E-ISSN 2549-8703 I P-ISSN 2302-7282

BIOTROPIKA *Journal of Tropical Biology*

https://biotropika.ub.ac.id/

Vol. 9 | No. 1 | 2021 | DOI: 10.21776/ub.biotropika.2021.009.01.02

COMPOSITION AND ECOLOGICAL ROLE OF SOIL MACROFAUNA IN SELOREJO AND PUNTEN CITRUS FARMING, MALANG - EAST JAVA

KOMPOSISI DAN PERAN EKOLOGIS MAKROFAUNA TANAH DI PERKEBUNAN JERUK SELOREJO DAN PUNTEN, MALANG – JAWA TIMUR

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Received : October 10th, 2020

Accepted : March 3rd, 2021

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ABSTRACT

Conventional citrus crop farming is a citrus farming system that uses citrus cultivation techniques with maximum use of chemicals material to support a sustainable agricultural system. Indicators of environmental quality can be known from the composition and ecological role of fauna, one of which is soil macrofauna. This research aims to investigate the diversity and community structure of the soil macrofauna and to identify its role in citrus farming at Selorejo, Dau and Punten Villages, Bumiaji, Malang Regency. This study is a descriptive exploratory study in order to study soil macrofauna capturing at each location for three times. The observation method of soil macrofauna used pitfall traps and hand shorting methods. All data were tabulated used Microsoft Excel. Abiotic factor measurements for two locations have a no different value in each sampling plot. The composition of soil macrofauna is obtained from the important value index (IVI) and the Shannon-Wiener diversity index (H'). Soil macrofauna was obtained from two locations as many as 21 families with the highest importance value index (IVI), namely Formicidae. The results showed that Selorejo citrus farming consists of predator 46%, herbivorous 25%, decomposer 11%, scavenger 7%, and others 11%, while in Punten citrus farming consists of 55% predator, 10% herbivorous,15% decomposer,5% scavenger, and others 15%.

Keywords*: composition, citrus farming, ecological role, soil macrofauna*

ABSTRAK

Budidaya tanaman jeruk secara konvensional adalah sistem budidaya jeruk dengan menggunakan bahan kimia secara maksimal serta mendukung sistem pertanian yang berkelanjutan. Indikator kualitas lingkungan dapat diketahui dari komposisi dan peran ekologi suatu fauna, salah satunya makrofauna tanah. Penelitian ini bertujuan untuk mengetahui keanekaragaman dan struktur komunitas makrofauna tanah serta untuk mengetahui perannya dalam usahatani jeruk di Desa Selorejo, Dau dan Punten, Bumiaji, Malang – Jawa Timur. Penelitian ini merupakan penelitian deskriptif eksploratif dalam rangka mempelajari makrofauna tanah. Pengambilan sampel penelitian dilakukan sebanyak lima plot dan diulang tiga kali untuk masing – masing plot. Metode pengamatan makrofauna tanah menggunakan metode pitfall traps dan metode handshortir. Semua data penelitian ditabulasi menggunakan Microsoft Excel. Pengukuran faktor abiotik untuk dua lokasi tidak memiliki nilai yang berbeda di setiap plot pengambilan sampel. Komposisi makrofauna tanah diperoleh dari indeks nilai penting (INP) dan indeks keanekaragaman Shannon-Wiener (H'). Makrofauna tanah diperoleh dari dua lokasi sebanyak 21 familia dengan indeks nilai penting (INP) tertinggi yaitu kelompok Formicidae. Hasil penelitian menunjukkan bahwa usahatani Jeruk di Selorejo terdiri dari 46% predator, 25% herbivora, 11% dekomposer, 7% scavenger, dan 11% lain-lain, sedangkan pada budidaya Jeruk di Punten terdiri dari 55% predator, 10% herbivora, 15% pengurai, 5% scavenger, dan 15% lainnya.

Kata kunci: *komposisi, makrofauna tanah, peran ekologis, pertanian jeruk*

How to cite:
Karinasari, Fitria, ZP Gama, AS Leksono. 2021. Composition and ecological role of soil macrofauna in Selorejo and Punten citrus farming, Malang-East Java. *Journal of Tropical Biology* 9 (1): 10-18.

INTRODUCTION

The diversity of fauna in a habitat is very high; for example, the fauna on the crops is the soil macrofauna. A fauna group is a group that is active and has a role in the terrestrial ecosystem environment [1]. Soil macrofauna is a fauna group that belongs to the insect class whose habitat is in the soil, both in the soil and on the surface of the soil. Morphological characteristics of soil macrofauna generally have a body length of > 1 mm and a body width of > 2 mm [2]. Soil macrofauna can be referred to as soil insects and grouped according to the food type, ecological role, and habitat [2]. Soil fauna, especially mesofauna and macrofauna, have an important role in the processes that occur in soil ecosystems [3,4]. Ecological functions associated with macrofauna and mesofauna include the decomposition and storage of water to the nutrient cycle in the soil. This shows that the survival of soil fauna is highly dependent on environmental conditions or habitats that are occupied. For example, the environment of soil macrofauna habitats that tend to be moist and have a soil pH level low enough to be neutral, then the macrofauna can be found in higher numbers [5,6]. In the environment or ecosystem, soil macrofauna has a variety of roles. First, soil fauna plays a role in the cycle of food webs in nature: eaters of plant parts (leaves, stems, flowers) called Herbivores. Second, soil macrofauna plays a role in eating the remains of animals and plants that die. They can decompose in nature and are called detritivores. Third, soil macrofauna that act as antagonist of other animals in nature are called predators. Fourth, soil macrofauna acts as a natural enemy by living with other insects (hosts) called parasitoids. Fifth, as a fauna that helps the natural pollination process known as insect pollinators [7]. The problem that often occurs from farmers is the assumption that most of the groups of insects on the citrus crop are groups of pests that can disturb plants. As a biological control effort to eradicate the fauna on the land, farmers sprayed pesticides as a whole and may not be on target. This happens because there is still no clear information regarding the functional status of the fauna. Therefore, it is necessary to increase understanding through an inventory of functional status or ecological roles regarding macrofauna groups on plantation or agricultural land. Thus, farmers are expected to take appropriate pest management measures as a conservation and environmental preservation step. The purpose of this research is to describe the composition and role of soil macrofauna in semi-organic citrus farming at Selorejo and Punten Villages, Malang – East Java. It causes to describe which one of soil macrofauna can survive in that condition relates to their ecological role.

METHODS

The study was conducted from January until April 2020. This research was carried out in the two locations with different elevation and environmental conditions, each semi-organic citrus crops farming in Selorejo and Punten, Malang, East Java (see Figure 1). The research location and sampling were chosen in semi-organic citrus farming. Semi-organic fields on citrus farming are plantations with crop cultivation techniques using chemical/non-organic pesticides with a mechanism of spraying land 3-4 times in one month. This research is a descriptive exploratory study and was conducted by a purposive sampling method at selected locations. In this study, soil macrofauna sampling used two main methods, namely, pitfall traps and hand collection [8]. The abiotic factor was observed in two locations, such as soil humidity, soil pH, light intensity, and also soil temperature. The soil macrofauna was collected and identified by the Arthropod identification book included Borror et al. (1992); Ekologi Hewan Tanah, Suin (2012); Classification of Insects, Brues et al (1954); Keys to The Terrestrial Invertebrates, Mohamed (1999) and also online arthropods databases (bugguide.net; Antbase.net). Identification of soil macrofauna up to the family level was conducted at the Ecology and Animal Diversity Laboratory of the Department of Biology, FMIPA, University of Brawijaya-Malang.

Pitfall traps methods. The first method was used in this research was pitfall traps. The trap was taken in two conventional citrus farming in Punten, Bumiaji, and Selorejo Village, Dau, Malang Regency. The trap method was carried out using a trap bottle placed in the ground for 1x24 hours [9]. Traps were made by bottles with a diameter of 70 mm and a height of 150 mm. The trap bottles were filled 1:1 with a detergent solution, and it was added with 70% alcohol, then labeled and put a plastic protector on the roof.

The traps were taken at each station consists of five plots and repeated three times. The distance between plots was 5 meters. The traps were installed in one plot with a size of 50 cm x 50 cm and placed in two places, every two bottles of trap under the stands of citrus plants and one bottle of the trap between citrus crops [7]. The plot design of soil macrofauna sampling can be seen in Figure 2.

Hand collection methods. The second method was hand-sorting. This method was used by taking soil with a size of 25x25 cm and a depth of 30 cm. After that, the soil was put into a plastic tray (25 cm in diameter and 10-15 cm high), and the soil macrofauna was sampled by hand for direct identification [10].

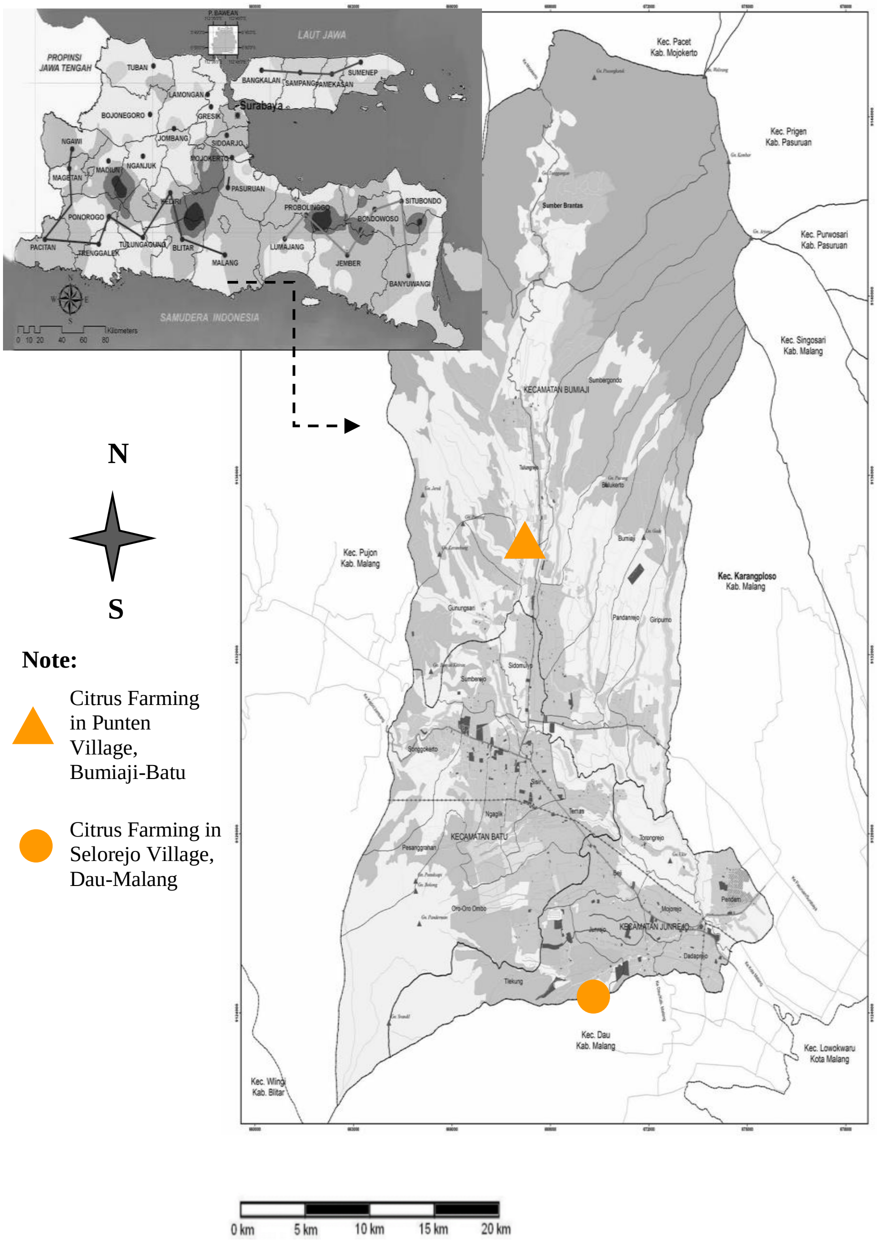

Figure 1. Maps of the research area in Selorejo and Punten, Malang – East Java

Sampling with this method was carried out in five research plots once a week and repeated three times in each plot. Hand collection was conducted at two sampling locations, each Selorejo and Punten Village, Malang city.

Data of soil macrofauna was combined by two methods; pitfall traps and hand-sorting. The combination method was due to collect soil macrofauna in and on the soil surface. Analysis data of the research is using Microsoft Office software and calculating abundance, taxa richness, important value index (IVI), and diversity index – H' (Shannon-Wiener) [11]. The correlation between the biotic index and the abiotic factor was analyzed using Biplot/Principal Component Analysis (PCA) in PAST software version 3.15.

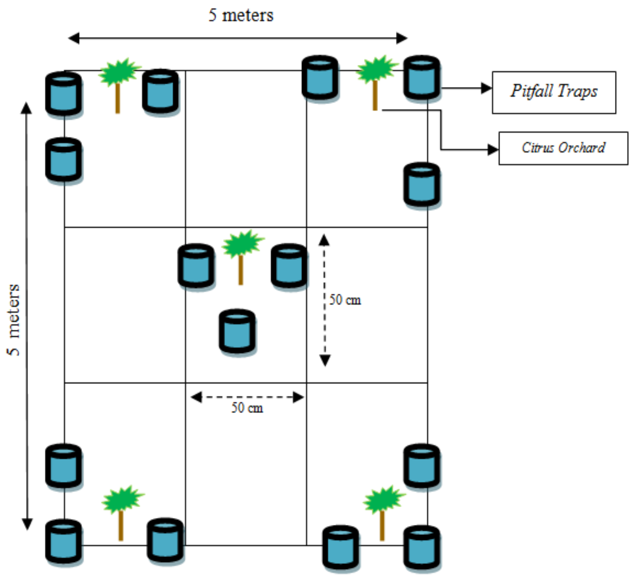

Figure 2. Design of placement scheme for pitfall traps in each research plot

RESULTS AND DISCUSSION

Composition of soil macrofauna. Based on the results of the study, it was found that the population of soil macrofauna in semi-organic citrus farming of Selorejo Village was more numerous and varied compared to semi-organic citrus fields of Punten Village. Biotic factors and land conditions influence the development and composition of soil macrofauna. After identifying the macrofauna, it turns out there were different species at the two research locations (Figure 3). Many families were found in both fields using the pitfall traps and hand sorting methods amounts to 21 families of Arthropods. The most populous families in both fields are the Formicidae. Formicidae families are the most common group of insects found on agricultural and croplands. Ecosystem habitat in this research presented the former condition of that land as increasing quality, which was dominated by a predator as the Formicidae, and also the ones who can survive in degraded land [25]. However, citrus farming is covered by dominant species of grass or above-ground vegetation as a food resource and as a protectant against predators. Formicidae was the type of insect, it has a body characteristic that consists of three parts and has a pair of antennas. Formicidae has no wings. That is because the insect wings have undergone a process of reduction [12]. Formicidae in an ecosystem has a significant role as a predatory insect against other insects [2].

A diversity index was used to express community structures, to measure the stability of the community, which is the ability of the community to keep itself stable even though there is interference with each of its components [16].

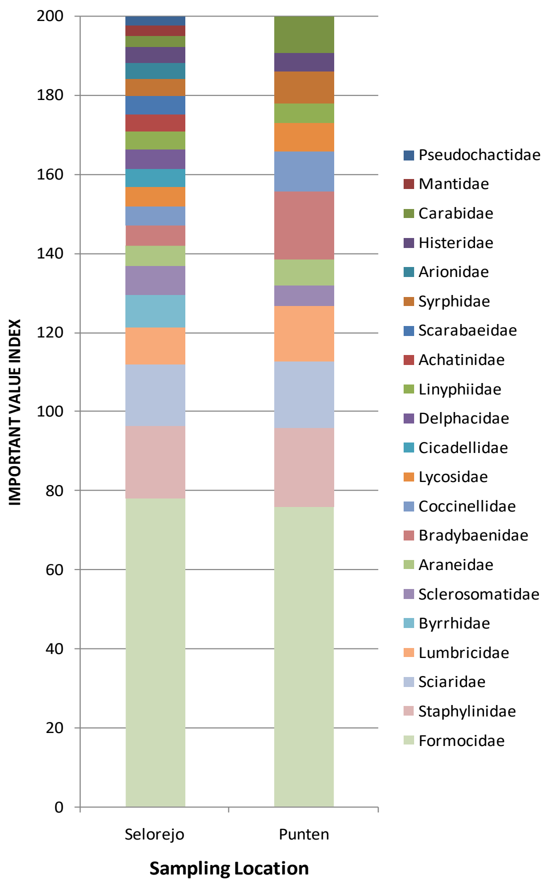

Figure 3. Composition of soil macrofauna in Selorejo and Punten area

The diversity of soil macrofauna was obtained based on diversity index analysis (Shannon-Wiener). Soil macrofauna diversity in Punten conventional citrus farming (H' = 2.12) was lower than Selorejo conventional citrus farming (H' = 2,25). However, the value of the diversity index of soil macrofauna in two locations showed the diversity included in the medium category [9]. That was because the number of certain species and the number of species in certain communities are very different [13]. Also, the availability of food and various abiotic factors in both locations could affect the presence of soil macrofauna.

The composition of vegetation in the soil as a habitat to live soil macrofauna in the two study sites had very significant differences. This was because the citrus crops of Punten Village consist of the main crop, which was the citrus tree. While in Selorejo citrus crops farming had not the main tree, there were also low plants. It was like weeds (grass) and chili crops. That was deliberately planted among the citrus trees. Other studies reported that the addition of other plants besides the main plant (monoculture) could affect the abundance of soil macrofauna. For example, monoculture farming coupled with legumes and herbaceous shrubs had a positive effect. Conversely, a reduction in total abundance and diversity of soil macrofauna would occur in monoculture farming which only consists of trees and low vegetation density [14].

Structure of soil macrofauna based on ecological roles. The composition and structure of soil macrofauna in both observation sites had different ecological roles. The results of the identification of soil macrofauna families based on the ecological role of each observation land were divided into four groups, namely as decomposers, scavengers, herbivores, predators, and others (Figure 4 and Table 1).

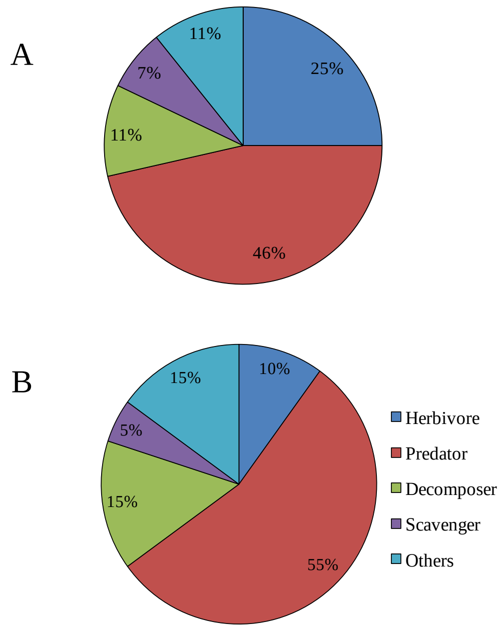

Figure 4. Composition of the ecological role of soil macrofauna; (A) Selorejo conventional citrus farming; (B) Punten conventional citrus farming

The results of the data analysis showed that soil macrofauna, which had the largest percentage based on functional status, were fauna groups with functional status as predators. The predatory insects found at the two observation sites were Araneidae, Byrrhidae, Carabidae, Coccinellidae, Formicidae, Linyphiidae, Lycosidae, Pseudochactidae, Sclerosomatidae, Staphylinidae, Sciaridae, and Syrphidae.

Table 1. Recapitulation of class and order in the Selorejo and Punten citrus farming

No	Class	Order	Family	Functional Status
1	Arachnida	Araneae	Araneidae	Predator
			Sclerosomatidae	
			Linyphiidae	
			Lycosidae	
		Scorpiones	Pseudochactidae	
2	Clitellata	Haplotaxida	Lumbricidae	Decomposer
3	Gastropoda	Bradybaena	Bradybaenidae	Herbivore
		Pulmonata	Achatinidae	
		Stylommatophora	Arionidae	
4	Insecta	Coleoptera	Byrrhidae	Herbivore
			Carabidae	
			Coccinellidae	Predator
			Histeridae	Detritivores/
			Scarabaeidae	Scavenger
			Staphylinidae	Predator
		Diptera	Sciaridae	Herbivore
			Syrphidae	
		Hemiptera	Delphacidae	Herbivore
		Homoptera	Cicadellidae	Herbivore
		Hymenoptera	Formicidae	Predator
		Mantodea	Mantidae	Predator

The composition of soil macrofauna, which has the smallest functional status percentage, was the scavenger insect group.

The organisms belonging to soil macrofauna include the Lumbricidae family (earthworms), Termittidae (termites), and Formicidae (ants) had an important and influential role in regulating the physical, chemical, and microbiological properties of the soil [15]. The diversity and abundance of these organisms were considered a bioindicator relevant to the quality of soil fertility. While the abundance of herbivorous soil macrofauna occurs due to the abundance of predatory soil macrofauna, which was higher than herbivorous.

Citrus farming is formed from an interaction between fauna and their abiotic environment. There were animals, plants, and other microorganisms. This interaction is an ecological function of an ecosystem. The terrestrial ecosystem is a land that is a habitat and consists of complex life. Based on previous research, in the soil, there were various types of the organism with various functions to gather carry out various metabolic or soil biological activities [17].

An example of a process that occurs in an ecosystem was the food cycle or trophic structure. A series of energy transfer processes occurred when nutrients and energy move from producers to trophic level 2, namely consumers, various predators to decomposers, or scavengers. However, arthropod food webs were very complex, and complex species were rarely arranged in linear food chains consisting of plants, herbivores, and predators [18,19]. This was due to the occurrence of omnivores and indirect interactions in the food web, making it very difficult to distinguish and assign species to different trophic levels. As a result, herbivore density and plant biomass could influence species that occupy more than one trophic [19].

The composition contained in food webs was inseparable from the source of the food eaten as well as the energy to be transferred. The conventional citrus crop ecosystem could not be separated from farming maintenance that uses chemicals as fertilizers or pesticides to kill pests. This condition could affect not only the number of fauna but also the balance in the cycle. Pesticides that accumulate from year to year could be carried into the tissues of organisms through the process of moving food, known as the food chain. For example, fauna species of shellfish occupied aquatic habitats with high DDT contamination, it could affect the health of the people living around the coast if they consumed it. DDT accumulates from organisms to other organisms through the food chain will tend to increase in concentration towards organisms that occupy the food pyramid or higher trophic levels [20].

In addition, we knew that soil arthropods had an important role in the agricultural environment, especially in the transformation of organic matter and nutrient cycling, so some experts grouping soil organisms as a central factor in maintaining soil productivity and soil health indicators [17]. There were some soil health characteristics such as ease to cultivate, deep enough, not excessive nutrients, no pests and plant diseases, good drainage, large beneficial soil organisms, no weeds, chemicals-toxins free, and resistance to degradation [21].

In this study, abiotic factors measured were light intensity (Lux), soil temperature (ºC), soil humidity, and soil pH. Abiotic factors in the two locations showed significant differences. Measurement of abiotic factors in Selorejo and Punten conventional citrus farming could be seen in the following table, Table 2.

Table 2. Abiotic measurement in Selorejo and Punten farming area

Abiotic factors	Selorejo	Punten
Light intensity (lux)	751,70 ±829,71	749,52 ± 535,19
Soil temperature (ºC)	22,66 ± 0,61*	21,24 ± 0,29
Soil humidity (%)	19,61± 1,54	17,31± 4,17
Soil pH	5,84 ±0,18	5,58 ±0,20
Litter thickness (cm)	3,00 ± 2,60	2,00 ± 1,40

*(*Significantly with t equal variances assumed, p-value < 0,05).*

The abiotic factors in the Selorejo citrus farming had a higher value than the Punten citrus farming when viewed from its average value. Significant differences in abiotic factors between the two research sites were found at soil temperature. This difference could be seen from the two-way significance value (t-tailed) at the Selorejo citrus farming, which had a significance <0.05. Meanwhile, the measurement of abiotic factors of soil humidity, soil pH, and light intensity did not differ significantly (p>0.05).

Correlation of abiotic factors and soil macrofauna. The most important abiotic factor was soil temperature and humidity. Conseverly, based on PCA analysis, it was found that the intensity of light was only positively correlated to the diversity index. Soil humidity, soil pH, and litter thickness negatively correlated to the index of dominance and evenness (Figure 5).

Light intensity is an abiotic factor that can affect other abiotic conditions, namely air temperature. Increasing light intensity would increase the air temperature in the environment and then increased the soil humidity. Light intensity also affects the presence of soil organisms. Sunlight affected insect activity, ability to see, fly, forage, larvae development, reproduction, and insect metabolic processes. This condition caused the light intensity to have a positive correlation with insect diversity. Light intensity suitable for insects was moderate light intensity so that it was warm enough and not too low [22].

The high value of dominance and evenness index was influenced by environmental factors such as soil organic matter content, pH, and humidity. Soil with high moisture would provide benefits for soil insects to adapt when facing the dry season, while the litter thickness in the environment was a feed preparation material or a source of food for the soil insects found [23]. The more diverse the litter would make high the diversity of soil fauna, including arthropods [24]. However, stands with a variety of litter could affect the composition of food needed by soil insects so that the number of undergrowth and litter could be a food source for soil insects.

However, it was positively correlated to abundance, taxa richness, and diversity index. The positive correlation showed that the abiotic factor had an effect that was directly proportional to the biotic index of soil macrofauna found at the research site.

CONCLUSION

Conventional citrus farming in Selorejo and Punten had a composition of soil macrofauna consisting of 21 families. The abundance of macrofauna found in Selorejo was higher than in the Punten area, where the numbers were 2657 individuals and 1412 individuals, respectively. Based on the analysis of abundance, taxa richness, the dominance index of soil macrofauna community, it showed a positive correlation with abiotic factors such as soil moisture, pH, and litter thickness. The soil macrofauna that dominated both lands was Formicidae. The soil macrofauna was grouped into four based on their ecological role, namely herbivores, predators, decomposers, and scavengers.

ACKNOWLEDGMENT

We give our thanks to Allah SWT so that we can finish this journal well. Not forget our blessings and greetings to the Prophet Muhammad SAW. The author would like to thank the parties involved in the preparation of this journal. All friends at the laboratory of Ecology and Animal Diversity, Department of Biology, Faculty of Mathematics and Natural Sciences, University of Brawijaya, Malang.

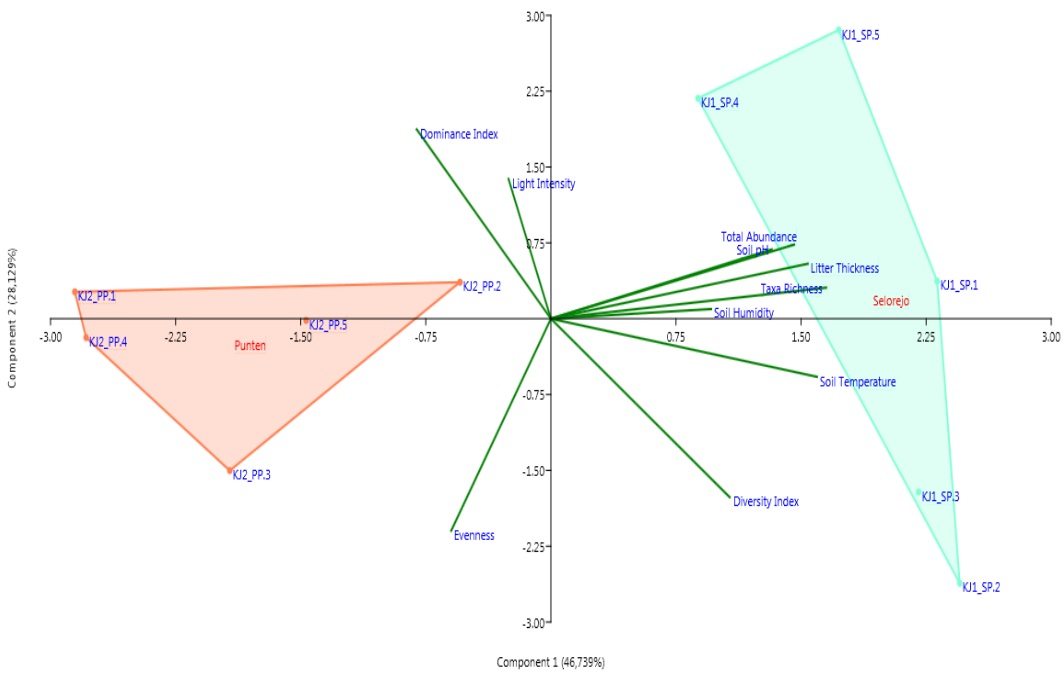

Figure 5. Positive correlation between light intensity and soil macrofauna diversity index based on PCA analysis

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