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Soil Macrofauna Diversity in Organic and Conventional Vegetable Fields in Ternate City

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ABSTRACT

This research is a descriptive exploratory study aiming for analyzing the abundance and diversity index of soil macrofauna in organic and conventional vegetable fields. The research method used is an entrapment (Pitfall traps) method where traps are installed in a land with 10 m x 25 m of size and results in 10 plots. Each plot has 5 points determined diagonally to place the pitfall traps; therefore, the total sample points are 50 samples per observation location. Identification of macrofauna trapped in the pitfall trap uses a microscope. Based on the results of diversity analysis, soil macrofauna in organic fields has H'2.6546 with an abundance of 2242 individuals, whereas the conventional fields have H'1.6775 with an abundance of 1507 individuals. In terms of dominance index, the conventional fields have a higher evenness of 0225 with a low value of 0229, while the organic fields have a low dominance index of 0077 yet a higher evenness value of 0344. It can be concluded that the diversity of soil macrofauna in the organic vegetable fields in Ternate city has a higher diversity value because the fields have abundant and more even availability of soil macrofauna so that there are no dominant species found. On the other hand, the conventional vegetable fields have low abundance so that the diversity of soil macrofauna in the fields is low due to one dominant species. The results of the analysis in the two fields indicate that the similarity index is 0.803, which means that the similarity value of the macrofauna species in the two fields is close to the index value. An index value is 0 if there are no similar species in both fields and the value is 1 when both fields have the same species composition. However, the diversity of soil macrofauna in the two different fields has an abundance of soil macrofauna so that it can increase soil fertility and maintain the stability of soil macrofauna and its function in a sustainable agricultural system.

Keywords: species diversity, soil macrofauna, organic, conventional

ABSTRAK

Penelitian ini bertujuan untuk menganalisa kelimpahan dan Indeks keragaman makrofauna tanah pada lahan sayuran organik dan konvensional Metode yang di gunakan adalah survey dengan pengambilan sampel secara diagonal menggunakan Pitfall trap yang di pasang di lahan yang berukuran 10 m x 25 m yang di bagi dalam 10 plot. Pada setiap plot di tentukan 5 titik secara diagonal untuk menempatkan Pitfall trap, jadi total titik sampel ada 50 sampel per lokasi pengamatan. Makrofauna yang terperangkap dengan pitfall trap dan diidentifikasi menggunakan mikroskop. Hasil penelitian diperoleh jumlah kelimpahan mikrofauna tanah di lahan Organik yakni 2242 ekor dengan H'2.6546 dan di lahan konvensional 1507 ekor dengan H'1.6775. Indeks dominansi pada lahan konvensional lebih tinggi pada lahan konvensional 0.225 namun dengan nilai kemerataan jenis rendah 0.229, sebaliknya pada lahan organik memiliki indeks dominansi rendah 0.077 memiliki nilai kemerataan jenis lebih tinggi 0.344. Untuk nilai kesamaan pada kedua lahan pengamatan yakni 0.80, di mana nilai kesamaan kedua lokasi tersebut memiliki kemiripan yang tinggi. Diharapkan informasi yang didapatkan bisa digunakan sebagai data pendukung dalam pengelolaan lahan pada tanah-tanah pertanian.

Keywords: keragaman spesies, makrofauna tanah, organik, konvensional

INTRODUCTION

Soil biodiversity understanding is still very limited regarding taxonomy and ecological functions. Determination of soil quality bio-indicators is needed to determine changes in soil systems due to different management. Soil quality is the soil ability that describes a certain ecosystem for agricultural system sustainability. Soil fertility is also influenced by nutrient availability and low nutrient availability reflects low soil fertility so that the presence of soil macrofauna as a remover of organic matter greatly determines the availability of nutrients in fertilizing the soil (Boror, et al, 1997). One of the soil fauna that can be used as bioindicators is soil macrofauna. Each soil biota has a special function and has a special ecological function (Peritaka, 2010).

Soil biodiversity is a form of alpha diversity that plays a major role in maintaining and enhancing the soil functions to support life in and on the soil. Each soil fauna group can be used as a bio-indicator because the presence of soil fauna highly depends on soil biotic and abiotic factors (Wulandari et al, 2007). The presence of fauna can be used as a parameter of soil quality. The soil fauna used as a bio-indicator of soil fertility has a relatively abundant amount (Hanafiah, 2013). Given the important role of soil fauna in maintaining the balance of soil ecosystems and the relatively limited information regarding the existence of soil fauna, it is necessary to explore the potential of soil fauna as a bio-indicator of soil quality.

According to Supriyadi (2007), the content of organic matter in the soil reflects the quality of the soil and it is said to be very low if < 2%, and low if > 2%, the organic matter content in the range of 2-10% has a very important role. Diversity defines as the nature of a community that shows the diversity level of organism types that exist in the community. Having an ability to recognize and differentiate species is sufficient to obtain this species diversity, although we cannot identify the types of pests (Siregar et al., 2014).

The role of macrofauna in maintaining the balance of the ecosystem, namely as a soil remodel and fertilizer, and the relatively limited information regarding its existence, soil insects need to be explored. Soil insects have high diversity, including in agricultural areas (Usman, 2017). Macrofauna is a large group of land-dwelling animals that is part of soil biodiversity and plays an important role in improving soil physical, chemical, and biological properties. Based on this role, macrofauna along with mesofauna is often referred to as "ecosystem engineers" (Nurrohman, Rahardjanto, & Wahyuni, 2018). Similarly, Wibowo & Slamet (2017) stated that soil macrofauna has a very important role in a habitat. One of the roles of soil macrofauna is to maintain soil fertility by changing organic matter and nutrient distribution. The life of the land macrofauna is influenced by environmental factors both micro and macro factors on the soil surface. The micro factors that influence soil insect life are litter thickness, organic matter content, pH, fertility, soil type, soil density, and soil moisture, while the macro factors consist of climate, altitude, plant species, and land use (Ma'arif et al., 2013). Therefore, research on the diversity of soil macrofauna is very important to maintain soil stability and increase its function for a sustainable agricultural system.

METHODS

This study was a descriptive exploratory study in which patterns or conditions or status of the phenomenon of the research object were described in detail and do not look for generally applied conclusions. The conclusion drawn was an illustration of what happens to the research object with the traps (pitfall traps) method. The pitfall trap method is a method used to determine the abundance of soil macrofauna. Pitfall traps are the best method for trapping inactive attacks above ground level. Pitfall traps as a tool to trap macrofauna insects that move above the ground and insects that are active day and night. Pitfall traps were made of plastic of 18cm diameter containing 70% alcohol that was attached to the ground parallel to the ground. Sampling used a diagonally sampling 4 times in a land sized 10mx25m. The land was divided into 10 plots and each observation plot was determined by 5 points to put Pitfall Trap; therefore, the total sample point observations at each location was 50 points. Identification of macrofauna species utilized books of Introduction to Insects (Boror, et al., 1997) and Soil Animal Ecology (Suin et al., 2012). Data analysis of several observation parameters on soil-macrofauna diversity samples in organic and conventional vegetable fields was according to the following parameters:

Abundance of Soil Macrofauna

Abundance is a description of the large number of individuals who occupy a particular location. Therefore, the abundance value of soil macrofauna used in this study referred to the number of individuals of a species found in a particular location.

Diversity of Macrofauna by using (*Shannon-Wiener Index*)

$$H' = -\sum Pi \ln pi \quad \text{and} \quad Pi = n/Ni \qquad (1)$$

where,

H ' : Shannon-Wiener diversity index
Pi : ni / Ni
Ni : Number of individuals I
N : The total number of individuals of all types

If the index value:

H ' = <1 ,: Low diversity
H ' = 1 - 3 : Moderate Diversity
H ' = >3 : High Diversity (Astriyani, 2014).

Evenness Value E (*Margalef Index)*

The density value used is the macrofauna species richness index using the following formula*:*

$$E = \Sigma(H'/ LN.S) \qquad (2)$$

where,

E : evenness index
H' : species diversity index
S : number of species found in one community

(Astriyani, 2014)

Similarity Value of Two Lands (Cs) (Sorensen Index)

The index used is the Shannon-Wiener diversity index, with the following formula:

$$Cs = \frac{2C}{A + B} \qquad (3)$$

where
Cs : Sorensen species similarity index (value between 0-1)
C : smallest species that are equal in both areas A and B
A : number of species on land A.
B : number of species on land B.

Value of Dominance (Simpson Index)

$$D = \Sigma (ni/N)^2 \quad \text{...} (4)$$

where,
D : Simpson's index of dominance
ni : number of individuals per species
N : number of individuals of all species

RESULTS AND DISCUSSION

Abundance of Soil Macrofauna in Vegetable Fields

Based on the results of sampling of soil macrofauna in the pitfall trap, it was found that the abundance of the two observation fields was different, as seen in Figure 1. The abundance of soil macrofauna was found in plants associated with various types of vegetables (chili, tomato, eggplant.) of 50 points on a land area of 10 m x 25 m. Macrofauna insects were taken using a pitfall trap in the form of a container with 18 cm of diameter and 10 cm of height filled with 70% alcohol and then put into the ground parallel to the soil surface and an umbrella was used to prevent water from entering.

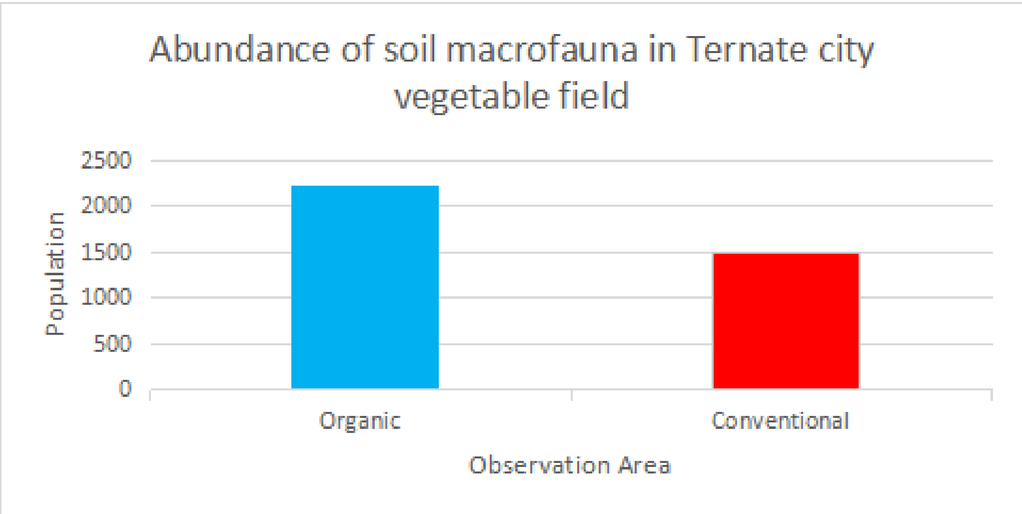

Figure 1. The Abundance of Soil Macrofauna in Vegetable Fields in Ternate City

Figure 1 indicates that the abundance of soil microfauna found in pitfall traps in both fields was different. The organic fields had a very high soil macrofauna abundance of 2231 individuals, whereas the conventional fields had a lower case of 1507 individuals. The difference was due to different land management applied in the two fields. The organic fields often used materials from nature such as organic fertilizers and vegetable pesticides, while the conventional fields often used high doses of chemicals such as synthetic insecticides that can destroy insects that decompose organic matter in the soil.

According to Sugiyarto et al. (2007), the number of individual soil macrofauna will increase with the increase in plant organic matter because it protects soil macrofauna from environmental stresses, such as high temperatures, and against predatory attacks. Due to the abundance of soil macrofauna in the organic fields, the soil in the study location indicated a soil criterion that was classified as fertile because of the high soil organic matter. According to Hanafiah (2013), soil fertility is also influenced by the availability of nutrients or soil organic elements; the low availability of nutrients reflects the low soil fertility; so that the presence of soil macrofauna as an organic matter remover determines the availability of nutrients in fertilizing the soil. The higher the organic matter content in the soil, the more fertile the soil will be and vice versa. Kurniawati (2015) stated that space heterogeneity affects arthropod species where the more heterogeneous a physical environment is, the more number and types of arthropods will be.

Ecological Role of Soil Macrofauna in Vegetable Fields

An ecosystem is balanced when ecological components are in balance. Components as macrofauna have an ecological role in organic and conventional vegetable fields as indicated in Table 1.

Table 1: The ecological role of soil macrofauna in vegetable fields in Ternate city

Ecological Role	Organic fields	Conventional fields
Detritivore	18.75	7.69
Herbivore	6.25	53.85
Predator	43.75	23,077
Decomposer	31.25	15.38

Table 1 indicates that the highest percentage of soil macrofauna was in the organic fields, namely predator insects of 43.8% that included order Coleoptera and Formicidae (ants) and followed by 31.3% decomposers and detrivore insects of 18.8%, whereas the lowest percentage was herbivorous insects of 6.5% (destructive insects). In conventional field, the highest was herbivorous insects (destructive insects) of 53.9% and followed by predatory insects of 23%, decomposers of 15%, and the lowest was detritivore insects of 7.7%. The abundance of predator insects could reduce insect pests in the organic fields, whereas in the conventional fields, decreased predatory insects caused increased herbivore insects (pests). On the contrary, organic-matter decomposer insects such as decomposers and detritivore were higher in the organic fields compared to the conventional fields; thus, this affected the soil condition or the source of nutrients in the two fields. The existence and activity of soil macrofauna can increase aeration, water infiltration, and soil aggregation and distribute soil organic matter so that an effort is needed to increase soil macrofauna diversity (Njira & Nabwami, 2013).

Evenness Index of Soil Macrofauna in Vegetable Fields in Ternate City

Based on the results of the Margalef index analysis, the organic fields had a high evenness value of 0.344 compared to the conventional fields, which was 0.229 lower as seen in the following histogram:

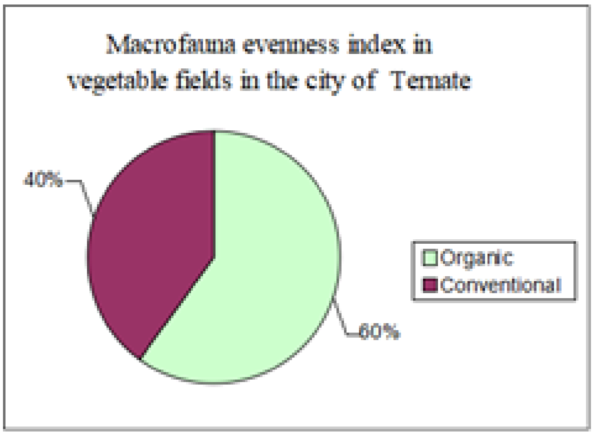

Figure 4. Evenness of Soil Macrofauna in Vegetable Areas

The results of the Margalef index analysis on the evenness of soil macrofauna in the vegetable fields show that the organic vegetable fields had 60% evenness value, while the conventional vegetable fields had 40%. Evenness value affected the dominance value on the two vegetable fields. This was also because several families in the organic fields were also found in the conventional fields. There were, however, several dominant species in the conventional vegetable fields; thus, the evenness value in the field was decreased. This was presumably because the organic fields did not use chemical pesticides. However, the research area was on the conventional fields where chemical pesticides were applied to control pests. According to Afifah et al. (2015), the minimum use of synthetic pesticides in non-conventional control will provide opportunities for other arthropods to compete in agricultural ecosystems.

Soil Macrofauna Diversity (*H ') Shannon-Wiener Index*

The calculation of the diversity index aims to determine the degree of diversity of a community of macrofauna species and to study the effect of environmental or abiotic factors on the community (Fachrul, 2012). Species diversity is indicated by the many types of organisms that form communities in a particular area. The results of the analysis of the diversity of macrofauna species in vegetables based on the Shannon-Wiener index were 2.6546 in the organic fields and 1.6775 in the conventional fields. The diversity of soil macrofauna species can be observed in Figure 2.

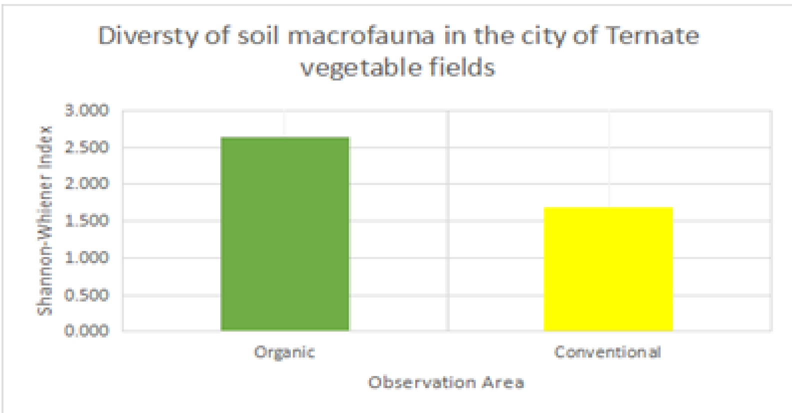

Figure 2. Diversity of soil macrofauna in vegetable fields using Shannon–Wiener index

It can be seen in Figure 2 that the diversity of macrofauna in the organic vegetable fields was higher than in the conventional vegetable fields. This was due to the two fields that had diverse macrofauna insect populations. The organic field was dominated by *Formicidae (Hymenoptera* and *Collembola families* that play a major role in breaking down organic materials into nutrients that can be used by plants for their development and growth to produce high-yielding plants. Formicids are an important part of an agricultural ecosystem and play a role in repairing damaged soil and nutrient cycling (Zahara, 2015).

The Hymenoptera are a very interesting group in terms of biology, as they exhibit a large diversity of habitual habits and an increasing complexity of behavior regarding the social organization of wasps, bees, and ants (Latoantja et al., 2013). Additionally, the conventional vegetable fields were dominated by the *Gryllidae*, *Grylotalphidae*, and *Tephritidae* families that are known to be insect pests that cause damage to crops due to the effect of resurgence which causes the number of pest populations to increase due to the killing of natural enemies such as predators from the family low *Formicidae*. The diversity of macrofauna in the soil can be used as a biological indicator of soil quality. Suin (2012) explains that soil organic matter determines the population density of soil organisms, one of which is soil fauna, where the higher the soil organic content, the more diverse the soil fauna in an ecosystem.

The Similarity of The Two Fields (Cs) – *Sorenson Index*

Based on the analysis of the similarity of Sorensen index in both fields, vegetables organic and conventional fields, in Ternate City, both fields had a slightly different management system so that the soil macrofauna found in both fields had a high degree of similarity. The results can be seen in Table 2.

Table 2. Macrofauna similarity index (CS) in both vegetable fields.

Method	Organic	Conventional	Sorensen Index
Pitfall Trap	2242	1507	0.803947719

The similarity index of the two fields (Cs) with the Sorensen index identified the number of similarities of individual types in the two fields. The similarity index has a value ranging from 0 to 1. Table 2 presents the results of the analysis in the two fields. The table suggests that the similarity index was 0.803, which means that the similarity value of the macrofauna species in the two fields was close to the index value. An index value of 0 occurred if no species are the same in both fields and a value of 1 will be obtained when the two fields had the same species composition (Suin, 2012). Rahmawati (2012) adds that excessive use of synthetic chemical fertilizers and synthetic insecticides can cause various problems. The problems include contamination of chemical fertilizers and pesticides, decreasing land quality, decreasing human health due to consuming agricultural products that contain chemical residues, and the extinction of certain types of soil macrofauna which results in the lack of diversity of macrofauna species in the land in the ecosystem. Latip (2015) states that the population of a family does not dominate the population of other families, so the evenness value tends to be high, on the contrary, if a family has a population that dominates the number of other populations, the evenness tends to low.

Species Dominance (D) using *Simpson Index*

Based on the results of the Simpson index analysis on the dominance of macrofauna in the vegetable fields, it was found that the organic fields were low compared to conventional fields that had a high dominant value. This can be seen in Figure 3 below:

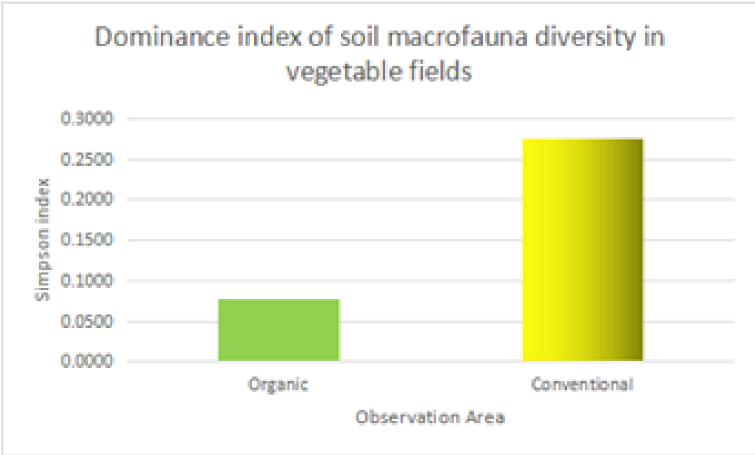

Figure 3. The dominance index of soil macrofauna in vegetable fields using Simpson index

It can be seen that the organic fields with a diversity value of H '2.646 (Figure 1) had a dominance value of 0.00772 (low) in Figure 3, while the conventional fields with a diversity value (H ' = 1.677) in Figure 1 had a dominance value of 0.2759 (high) in Figure 3. In a community with high diversity, a species will not be dominant and vice versa in a community with low diversity, one or two species will become dominant. Pradhanaet al. (2014) state that the low species richness index indicates the dominance of several insect species. The results suggested that the conventional fields had the highest population of the Orthoptera Order compared to other orders, while the organic fields had a balanced population of each order with no dominant insects. The dominant order in the conventional field was Orthoptera order, namely the *Gryllidae* family, the *Gryllotaphidae* family, and the *Acrididae* family. These families have an ecological role as herbivores (pests). Pests are insects that destroy the main crop. The population of these pests was dominant due to the decline in natural enemies population such as predators of *Hymenoptera* and *Coleoptera.* Insects have an important role in the agricultural ecosystem, not only they are the largest class in the arthropod phylum, but insects from that phylum can dominate other insects because the ecosystem has many natural mechanisms that work effectively and efficiently (Soesanthy & Trisawa, 2011). Dominance is a value that describes the control of a certain type over other types in the community. The greater the dominance value of a type, the greater the influence of control of this type on other types (Prihantoro, 2013).

CONCLUSIONS

Based on the findings of soil macrofauna types in the two vegetable fields using the pitfall trap method, there were 16 families in the organic fields and 13 families in the conventional fields. The Shannon-Wiener index of macrofauna diversity in the organic vegetable fields had a high diversity value of H '2.66, while the conventional fields had a low macrofauna diversity value H' of 1.66. The diversity value also affected the dominance value in the two locations where the organic vegetable fields had a low dominance value because the fields had a high evenness value. Moreover, the conventional vegetable fields had a high soil macrofauna dominance value because the fields had a low evenness value due to the presence of a high species. The difference was also caused by differences in the management of different vegetable fields in the two locations. The organic fields focused more on the use of natural ingredients that do not affect the soil quality. The conventional vegetable fields, on the contrary, emphasized the excessive utilization of synthetic materials and a broad spectrum. Consequently, an increase in one type of species as occurred in the conventional fields involved the killing of natural enemies, such as the Formicidae family so that there is a resurgence in the *Gryridae, Grillotalphydae*, and *Acrididae families* which have an ecological role as plant-destroying pests. In addition, this also causes soil macrofauna such as detritivore insects and decomposers to decrease, which can ultimately disturb the stability of the ecosystem. The Sorensen index on the similarity of the two fields had a value of 0.8, which means that the similarity value of macrofauna in the two fields was high. The existence of soil fauna is strongly influenced by soil conditions, one of which is the presence of organic matter in the soil. The existence of fauna can be used as a parameter of soil quality, the soil fauna which is used as a bio-indicator of soil fertility has a relatively abundant number.

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