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Relation of macrofauna diversity and chemical soil properties in rice field ecosystem, Dukuhseti district, Pati regency, Indonesia

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Indonesia is a country with the third largest biodiversity after Brazil and Madagascar. Of the about 325.530 species of flora and fauna globally, an estimated 25% of the world's species are found in Indonesia. Macrofauna, a land animal that plays a role in influencing the soil ecosystem has specific environmental requirements that enables it to be used as biological indicators of ecosystem conditions, mainly rice paddy ecosystem. This research is necessary owing to the demand for an easy and accurate indicator in predicting soil fertility for farmers. In addition, this study conducted in July TO August 2018 can be used as an inventory of macrofauna indigenous species that may still remain in the paddy field, Dukuhseti district. The implementation of observations was done in paddy fields in the Dukuhseti district in Pati regency, Central Java. Macro fauna specimens and soil samples were taken at various points. 121 individual macro faunas were found and divided into three phyla and 10 Order. The results showed that macro fauna diversity was not always positively correlated with soil chemical properties. Total N, available P, organic C and pH is not directly proportional to the increasingly diverse types of macro fauna in a rice field. The soil's chemical nature in the form of base saturation has a positive correlation with macro fauna diversity that makes it serve as an indicator of fertility. Base saturation in the fields can be associated with the presence of different kinds of macrofauna decomposers such as earthworms, millipedes and denitrivor. Indigenous macrofauna species was not found in the paddy fields in the Dukuhseti district due to intensive land management.

Key words: Macrofauna, soil fertility, soil biology.

INTRODUCTION

Biodiversity is the number of life contained in a region (Sugiyanto et al., 2007) and Indonesia is the third largest country with the amount of biological diversity after Brazil and Madagascar. Of the about 325.530 species of flora

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and fauna globally, an estimated 25% of the world's species are found in Indonesia (Rahmawati, 2013). Soil macrofauna have a very important role in the ecosystem, which is to keep the soil macrofauna soil fertility through overhaul of organic matter, nutrient distribution, increase soil aeration and many more. Soil macrofauna is responsible for chemical transformations in the soil. mineralization rates getting higher and concentrations of mineral nutrients in ant nests suggest that ants alter the abundance, and perhaps the taxonomic identity (Petal, 1980; Friese and Allen, 1993). Soil macrofauna such as herbivor, denitrivor and predator had multiple roles in soil ecosystem, which is to manage the nutrient cycle in soil ecosystem (Melman et al., 2019). Nutrient cycle is one of the many roles to determine productivity on agricultural practice. Soil macrofauna was proofen to giving an impact for plant growth productivity and other soil processes (van Groenigen et al., 2014).

Value of soil macrofauna species diversity tends to increase at lower soil temperatures and largest percent dense cover. Soil organic matter content could be expected to affect the level of soil macrofauna diversity. Soil organic matter content of the higher have a tendency to increase the diversity of soil macrofauna (Cahyo and Shamsuddin, 2017). Ants can be used to estimate the extent of forest recovery stage. Classification stage of ant genera has the advantage of a faster and cheaper method than that of determining the physical, chemical and biological soil atrributes (Julia et al., 2019).

Soil macrofauna is the most sensitive indicator to changes in land use, so it can be used to predict the quality of the land (Rousseau et al., 2012). In carrying out his activities, soil macrofauna require specific requirements. The environmental conditions are the main factors that determine the survival, namely: climate (rainfall, temperature), soil (acidity, humidity, soil temperature, nutrients), vegetation (forest, meadow) and sunlight (Sugiyarto et al., 2007).

This research needs to be done considering the use of intensive management, thus affecting biodiversity in the soil of rice field. Local farmer in dukuhseti had used intensification practices for many years and it affect their land biodoversity. This study can also be used as an indicator of the status of soil fertility in the soil macrofauna biodiversity observation and an indication of the indigenous macrofauna that may still remain in place. The study could be a reference to the local farmer and given the knowledge advantage and hopefully improving better agricultural practices.

MATERIALS AND METHODS

Sampling macro fauna

This research was conducted in July to August 2018 and its focus is on the implementation of observations done in paddy fields at the Dukuhseti district in Pati Regency, Central Java location. Rice field is located in the Dukuhseti district, Pati Regency, Central Java province. The extent of rice fields and uniform type of vegetation causes of the sample was determined to be 10 point locations. The sampling method used, among others, is purposive sampling method.

Interviews with farmers' groups were conducted to determine the type of management that applies to land, because it is highly sensitive to biological indicators impact by land management factors, especially against mechanical ploughing treatment and fertilization (Setälä et al., 1990).

Soil fauna is picked up from soil using Pitfall Trap methods. Pitfall traps procedure involves the use of chemical to isolate the fauna that runs on land and soil depth <5 cm (Setälä et al., 1990). The collection of primary data including data type of the plant was taken using purposive sampling method. A basis for determining the sampling point is through consultation with local residents about the condition of the land in the area, so that treatment used on the land can be known. Same treatment such as plowed land use mechanical machines and the use of chemical fertilizers was employed. At a point, one plot per observation area was made with two replications. Plot observations were made amounting to two plots in each field observations. Observation plots have a size of 25 cm × 25 cm that is based on visual observations by focusing on sites that have sufficient moisture and enough shade.

The sampling procedure for soil macro fauna advanced in all the litter in the observation plots was quickly removed and transferred into clear trash bag. Further, a layer of surface soil (0-10 cm) on plots were dug quickly and then transferred into another clear trash bag. Thereafter, clear trash bag was removed from each block where the discovery observations annotated (soil/litter), swath number, and location of the plot (Cahyo and Shamsuddin, 2017). Soil surface macrofauna was collected using Pitfall traps methods (Decoy trap).

Decoy trap method

Random sampling point was made on the plot to obtain a hole-sized glass trap. Glass trap containing 4% formalin was inserted into the hole, and the glass (rims) surface was made parallel or flat to the ground. Thus, rain water does not enter the glass trap through the glass trap roof. Traps were left for 24 h. Subsequently, trapped macrofauna were identified in the laboratory (Suin, 2012).
Soil macrofauna caught from litter and soil material were identified up to the family level. Books such as *Keys to The Terrestrial Invertebrates* (Mohamed, 1999) and *Introduction to Lesson Insects Edition 6* (Borror et al., 1996) were used for identification of macrofauna soil. Species diversity was calculated using Shannon-Wienner diversity index (Odum, 1993) using the following formula:

$$H' = -\Sigma\, Pi \ln (Pi),$$

where Pi = (ni / N); H '= Shannon-Wienner diversity index; ni = Number of individual types of I and
N = Number of individuals of all species

Shannon diversity index value criteria - Wiener (H ') are as follows:

H '<1: lower diversity
1 <H'≤3: diversity is being
H '> 3: high diversity

Laboratory analysis

Chemical properties of the samples were examined such as soil total N, available P, organic carbon, base saturation and pH. Sampling at each point is done at a depth of 0-20 cm by taking a 5-sub point then composited. Sampling was conducted by composite soil because it can represent the condition of each sampling point (Supriyadi et al., 2015). Analysis of the laboratory was carried out in the Laboratory of Chemistry and Soil Fertility, Soil Science Department, Faculty of Agriculture, University Sebelas Maret, Indonesia. This research was conducted from July 2018 to September 2018. Analysis of soil fertility indicators include pH H_2O (Volumetric Elektrometrik, C-Organic by Walkley and Black Method (Balittan, 2009) total N with Kjeldahl Method (Balittan, 2009), and available P using Olsen method (Balittan, 2009).

Data analysis

Normality test was performed with SPSS software version 21 which showed normal data distribution. Tests carried out by the correlation between diversity index of macrofauna with the chemical properties of soil fertility was performed using Pearson correlation test with an accuracy level of 95%. Normality test was done using Kolmogorov-Smirnov test (De Vaus, 1991)

RESULTS

Importance value index on macro fauna at sampling location

Test for normality using Kolmogorov Smirnov was carried out and the results obtained showed that normal data distribution and standard deviation of diversity index is (+) 0.17197 with an average of 1.3780. Standard deviation (+) 2.24343 with an average of 9.1470 using a 95% confidence level indicates the number -0.412 which means below -0.500 (Table 1).

It states that P availability is not significantly correlated with macrofauna diversity index (H). The results, according to the theory of P availability, have been disposed of through regular mineralization cycle, regardless of fluctuations in biological activity. Pearson correlation test between variables method with variable Diversity Index, Total soil N, Standard deviation (+) 0,3507 0,07087 and the 95% average use rate shows that the value 0,412 thus declared revealed no significant correlation between the diversity index (H) with total soil N levels (N) (Table 2).

The results of Pearson correlation test between the method of data macrofauna diversity index (H) with Base saturation levels (KB), standard deviation (+) 27,5207 4,91392 and 95% the average use level showed significant figure above -0,654 × 0.500 (P > 0.05) which stated that among the variables with base saturation diversity index there was a positive correlation. The results of Pearson correlation test method with a confidence level of 5% shows the results -0, 491 which implies that no correlation was found between the diversity index of soil organic C content. This indicates that the diversity of macrofauna in the fields, do not necessarily lead to higher soil organic C. The results of Pearson correlation test between the method of data macrofauna diversity index (H) was obtained with a pH of standard deviation (+) 0,96375 and an average 6 (Figures 1 and 2).

DISCUSSION

Total soil nitrogen levels

No significant correlation was found between the variable diversity index (H) with total soil N content (N). Lowest total N measured was around 0,28 in accordance with Balitan clasiffication (2007) classified as medium level/degree. Highest levels of total N was measured at 0,3 which means that the entry (2007) is classified as being medium level. All sample points have classified their nitrogen levels as the medium level, where it is suspected because of the intensive use of inorganic fertilizers.

Macrofauna role in the decomposition of organic matter, among others, is the process of fractionation (separation into smaller fractions OM), Distribution (Translocation fraction) and a medium for other organisms. Existence of some macrofauna species can be attracted to the others since macrofauna functions either as predator or antipredator. This causes an increase in the macrofauna diversity index when the rate of decomposition increases (Lavelle et al., 1994; Brussaard, 1998).

Minimum raw organic matter field conditions (litter thickness = 0) impacted on low diversity of macrofauna in this study. Micro-climatic conditions such as high temperatures causing nitrogen content changed into gas, because evapotranspiration is directly proportional to the rate of evaporation of nitrogen (Susanti and Halwany, 2017).

Temperatures measured in the field when the research was held ranges from 30-36°C. The soil temperature is measured at the range of 28 to 37°C. A constant temperature of 15°C causing the growth of certain macrofauna rapidly increased, raising macrofauna growth and resulting to increased diversity of macrofauna (Sukarsono, 2009). The dominant condition of dry rice fields, causing the insect class of ants had bigger dominance than insects that require high environmental humidity levels (molluscs, arthropods, centipede) levels. Higher nitrogen content was found on land that had been used as a nest of ants. This indicates that within the ant nest, there were conditions causing probable mineralization of N to happen compared to humification (Petal and Kounsiska, 1994). The temprature shouldve been controlled with macrofauna and nitrogen keep up at their optimum phase.

Available soil P levels

P element was not only released on the biological cycle, but also plays a role in chemical reactions, in contrast to N elements that almost fully rely on the biological cycle (Stout et al., 1976). Moreover, previous research by Cline et al, (1985) reported that in alluvial soil, mineralization of P was only caused by the chemical transformation

Table 1. Importance Value Indeks (IVI) Macrofauna Species in Dukuhseti Rice Fields.

Name	Phylum	Order	IVI (%)
Pila ampullacea	Mollusca	Gastropoda	13
Chrysolina sp.	Arthropoda	Coleoptera	11
Camponotus sp.	Arthropoda	Hymenoptera	45
Polyrarchis sp.	Arthropoda	Hymenoptora	36
Lycosa sp	Arthropoda	Araneae	24
Coenagrionidae sp.	Arthropoda	Odonata	3
Atractomorpha sp.	Arthropoda	Orthoptera	4
Ortherum sp.	Arthropoda	Odonata	6
Ortherum sp.	Arthropoda	Odonata	1
Gryllidae	Arthropoda	Orthoptera	1
Dermaptera sp.	Arthropoda	Dermaptera	6
Lumbricus sp.	Annelida	Megadrilacea	20
Coccinellidae	Arthropoda	Coleoptera	1
Culex sp.	Arthropoda	Diptera	17
Siphanta sp.	Arthropoda	Hemiptera	1
Monomorium sp	Arthropoda	Hymenoptora	24

Table 2. Soil lab analysis results on all mean sample and category according to Balitan (2009).

Attribute	Value	Category
N Content	0.35 cmol/kg	Medium
Available P	9.15 ppm	Medium
Base saturation	27.52%	Low
Organic C	2.16%	Medium
PH	6.11	Pretty acid

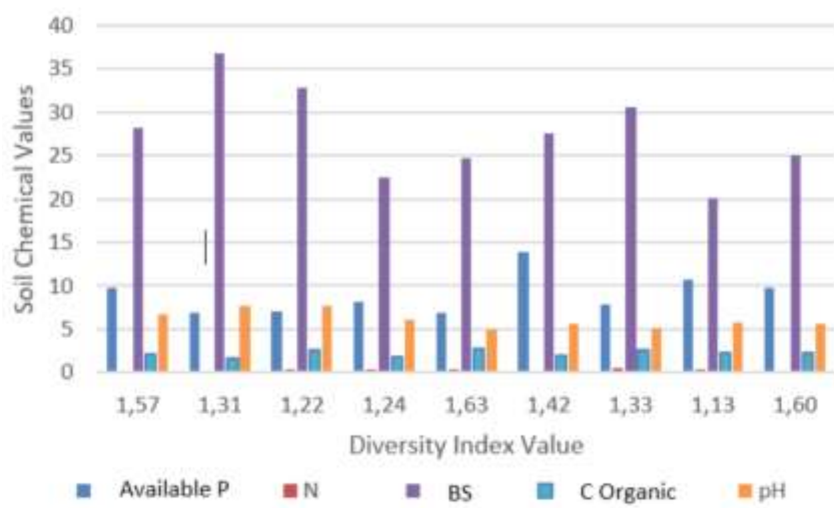

Figure 1. Diversity Index Value chart on each site sampling, and their soil chemical properties value that had been tested on each sample.

compared with biological transformation.

Although the diversity of macrofauna was not significantly correlated with the availability of P in the soil in this study, According to Anderson and Ineson (1984) in Ingham et al. (1985), most nematodes and protozoa accelerate mineralization P, while the worm does not

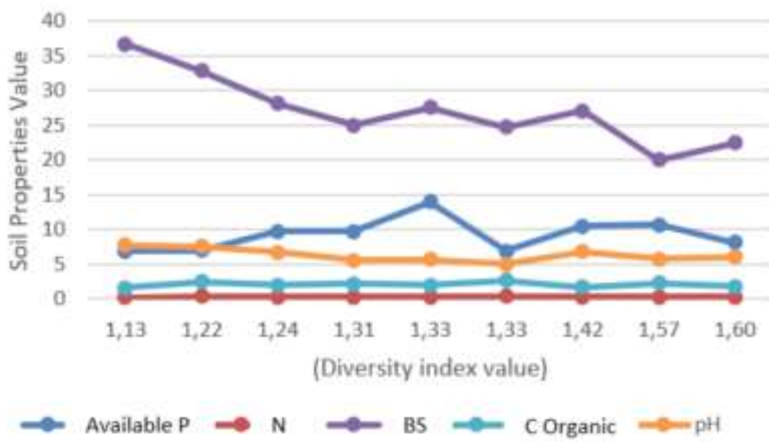

Figure 2. Diversity Index Value had been sorted from his lowest to highest, Each Chemical Soil Properties showing their trend.

affect the P but can be extracted from KCl in the pine forest litter (Setälä et al, 1990). McBrayer (1977) emphasizes the utilization of land mesofauna as immobilization agent P and invertebrates as ion releasing agent at ongoing basis to maintain the fertility of conifer forest ecosystems with the goal of long-term plantations (forest).

Research conducted by Schipper et al. (2009) states that there is no real influence on the environment with epigeic worm to soil organic matter content although comparison of the addition of phosphate fertilizers was observed. This shows that P did not relate significantly to the macrofauna dynamics in the soil. Directly, macrofauna diversity is positively correlated with soil physical attributes. Soil physical attributes lead to improved quality of chemical and biological attributes of soil, especially soil biological attributes that are directly influenced by the fauna. Macrofauna diversity causes an increased mikrofauna cluster so that the cycling of nutrients process becomes faster (Manyanga et al., 2014). There is no significant correlation between available P and diversity macrofauna proofen in this study, because P available more influenced by microfauna (Setälä et al, 1990)

Base saturation levels of the soil

The results of Pearson correlation method test between the data of macrofauna diversity index (H) and Base saturation levels (KB) using a 95% confidence level indicates the number -0,654* which means above -0,500 (P> 0.05). Soil fauna which proved instrumental in base saturation levels of most of the types is macroinvertebrata. Macroinvertebrata on calcaerous ecosystems had a role in actively generating mull (humus formed on the ecosystem of non-acid) by increasing the activity of microbes (Scheu, 1990) where cutting litter becomes smaller and burial of organic material was noticed (Van der Drift, 1963; Hirschenberger and Bauer, 1994).

At the study site, the type of macroinvertebrata encountered was predominantly of three order, the Hymnenoptora, Annelida and Areneae. Macrofauna that resulted from order Hymenoptora is from formidae tribe like ant with an IVI (Importance Value Index) of 81%, the most in a rice paddy ecosystem here. Profit from the order Araneae was found with IVI by 24%. From the order Annelida, earthworms with an IVI of 20% was found and it can be concluded that macroinvertebrata have a considerable role in the ecosystem of the fields here.

According to Ondina et al. (2004), an estimated few specific insect species which include rove beetles (*Tachyporus dispar*), land snails (*Cochlicopa lubrica*) and *Arion circumcriptus* can be an indicator for positive correlation with base saturation content. Barros et al. (2002) also support this statement, he stated that the litter arthropods, especially *Isopoda* and *Diplopoda* groups most commonly appear in soil that has a high base saturation.

Paddy soil management factors showed that using tractor mechanics leads to lower macrofauna IVI class *Gastropoda*, *Diplopoda* and *Isopoda* which is only for an amount equal to 14% because the management of an inch layer of soil causes macroinvertebrata leading to shrinkage (Barros et al., 2002). Land management practices need to be reduced in such intensity to maintain the diversity of macrofauna, because the increased macrofauna is a way to consider improving and maintaining the paddy soil base saturation levels.

Levels of soil organic C

Availability of organic material can be estimated by comparing the levels of organic C and N total, thus obtained C/N ratio can be used to predict the avaiLabileity of nutrients from organic matter mineralization (Sukmawati, 2015). Application of intensive agriculture leads to decline in soil organic C levels. The content of soil organic matter can be maintained at 2% level when given minimal input of organic materials as much as 8-9 tonnes/ha (Young, 1989).

Macrofauna have a role in recycling and storage of carbon (C). Low soil organic C is caused by the nature of movement of carbon cycle into the biomass in the organism so that it becomes immobilized. A high diversity causes the displacement of carbon into biomass in bulk (Moco et al., 2010).

Although this study did not find a correlation between diversity and levels of organic Carbon (C), some types of macrofauna are known to have an influence on the decomposition of organic matter, cycling of nutrients (nitrogen, phosphorus and carbon), better productivity of agriculture and improvement of the physical, biological and chemical soil (Brussaard et al, 2007). Macrofauna digestive activity causes the formation of aggregates and changes recalcitrant into simpler forms, thus improving the quality of soil physical properties.

Macrofauna dominance in rice field sample point is not balanced. Family important value index represented in annelid worm ranks second after the family Formicidae. The spread of organic C in the soil has a correlation that is important to earthworms, which revealed that the isotope levels of ^{14}C being introduced has moving and average concentrations in soil depth that contained earthworm activity as compared to that without earthworm activity (Stout and Goh, 1980).

Soil organic C content is also indicated by the presence of macrofauna and larvae type groups that are decomposers, such as coleopterae that indicates high soil C content (Rousseau et al, 2012). Research located in countries having cocoa forests like Brazil also shows that coleoptera larvae is associated with lignin and wood-consuming, resulting in the efficiency of nutrient cycling and carbon (C) (Moco et al, 2010). Macrofauna diversity could be a solution in order to keep soil organic carbon at optimum phase.

Soil pH levels

It can be concluded that no correlation was found between the diversity of macrofauna with soil pH. According Suin (2012), soil fauna pH have linkage relationships of mutual influence. Soil pH levels affect soil macrofauna density, due to the pH of determining levels of nutrient avaiLabileity in the soil (Suin, 2012). A known pH 6-7 range is found to cause optimal nutrient availability in the soil (Hairiah et al., 2004). pH is not an absolute determining factor of macrofauna existence, because according to Suin (2012), certain types of soil fauna can survive in extreme circumstances like acidic or alkaline.

The decomposition process of macrofauna have been affected by pH. According to Notopriwihardjo (2000), temperatures for slightly acidic to slightly alkaline pH range are good in accelerating the decomposition of organic matter. The role of pH in this case is to provide a good environment for organisms that decompose organic material. pH range >5.5 could provide a good environment for N fixation bacteria, phosphate solvent bacteria and nitrification bacteria (Hardjowigeno, 1995).

It is known that the pH has a positive influence, directly or indirectly, especially against predatory macrofauna according to research results by Moco et al. (2010) in cocoa plantations and forest in Brazil. In addition, Lavelle et al. (2003) confirms that the environment shows a high population diversity of *diplopoda* and *Diptera* species of larvae, which are classified as decomposers of litter. This explains the abundance of macrofauna predators in the ecosytem. Young (1986) stated that the Diptera larvae grow well in alkaline pH conditions. The discovery of macrofauna samples with little population are not well saturated due to the continuous changes in ecosystems on this macrofauna habitat. Systematically, flooding treatment on rice field causes rapid ecosystem changes and resulting periodic overhaul of macrofauna population. According to Folgarait et al. (2003), the environment has the same mechanism of the fauna species.

Ecosystem, have a tendency to adopt the behavior of new species with the same role when they lose a species rather than adopting various new species all the time. As a result, the diversity of fauna ecosystems never returned exactly the same after the changes in habitat. Case studies in Argentina showed that after natural grasslands were changed to rice fields, the ecosystem does not return to its original state (as natural grasslands) despite being rehabilitated within a period of 15 years (Thomas et al, 2004). Macrofauna couldnt be a precise indicator to fortell soil pH level because macrofauna diversity and soil pH level had mutual relation.

Conclusion

Macrofauna diversity have a positive correlation with soil chemical properties, including the base saturation. Macrofauna cannot be used as the sole indicator of soil fertility in a particular place; this is because macrofauna are highly dependent on microclimates and microecosystem. Fauna found on the same land use in different places are not necessarily identical; macrofauna possess the interplay of the soil pH. Soil pH caused optimal conditions for the growth of macrofauna which helps maintain balanced pH levels.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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