Biodiversity represents the variety and heterogeneity of organisms or traits at all levels of the hierarchy of life, from molecules to ecosystems with the focus is on species diversity (Morris et al., 2014).

Generally, agroforestry system in Indonesia providing natural resources (i.e. food, medicine, lumber, wood product) (Evizal et al., 2009), have the potential to maintain higher levels of biodiversity (i.e. pollinator, natural enemy), and greater biomass (i.e. litter accumulation, tree biomass) than lower diversity crop or pasture systems (Gliesmaan, 2007). Greater plant diversity may also enhance soil quality, further supporting agricultural productivity in nutrient-limited tropical systems (Sistla et al., 2016). One of well know typical agroforestry system is involving selected economic tree species such cocoa (Toana et al., 2014) or coffee) under canopies of other trees such as *Pines*, *Albizia* or *Mahogany* (Verbist, 2005; Evisal et al., 2016). Toana et al. (2014) who reviewed this system in improving biodiversity reported that in cocoa plantation at Central Sulawesi, under two strata of shade tree, Species Richness (R), Species Evenness (E), Shannon and Simpson index were the highest with value of 18.216, 0.839, 4.383 and 0.833 respectively. This value compared to one stratum of a shade tree, with species richness (R), species evenness (E), Shannon and Simpson index with the value of 10.635, 0.714, 3.356 and 0.683. In addition, without shade tree, species richness (R), species evenness (E), Shannon and Simpson index were the lowest with the value of 5.424, 0.497, 2.011, and 0.450.

The number of major pests occurred, and the composition of arthropods is incapable of supporting the ecosystem balance. Monoculture system creating unstable ecosystem condition suspected to outbreak to pest and disease (Altireri and Nicholls, 2004; Altieri et al., 2009). Another result that has been reported by Kinasih et al. (2016) under West Java Pines agroforestry system showed the highest abundance was recorded at coffee plantation (2477 individuals) while pine plantation (1372 individuals) as the lowest. All collected soil invertebrates grouped into 3 classes (*Arachnida*, *Chilopoda* and *Insecta*), 16 orders, 47 families, and 124 morphospecies. Soil invertebrates were dominated by Formicidae, Scarabaeidae, Blattidae, Forficulidae, and Phalangiidae. The average diversity index of soil invertebrates was 2.25 at coffee plantation plot, rising to 2.64 at coffee and pine plantation and drop to 1.85 at pine plantation. The study showed an agroforestry effect on enriching soil invertebrate abundance and diversity of the monoculture pine system. However, the establishment of soil invertebrate is a result of the several factors such as the availability of organic matter inputs, microclimate conditions and the interactions between soil communities. If there are any changes of the plant covers and human activities these systems are easily being affected (Baross et al., 2003; Vasconcelos et al., 2009; Lavelle et al., 2006; Zaitzev et al., 2014).

The UB Forest area is a limited protected forest area where intensive agricultural activities are still very limited. The area which is an education forest with an area of about 540 ha which is mainly a production forest stand dominated by timber species of Mahogany *(Sweithenia mahogany)* and Pine *(Pinus merkusii)*. Various types of flora under stands such as colacasia, banana, coffee, ginger, etc., conditions will affect the type and diversity of fauna and microbial activities in the soil. Unfortunately, some of UB forest's land area has been converted into agricultural areas and other cultivation purposes.

Land use change will have an impact on shrinking or loss of native vegetation, and production forests so that in the long run it will affect the activity of soil biota including the soil invertebrates. These areas have unique management whereas the main shading tree has never been tinning or pruning, as there a regulation that these activities are prohibited and not allow for being implemented as it status is under KHDTK (forest with specific purposes) scheme. The result is a dense canopy cover, low light intensity, but a high input of organic matter and low rate decomposition processes. This condition and under combinations of low intensity of management may affect soil invertebrate communities and structure through a slowing on the turnover of soil nutrient cycle, reducing the ability of soil invertebrate for growing under optimum conditions, caused by high soil acidification and low soil pH status (Zaitsev et al., 2014).

Soil macrofauna is also an important key in decomposition and biodegradation processes that have died, soil organic changes, humification, nutrient cycles and physical properties of soil such as bulk density, porosity and groundwater availability (Blanchart et al., 2009) but their structure and communities are rely on the inputs of organic matter derive from the tree cover (Merlim et al., 2005). Most agroforestry systems are designed to achieve optimum production of the tree being cultivated, but in some cases, the tree arrangement and their management are becoming a crucial part of maintaining soil biota diversity. The different tree species will give different quantity and quality of litter which become the primary source of energy for soil microorganism. Despite the importance of the agroforestry system maintaining soil diversity and nutrient cycle, there is a very limited study on the impact of different management of pine-agroforestry system on the dynamic of soil invertebrate. The objective of this study was to examine the diversity of soil invertebrates of coffee-pines agroforestry system under different age of planting compared to other systems (pines monoculture, pines + vegetable, mahogany + tarro and mahogany + coffee).

## Materials and Methods

***Study area***

The research was conducted from November 2017 until February 2018 at UB's education forest, Sumbersari and Buntoro sub-village, Tawang Argo Village, Karangploso District, Malang Regency, East Java Province. This site geographical position is at 7°49'35.58" S and 112°34'42.57" E with the elevation of 1000 m above sea level. The soil in the study developed from the southwestern part of Mount Arjuno volcanic activity and can be classified as Andisols with the slope ranging from 15 to 30%.

***Procedures***

*Soil invertebrates sampling*

Soil invertebrates sampling was conducted using two different methods which were then compared : (1) Metal frame (20 cm x 20 cm) + hand sorting (inserted into 30 cm of soil depth) (modified TSBF method, Anderson and Ingram, 1993; Salazar et al., 2015) and pitfall traps (plastic bottle with size of 8 cm in diameter and 12 cm in height) were placed in the soil surface (modified from Siquera et al., 2014). Metal frame + hand sorting was used to collect all soil invertebrates by placing at 3subplots with tree replicated, while for pitfall traps were placed at 15 points for each plot with the distance of 4 m each, collected in December 2017 to February 2018. All sample specimen were stored in formalin 4% (before identified) were grouped and identified using a microscope and then was classified its morphospecies level based on *Study of Insects,* 7th Edition (Borror et al., 2005) and *Biology Soil Guide* (Dindal, 1990).

*Environmental and soil factors measurements*

At each plot litter traps were placed at 3 positions within an area of 3 m x 1 m and litters were collected weekly, while in situ litters were measured using destructive sampling using a metal frame within an area of 50 cm x 50 cm and litter thickness was randomly identified using a handheld ruler (50 cm). Total soil organic C were determined using the Walkley and Black method (Walkley and Black, 1934) along with Soil C fractionation technique using POM (particulate organic matter) C methods.

***Data analysis***

Variables observed in this research were the number of species and their population. Based on the data each variable some ecological indices, such as Shannon-Weiner Indices (H), Species Evenness Indices Pielou (E), Species Richness Indices Margalef (DMg), Dominance Induced Simpson (D) as described below:

*Diversity Indices Shannon-Wiener (H) adopted from Ludwig and Reynold (1988), Toana et al. (2014), and Kinasih et al. (2016).*

$$H' = \sum_{\substack{i=l \\ Pi=n\ /N}}^{S} [Pi \ln Pi]$$

where:

| | | |
|---|---|---|
| H' | : | Diversity indices |
| Ni | : | Population of i species |
| N | : | Population of all species |
| Pi | : | Proportion population of is species to all species |

If H' <1 = low, unstable ecosystem, low productivity and low diversity, H' between 1-2 = medium condition, and H' >2 = high, stable ecosystem, high diversity and productivity (Kent and Cooker, 1992).

*Evenness Indices Pielou (E) adopted from Mulder et al. (2004), Toana et al. (2014), and Kinasih et al. (2016).*

$$E = \frac{H'}{\ln S}$$

where:

| | | |
|---|---|---|
| E | : | Evenness Indices Pielou |
| H' | : | Diversity Indices Shannon (H) |
| S | : | Total species number |

*Richness Indices Margalef adopted from Ludwig and Reynolds (1988), Toana et al. (2014), and Kinasih et al. (2016).*

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

where

| | | |
|---|---|---|
| DMg | : | Richness Indices Margalef |
| S | : | Total species number |
| N | : | Total individual of all species |

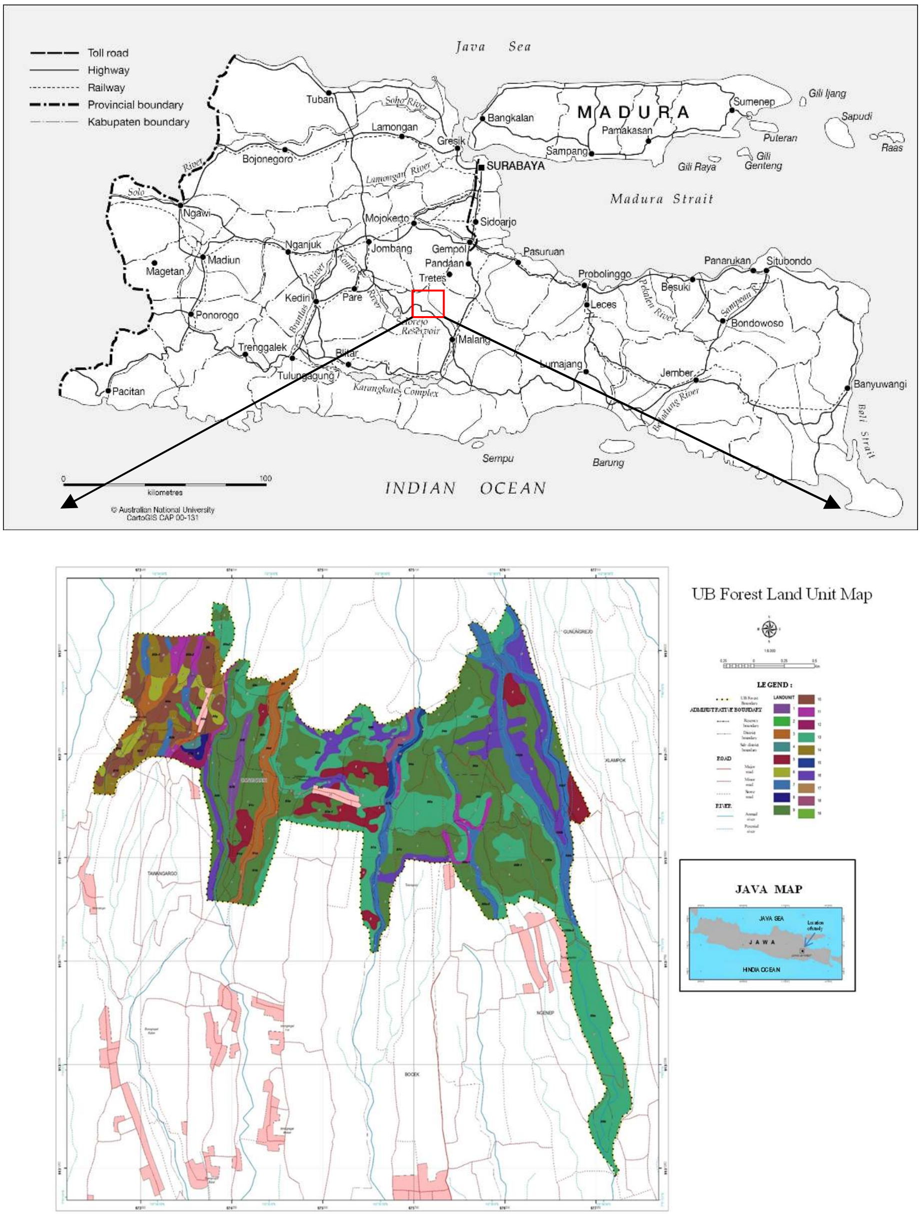


Figure 1. Study site at Tawang Argo Village, Karangploso District, Malang Regency, East Java Province Soil invertebrate was sampled at 9 different vegetation types (Table 1), comparing pines with different ages of planting with coffee underneath to pines monoculture, pines + vegetable, mahogany + coffee and mahogany + taro

Table 1. Different vegetation types at the study site

| Plot | Vegetation type |
|---|---|
| PK4 | Pines at the age classes of 4 (20 yr after planting) + coffee underneath |
| PK6 | Pines at the age classes of 6 (30 yr after planting) + coffee underneath |
| PK7 | Pines at the age classes of 7 (35 yr after planting) + coffee underneath |
| PK8 | Pines at the age classes of (40 yr after planting) + coffee underneath |
| PM | Pines monoculture |
| PS | Pines + vegetable |
| MK | Mahogany + coffee underneath |
| MT | Mahogany + taro underneath |

*Dominance Indices Simpson (1/D, adapted from Brower et al. (1990), Morris et al. (2014), Toana et al. (2014), and Kinasih et al. (2016).*

$$D = \frac{\sum ni\ (ni-1)}{N(N-1)}$$

where

ni : Total individual species i

N : Total individual from all species

## Results and Discussion

We collected 554 individuals during sampling using hand sorting method which is comparable to 572 individual using pitfalls technique (Table 2), while almost 50% difference between those two methods in term of in the total number of species. Amongst all plots the highest abundance no of individual and no of species were at PK4 (Pines at the ages classes of 4 (20 years after planting) + coffee underneath, while the lowest was at PS (Pines + vegetable) plots, using hand sorting approaches. In term of comparing the method, consistently the PK4 had the most significant number of individual, but for highest no of species were obtained from PK7 (Pines at the ages classes of 7 (35 yr after planting) + coffee underneath. The lowest number of individual and species of soil invertebrates using Pitfalls technique was detected at PM (Pines monoculture) plots (Table 2). It can be concluded that in general, the agroforestry system plays important roles for maintaining the abundance of soil invertebrates or even increasing the number of individual or species, compared to monoculture systems. Monoculture agriculture such as frequent land clearing and burning, continuous tillage, monoculture practice, crop rotation, little organic residue inputs retention and use of agrochemicals have been shown to be among the causes of the alterations of soil fauna population structure. Moreover, it can cause disappearance or reduction of key families and in some cases extremely low abundances of some indicator species (Sisay and Ketema, 2015). Tillage system and soil cover are the factors affecting the organic matter and litter production in agricultural fields and therefore the food availability for soil fauna (Siquera et al., 2014). The total number of individual and species in this study can be comparable to those result from a cocoa agroforestry system in Central Sulawesi, indicate that number of arthropod species and the same species found in all strata types of shade tree were the highest in the cocoa plantation under two strata of shade tree, 186 and 34 species, respectively.

Table 2. Total number of individuals and species across different vegetation types under different method (Hand sorting vs pitfalls) ($P<0.05$)

| Plot | Number of individuals | Number of species | Number of individuals | Number of species |
|---|---|---|---|---|
| | Hand sorting | Hand sorting | Pitfalls | Pitfalls |
| PK4 | **104** | **40** | **101** | 21 |
| PK6 | 80 | 31 | 63 | 10 |
| PK7 | 50 | 24 | 95 | **25** |
| PK8 | 72 | 29 | 66 | 15 |
| PM | 74 | 26 | **45** | **13** |
| PS | **52** | **23** | 63 | 18 |
| MK | 57 | 28 | 78 | 9 |
| MT | 65 | 28 | 59 | 12 |
| Total | 554 | 229 | 572 | 123 |
| | P<0.05 | P<0.05 | P<0.05 | P<0.05 |

PK4 did not only have the highest number of individuals and number of species, but also had the highest diversity (H), richness (DMg) and dominance (1/D) of soil invertebrates (Table 2), and PM plot is the lowest. Monoculture system has proven to reduce soil invertebrates, and the ecosystem becomes unstable. However, using Pitfalls methods the highest diversity (H) richness (DMg) and dominance (1/D) of soil invertebrates were detected at PK7 plots (Pines at the ages classes of 7 (35 yr after planting) + coffee underneath, and MK plots was the lowest (Table 3). It is clear that different technique of sampling has a different ability to collecting certain soil invertebrates. Shannon and Pielou index across different land use type using pitfall technique ranged between 0.43 (apple guava) to 2.7 (native forest) and 0.11 (apple guava) to 0.86 (tomato), respectively (Siquera et al., 2014), which lower than the value of H and E in this study (Table 4).

Table 3. Ecological indices across different vegetation type (Hand sorting method) (P<0.05)

| Plot | Shannon (H) | Pielou (E) | Margalef (DMg) | Simpson (1/D) |
|---|---|---|---|---|
| PK4 | **3,68** | 0.99 | **5.55** | **38.60** |
| PK6 | 3,42 | 1 | 4.45 | 31.26 |
| PK7 | 3,28 | 0.99 | 4.23 | 27.53 |
| PK8 | 3,24 | 1 | 3.96 | 26.52 |
| PM | **3,18** | 0.99 | **3.72** | **23.99** |
| PS | 3,19 | 0.99 | 3.91 | 24.81 |
| MK | 3,46 | 1 | 4.75 | 33.33 |
| MT | 3,45 | 0.99 | 4.81 | 32.99 |

Table 4. Ecological indices across different vegetation type (Pitfalls method) (P<0.05)

| Plot | Shannon (H) | Pielou (E) | Margalef (DMg) | Simpson (1/D) |
|---|---|---|---|---|
| PK4 | 3,00 | 0.99 | 3.03 | 19.90 |
| PK6 | 2,29 | 0.99 | 1.68 | 10.33 |
| PK7 | **3,21** | 0.99 | **3.59** | **25.47** |
| PK8 | 2,62 | 0.96 | 2.39 | 13.32 |
| PM | 2,48 | 0.96 | 2.23 | 12.11 |
| PS | 2,85 | 0.98 | 2.80 | 17.68 |
| MK | **2,19** | 1 | **1.46** | **9.31** |
| MT | 2,48 | 1 | 2.01 | 12.58 |

There were differences of species richness R, species evenness E, and species diversity (Shannon H` and Simpson index D) in cocoa plantation under the three types of shade tree (Toana at al., 2014). The result showed that species richness (R) of arthropods under the two strata of shade tree, species evenness (E) and both of species diversity indices Shannon (H`) and Simpson (D) were the highest at the value of 18.21, 0.83, 4.3, and 0.83 respectively, followed by one stratum of shade tree and without shade tree as the lowest. Different agroforestry system at Columbian Amazon was reported influenced the abundance of soil macrofauna, based on their diversity index (H) and evenness index (Salazar et al., 2015). The Abarco agroforestry system had the highest H and E index followed by Rubber-Parica agroforestry system, Uvito agroforestry system and then Rubber agroforestry system. Agroforestry system can provide more abundance and diversity soil macrofauna (Moco et al., 2009), this system had divers in vegetation, provide different niches, more alternative source of food (Rahman et al., 2012;), but the consequences are a complex interaction between soil environmental aspect (i.e. light, temperature, humidity etc). PK4 had the densest vegetation since most of the tree this system never been thinned or pruned creating a unique condition for soil invertebrates, while PK7 is more open in spacing between the tree. In general, we found that the individual and species at UB forest agroforestry system are significantly affected by the type of vegetation types (P<0.05). Dominant soil invertebrates at PK4 using hand sorting method at Family level were Lumbricidae, Scarabaeidae, and Thromisidae. The family of Formicidae, Stratiomyidae and Isotomidae were frequently found at PK6. At PK8, an abundance of Formicidae was also dominant along with Carabidae and Gryllidae (Table 5). The result of total individual species using pitfalls traps is presented in (Table 6). The pattern of individuals' soil macrofauna was completely different from hand sorting methods. At PK4, the primary soil invertebrate was the family of Formicidae followed by PK7 plots, while Scarabidae family was more abundant at PK6 and MT plots. There was an indication that the family of Oxyopidae was frequently collected from PK4 and PK7 plots and the highest abundance of Gryllidae family was at PS plot. The above information indicates that each method has a different ability for collecting soil macrofauna. As suggested by Siquera et al. (2014) and Araujo et al., (2013), the pitfall trap is a sampling method most adequate for Araneae, Coleoptera, Formicidae, and Orthoptera, whereas other soil taxa should be investigated using other different methods. At various agroforestry systems at Bahia-Brazil, Collembolla (41%) was dominant species followed by the family of Formicidae (32%) (Moco et al., 2010). Isoptera is dominant taxa at rubber agroforestry, while Diplopoda is commonly detected at Abarco system (Salazar et al., 2015).

Table 5. Total number of individuals collected by hand sorting method (P<0.05)

| Ordo | Family | PK4 | PK6 | PK7 | PK8 | PM | PS | MK | MT |
|---|---|---|---|---|---|---|---|---|---|
| Haplotaxida | Lumbricidae | **23** | 5 | 6 | 11 | 7 | 2 | 7 | 7 |
| Coleoptera | Carabidae (Larva) | 5 | 1 | - | **8** | - | - | 1 | 2 |
| | Coccinelidae | - | - | - | - | - | 1 | 1 | - |
| | Hispidae | - | 3 | - | 1 | - | - | 3 | 1 |
| | Scarabaeidae | **15** | 7 | 1 | - | - | - | 3 | 7 |
| | Staphylinidae | **11** | 0 | 4 | - | - | - | 1 | - |
| Hymenoptera | Formicidae1 | 25 | **29** | 18 | **29** | 25 | 26 | 16 | 24 |
| | Formicidae2 | 2 | - | - | 1 | 3 | 6 | 2 | 6 |
| Hemiptera | Reduviidae1 | - | - | - | 1 | - | - | - | 2 |
| | Reduviidae2 | - | - | - | - | 2 | - | 3 | 1 |
| Orthoptera | Gryllidae | - | - | - | **6** | 3 | 5 | 4 | - |
| | Gryllinae | - | 3 | - | - | - | - | - | - |
| Isoptera | Rhinotermitidae | 3 | - | 4 | - | 4 | - | - | - |
| Diptera | Stratiomyidae | 5 | **16** | 3 | 7 | 10 | 1 | 2 | 2 |
| Collembola | Isotomidae | 1 | **15** | 8 | 4 | 4 | 4 | 3 | 4 |
| Acari | Tetranychidae | - | 1 | - | - | - | - | 3 | 2 |
| Aranneida | Thromisidae | **14** | - | 1 | 3 | 12 | 7 | 4 | 4 |
| Scolopen-dromorpha | Scolopendra | - | - | **5** | 1 | 4 | - | 4 | 3 |

Table 6. Total number of individuals collected by pitfalls method (P<0.05)

| Ordo | Family | PK4 | PK6 | PK7 | PK8 | PM | PS | MT | MK |
|---|---|---|---|---|---|---|---|---|---|
| Coleoptera | Scarabaeidae | 3 | 60 | 4 | 9 | - | - | **78** | 53 |
| Hymenoptera | Formicidae | **74** | - | 54 | 38 | 33 | 26 | - | 3 |
| Orthoptera | Acrididae | - | - | 4 | - | 2 | **9** | - | - |
| | Gryllidae | - | - | - | - | 5 | **15** | - | - |
| Lepidoptera | Geometridae | - | - | 4 | 3 | - | - | - | 1 |
| Araneae | Oxyopidae | 24 | 3 | **29** | 16 | 5 | 13 | - | 2 |

Table 7. Environmental data across different vegetation type (P<0.05)

| Environmental factors | PK4 | PK6 | PK7 | PK8 | PM | PS | MT | MK |
|---|---|---|---|---|---|---|---|---|
| Litter (*in-situ*) (g/m$^2$) | 59.3 | 65.54 | 184.68 | 161.29 | 87.96 | 32.67 | 80.59 | 93.55 |
| Litter input (g/m$^2$) | 122.1 | 157.2 | 355.7 | 352.2 | 71.5 | 49.7 | 208 | 317.5 |
| C-organic (%) | 2.22 | 2.39 | 3.81 | 3.65 | 3.19 | 1.99 | 3.64 | 2.44 |
| Labile C-fraction (%) | 2.40 | 2.39 | 2.86 | 3.35 | 1.73 | 1.32 | 3.15 | 2.67 |
| Stabile C-fraction (%) | 2.16 | 2.34 | 2.94 | 3.01 | 1.58 | 1.40 | 2.35 | 2.35 |

The lack of existing family Scarabaeidae, Staphylinidae and Gryllinae using hand sorting method (Table 4), can be used as soil invertebrate's indicator which shows the impact of agroforestry system compare to monoculture system (PM and PS). Moreover, the high density of Lumbricidae, Formicidae and Thromisidae were more frequently detected on agroforestry system. On cacao agroforestry system Hymenopter and Dopter can be classified as parasitoid or predator groups (Toana et al., 2014), whereas they can control pant pest (herbivore) and could protect plant from damage, as these systems provide shelter, food and suitable microclimate for living (Rodriquez-Saona et al., 2012; Toana et al., 2014). Wardle et al. (2006) concluded that some macrofauna prefers under the condition of high and rich organic matter and some of them prefer under the low quality of litter (slow decomposed). Kinasih et al. (2016) concluded that in long term period coffee pines agroforestry system in West Java, created specific niches for certain taxa (i.e. Anisolabididae, Apidae while Berytodae, Calliphoridae, Dolichopodidae, Dytiscidae, and Histeridae) for coffee plantation. In this study using pitfalls method, it was clear that the family of Gryllidae and Acrididae were dominant on the monoculture system (PS), while Scarabaeidea was absent. These taxa certainly choose agroforestry system, either under Pines or under Mahogany for a living (Table 5). Specific Pines litter which may contain high lignin and polyphenolic made it a favourable condition for only specific soil invertebrates with their ability to survive under the thickness and accumulation of high abundance of Pines litter and its slow decomposition rates (Kinasih et al., 2016). From this study, only the family of Lumbricidea and Formicidea could adapt well to these conditions. Even though plat litter has been recognized as determinant material for soil macrofauna communities and structure depends on their quality, in fact, that in the field plant species occur in mixture condition so that the litter also mixed creating specific litter layer (Wardle et al., 2006). Agroforestry provides different sources of food, shelter with the unique incident of light, temperature, soil moisture, low soil disturbance and may result in a higher abundance of soil biota (Rahmat et al., 2012; Barros et al., 2002). Environmental data across vegetation types are significantly different (P<0.05), which conation the total of litter in situ, litter inputs, soil organic C and labile and stable POM-C fractions (Table 7). The highest accumulation of litter inputs was at PK7 followed by PK8 plot, a similar trend was observed for the production of litter inputs which affected the rapid accumulation of labile POM-C and stabile POM C-fraction. The result showed that there was a positive trend between litter input and the status of soil organic-C (Figure 2). There was a close relationship were detected between the number of individuals and litter thickness (Figure 3), analysed using multivariate Biplot approaches which could accommodate 99,68% of the assessments.

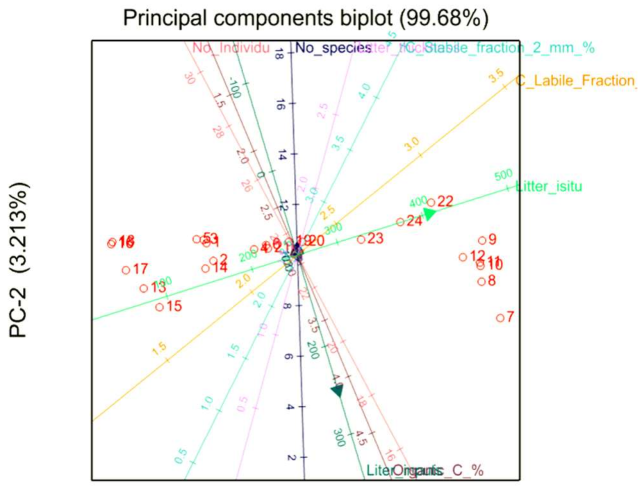


Figure 2. Biplot analyses between groups of variables to determine their relationship

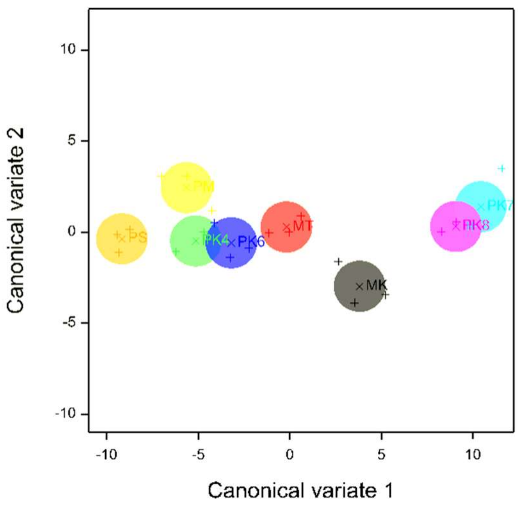


Figure 3. Canonical variate analyses (CVA) between groups of variables across different vegetation types at the UB Forest

Principally, this analysis determined the magnitude and the distance between parameters. In additions, using path analysis confirmed that only polyphenolic content on the litter had a negative impact on the density of total fauna, not for the total N and P content. There is no relationship between soil parameter to soil fauna except the soil pH and soil organic C, total N and clay content of the soil had an adverse indirect effect to the richness of soil invertebrates (Moco et al., 2010). However, in other studies, soil invertebrate communities were decreased when the soil had increased with soil N and low pH status, globally (Wu et al., 2011).

Canonical variate analyses were employed to distinguish the relationships between groups of variables (number of individuals, number of species, in situ litter, litter inputs, soil organic-C, labile and stable POM-C fractions) in two-dimensional data set. The data set was split into two groups X (CV1) and Y (CV2), based on the multiple parameters above. The purpose of the canonical analysis is then to find the relationship between X (CV1) and Y (CV2). Figure 3 shows that most of the plots separately along X (CV1), whereas PS plots was a bit in the distance compared to the other plots. PK7 and PK8 could be clustered together as they were overlapping with each other and mostly had a similar characteristic. PK4 was located in the centre close to PK6 and MT plots, while PM is a situated at the top position. Principle component analysis was used to determine soil macrofauna distribution at agroforestry system in Columbian Amazon, which confirms that agroforestry system determine the present or absent some taxa of soil macrofauna (Salazar et al., 2015)

## Conclusion

Agroforestry system is bringing various benefits to improve soil invertebrate population and their diversity through the development of specific niches soil macrofauna living under the thickness of litter, the high abundance of litter inputs, and low decomposition rates. Biplot and CVA approaches can be used as tools to determine the impact of different management of agroforestry system on the abundance and diversity of soil invertebrates

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