TO STUDY THE EFFECT OF SOIL MACROFAUNA ON SOIL QUALITY IN KEDUANG SUB WATERSHED BASED AGROFORESTRY SYSTEM, WONOGIRI

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ABSTRACT

Agroforestry land management system conducted in sub-watershed Keduang due to land use change in sub watersheds Keduang Wonogiri. Agroforestry system is expected to improve soil quality in DAS Keduang. To improve conditions of soil macrofauna as indicator of biological activity which is able to improve soil quality? This study aims to know condition of macrofauna as result of land improvement management in watershed by agroforestry. To know how the condition soil macrofauna on soil quality in sub watershed keduang. This research use descriptive exploratory research method through field survey. To determine the sample point using the overlay map of soil types, parent material, slope and land use. The analysis of soil macrofauna diversity was using Shannon-Wiener and Simpson diversity index formula. Soil quality is determined by collecting data indicators that have been chosen for each functions of soil or the Minimum Data Set (MDS). MDS determined using Principle Component Analysis (PCA). Sample point based on the Land Units (LU) which has the same characteristics. LU determination results obtained from the overlay map of slope, soil type, geology and land use. Parameters analysis in this study include soil pH, C-organic, soil aggregate, soil depth, P_2O_5*, soil bulk density, and soil respiration. This research showed that the condition of the soil macrofauna on agroforestry land more diverse and has a higher diversity index. The condition of soil macro fauna in sub watershed Keduang is not significant to the soil quality value in sub watershed Keduang. The indicators used should include soil fauna as a whole not just the soil macrofauna alone, so it is possible can significantly affect the value of the quality of the soil.*

Key words: Agroforestry, Soil Macro fauna, Keduang, Soil Quality.

Introduction

Land conversion in Keduang sub-watershed has occurred massively by the local community, which originally forests changes to agricultural land. Forest degradation extremely can decrease soil biodiversity (Mathieu et al, 2005; Rossi et al, 2010). Land conversion that occurred can lead to a lot of issues such as declining soil fertility, erosion, the extinction of flora and fauna, floods, droughts and even global environmental change. Protection of land resources and prevention of changes of land use is very important for environmental sustainability (Acton and Gregorich, 1995).

Agroforestry is a land improvement system with integrated management of forest land with agricultural cultivation. According to Young (1991), agroforestry systems can control soil erosion, maintain soil organic matter, maintain the soil physical properties, increase nitrogen fixation, increase soil nutrient inputs, efficient nutrient cycles, reduce soil's toxicity, increase soil water availability for plants, and support faunal activity. Agroforestry systems performed as a sustainable production system with a stable land cover, diversification of production and the effectiveness of nutrient cycling (Schroth et al, 2001; Hartemink, 2005). Land improvement management by agroforestry system is expected to improve soil quality in sub-watershed Keduang Wonogiri.

Soil Quality is the capacity of Soil to serves within the limits of the ecosystem and interacts positively with the surrounding environment as: (1) plant growth medium and biological activity; (2) regulator, flow divider and water storage in the environment; and (3) support the environment from destruction by harmful substances (Larson and Pierce 1996). Soil macrofauna is one indicator of biological activity that is able to improve soil quality. Soil macrofauna have an important role in the improvement of soil biological, chemical and physical properties through the immobilization and humification process. Soil macrofauna has a large role in the decomposition process, carbon flow, nutrients redistribution, nutrient cycles, bioturbation and soil structure formation (Anderson, 1994). This group is sensitive to changes in the environment and ecosystem effects (Mathieu et al, 2005; Paoletti, 1999). Soil macrofauna, especially the engineers (egg ants, earthworms), can have a significant effect on the soil and ecosystems so that they reflect important ecological processes within ecosystems (Lavelle et al, 2006).

Thus the study for observation concerning existence of soil macrofauna in agroforestry system as land improvement process conducted in Keduang sub-watershed. How is the relationship between the abundance of soil macrofauna with the soil quality in agroforestry system as soil quality improvement process in Keduang sub-watershed?

Materials and methods

Sampling techniques

This study used descriptive exploratory research through field surveys. The determination of sample points used purposive sampling method, which the sample points were taken on locations of agroforestry land use. Sample point based on the Land Units (LU) which has the same characteristics. LU determination results obtained from the overlay map of slope, soil type, geology and land use. The location of this research conducted on the use of a forest area or agroforestry so LSU besides forest land use are ignored. Hence on study sites there are 9 LU's. Soil samples were taken in the LU is considered to represent the LU with priority range and extent of the LU so there are nine sample points.

Data collecting technique

Primary data
Sampling of macrofauna (size> 2 mm; Lavelle and Spain, 2001) on the soil surface using a barber trap method or commonly referred to as pitfall and hand sorting. Identification each type of soil macrofauna based on the animal taxonomy classification and every determined type of orders and the name of region.

Soil sampling was done by using composite technique so it can represent conditions of each soil sampling point. To support obtained data, it is also necessary to analyze the soil physical and chemical properties because these properties can affect the life of soil fauna. Parameters analysis in this study include soil pH, C-organic, soil aggregate, soil depth, P_2O_5, soil bulk density, and soil respiration.

Vegetation collecting data using 5 belt size 10X50 m^2. Each belt contain 5 plots for each level with size 10x10 m^2 (trees), 5x5 m^2 (shrubs and saplings), and 1x1 m^2 (herbaceous, shrub seeds, and seedlings).

Secondary data
Secondary data consist of soil type map; slope map; geological map and land use map.

DATA ANALYSIS METHOD

The analysis of soil macrofauna diversity was using Shannon-Wiener and Simpson diversity index formula (Odum, 1993).

Diversity index = Σ (ni / N) ln (ni / N)
Description: ▪ ni = number of individuals of each type
▪ N = total number of all types

Soil quality is determined by collecting data indicators that have been chosen for each functions of soil or the Minimum Data Set (MDS) which then rated based on Table 1. Calculation of soil quality index is done by summing soil quality indicators scores. From the parameters that have been obtained and analyzed using the Principal Component Analysis method (PCA) (Li et al, 2007) to obtain the appropriate MDS. Calculation of Soil Quality Index (SQI) by using the formula;

$$SQI = \sum_{i=1}^{n}(Wi\ x\ Si)$$

SQi= soil quality index; Wi = *Weighting Factor* in PC (Principle Component); Si = scores on each indicators of soil quality. In the end, value of the selected SQI will be classified based on the table below. Selected Data were analyzed using Minitab software 13.0.

Table 1. Soil Quality Class

Soil quality	Scale	Classes
Very good	0.80 – 1	1
Good	0.60 – 0.79	2
Moderate	0.35 – 0.59	3
Low	0.20 – 0.34	4
Very Low	0 – 0.19	5

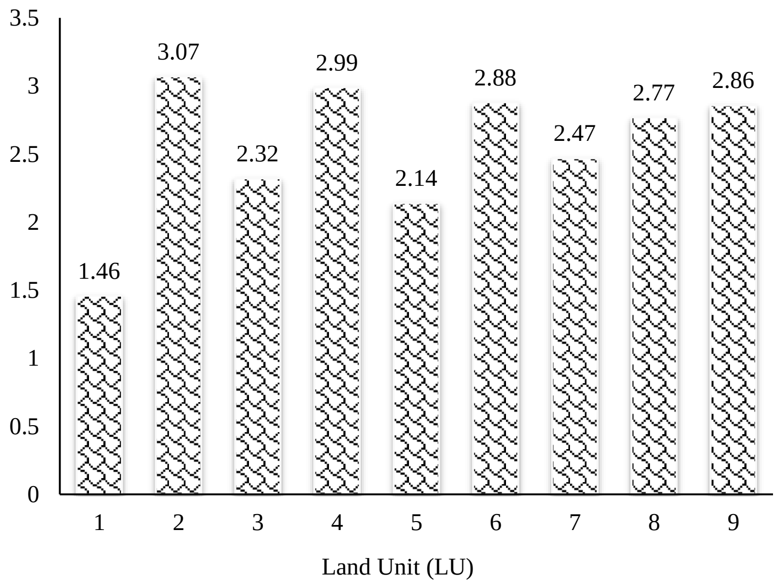
(Cantu et al, 2007 with modification)

Results and discussions

Vegetation diversity

Sample points conducted on agroforestry land use and also taking on forest land as a comparison. From the obtained data, the number of diversity indexes each sampling point known. Diversity index is the number of plants species or animals that live in a certain area. Vegetation diversity can described from the vegetation component species variety which is characteristic of its biological group and can used to describe the structure of the community. According Andreu (2008), the diversity of vegetation can used to measure the stability of the vegetation communities, the ability of a crop community to remain stable even gets interference to its components.

Figure 1. Diversity index of vegetation in the study sites.



LU 1 has lower diversity index due to the LSU-1 is homogeneous forest which has almost the same type of vegetation of pine trees and shrubs such as ferns and grasses. Compared with other LU has more diverse vegetation types. In LU 2 with the use of agroforestry has highest vegetation diversity index 3.07 vegetated forms of Jackfruit, cloves, mahogany, pine, avocado, cassava, banana, lemon grass, tobacco, chili, galangal, and green beans. Here in after consecutively in LU 4 (2.99), 6 (2.88), 9 (2.86), 8 (2.77), 7 (2.47), 3 (2.32), and 5 (2.14).

According to Odum (1993), high species diversity in forest obtained from equal abundance in each type and equitable distribution due to the balance which occurs in the forest. It is proved in LU with the use of agroforestry has higher diversity index than in LU with the use of natural forest land. The use of agroforestry has equal abundance compared with the use of natural forest land. Agroforestry with components as trees, crops, grasses, livestock etc. provide all kinds of life support (Angelsen and Kaimowitz, 2004).

Soil macrofauna abundance

Soil macrofauna is a component which can affect the nature of soil in an environment. The existences of soil macrofauna are also influenced by the climate and the availability of food. According Hadisudarmo (2009) soil macrofauna (> 2 mm) are the most visible soil animals include ants, termites, amphipods, larvae and adult insects, earthworms, enchytraeidae worms, slugs and snails. Soil macrofauna contribute to the availability of water for plants, because it affects the improvement of soil structure and permeability (Henke, 1994; Francis and Fraser, 1998; Leonard and Rajot, 2001). Soil macrofauna used as an indicator of environmental conditions or specific ecological processes in soil (Doube et al, 1997; Lobry, 1997). Abundance of soil macrofauna based on its diversity index on each LU, have different values.

Table 2. Soil macrofauna diversity index each LU in sub-watershed Keduang**.**

LU	Land Use	Total Soil-Macrofauna	Number of Species	Index Diversity
1	Homogeneous Forest	13	6	1.53
2	Agroforestry	30	9	1.98

3	Agroforestry	18	7	1.67
4	Agroforestry	19	7	1.91
5	Agroforestry	26	8	1.67
6	Agroforestry	26	8	1.76
7	Agroforestry	13	6	1.42
8	Agroforestry	19	7	1.63
9	Agroforestry	20	7	1.71

Based on the data the highest diversity index of soil macrofauna is LU 2 which is agroforestry land use. LU 2 has soil macrofauna total 30 individuals with a diversity index of 1.98. Diversity index in all LU has a value in the moderate category. The use of agroforestry in LU 2 with vegetation cover in the form of jackfruit tree, clove, mahogany, pine, avocado, cassava, banana, lemongrass, tobacco, chili, galangal, and green beans, has the highest soil macrofauna diversity index of 1.98 with the number of species 30 individuals. The location of LU 2 has the highest diversity of vegetation index that is 3.07. It showed that vegetation factors may affect habitat for soil macrofauna. The higher the vegetation diversity index, so the ability to provide energy and food source for soil macrofauna will be higher. The higher the availability of energy and nutrients for soil macrofauna, so growth and activity of soil macrofauna will be better. Environmental factors will determine the structure of soil macrofauna communities. Soil macrofauna contained in LU 2 dominated by fauna such as ants. Ants can indirectly increase the porosity, helping the spread of nutrients, improve soil hydrological processes, and improve the exchange of air in the soil. According to the Hole (1981), soil macrofauna affect nutrient cycling, soil bioturbation and formation of soil structure.

According to Ruslan, (2009) vegetation factors can also affect the habitat for soil fauna. Insect soil surface depends on the availability of organic material such as dried leaves are above the soil surface. The existence of surface soil insects in the soil depends on the availability of energy and food sources to carry out his life, such as organic matter and biomass of life which are all related to the flow of the carbon cycle in the soil. Other factors such as the availability of food and habitat differences affect the abundance and species composition of soil organisms (Castellani et al, 2002; Uhia and Briones, 2002).

Land cover provides favorable environment for soil macrofauna, protects to water and wind erosion, maintain humidity and temperature, as well as increasing the organic matter. Soil macrofauna considered in maintaining the health and function of the soil (Lodry de Bruyn 1999). Soil macrofauna considered as components of the ecosystem balance nets food, because they can modify the soil macrofauna organic and inorganic elements (Brussaarda 2007).

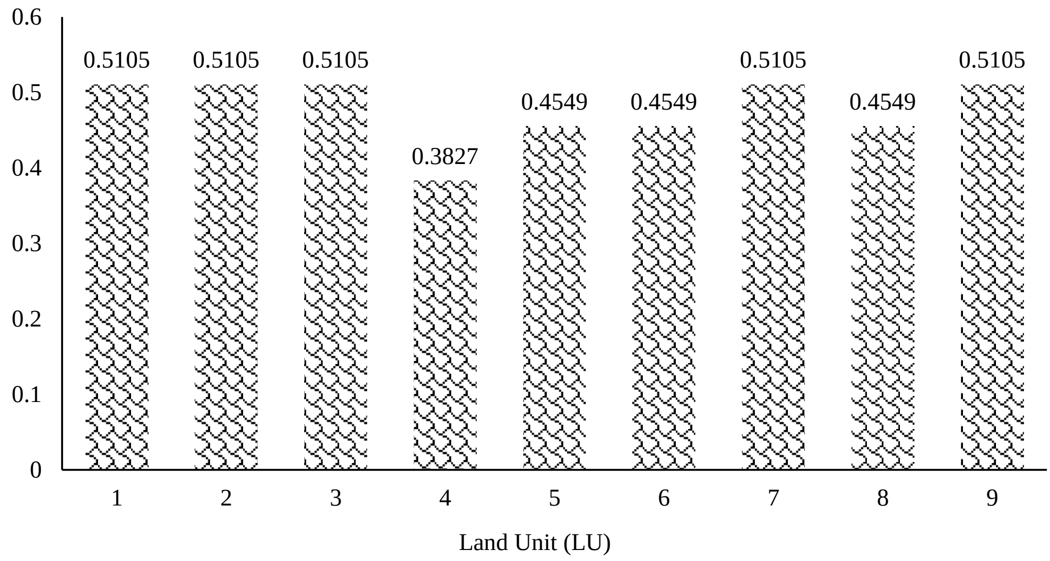
According to Rafael, et al, (2013) there was a significant correlation between the quality of soil nutrients and soil microbial activity. Soil macrofauna instrumental in soil microbial activity, helping mineralization of nutrients and provide food for the plant. Ecosystems that have high quality chemical properties indicate the abundance and diversity of macrofauna better.

Soil macrofauna considered as an important component of the ecosystem to maintain soil nutrient cycles and soil biological fertility. Soil macrofauna is a useful indicator of soil quality because they are sensitive to changes in land management and is involved in many functions of soil. As an indicator of soil quality, abundance and diversity of soil fauna integrate the physical, chemical, and biological properties of soil and reflects changes in the general ecology (Yan et al, 2011).

Soil Quality Index

Soil quality is the capacity of a soil in a field to provide the necessary functions of human or natural ecosystems in a long time. That function is its ability to sustain the growth and productivity of plants and animals, maintain air and water quality or maintain environmental quality. Soil quality can maintaining the forest to stay healthy and growing a good crop (Plaster 2003). Soil quality indicators selected from properties that demonstrate the capacity of soil functions. Based on soil functions to be assessed and then selected some appropriate indicators. Value of soil quality can be seen in (Figure 2).

Figure 2. Histogram Soil Quality Index at each sample point.



Value of soil quality at all LU in category moderate between 0,35 to 0,59 with the soil quality score is worth 3 refers to the class of soil quality based Cantu et al (2007). Soil quality in the LU 1, 2, 3, 7 and 9 have a value of 0.5105 at LU 5, 6 and 8 have value 0.4549 soil quality while at LU 4 has a value of 0.3827 soil quality. The value of the land considered a very good quality which is worth 0.80 to 1, while considered very bad value between 0 and 0.19. Parameters that affect the value of the quality of the soil at the study site based on the results of the PCA step, which is the condition of the soil pH, aggregate stability, C-organic content and weight volume of soil.

The pH value of the soil at each SPL ranges from 5.3 to 6 in the category of moderate. Stability of soil aggregates in each category SPL has moderate to low with values approximately 38 to 76.33. Content of C-organic in each SPL has a value between 1.16 to 1.68 with the medium category, which is why the value of the quality of the soil in each SPL has a low value.

Soil have high quality if it has the following properties: (1) adequate but not excessive in nutrient supply (2) has a good structure (3) has a layer depth sufficient to rooting and drainage 4) have good internal drainage (5) populations and parasitic diseases is low (6) populations of organisms that encourage high growth (7) pressure vegetation (weeds) is low (8) does not contain chemical compounds that are toxic to plants (9) resistant to damage and (10) the elastic to follow a degradation process (Syarifudin 2004).

Soil quality is determined by collecting data indicators that have been selected or minimum data sets (MDS). Once the indicator data collected, the information is then combined to determine soil quality index. The soil quality index can be used to view and estimate the impact of farming systems and management practices on soil quality quantitatively measuring or analyzing the indicators used (Seybold et al, 1997). Soil quality values can describe the state of the soil to support plant life, as a function of land. The negative impact of the inability of the land to fulfill its function is the disruption of soil quality resulting in increased breadth of critical land and declining soil productivity.

To determine the correlation between soil quality indicators, the data obtained were then analyzed the correlation test. Correlation test on each parameter using Minitab 13. The correlation test on each of the indicators presented in Table 3.

Table 3. Test results of correlation analysis between indicators of soil quality and soil quality index value.

	pH	AGG	SD	C-org	qCO2	ISM	P2O5	WV
AGG	0,344 0,365							
SD	-0,260 0,499	0,777 0,014						
C-org	-0,068 0,862	0,204 0,599	0,024 0,952					
qCO2	-0,751 0,020	-0,149 0,701	0,319 0,402	-0,323 0,397				
ISM	0,049 0,901	-0,013 0,973	0,048 0,902	-0,643 0,062	0,477 0,194			
P2O5	0,009	0,354	0,106	0,700	0,029	-0,365		

	0,982	0,350	0,786	0,036	0,942	0,335		
WV	0,344	0,177	-0,070	0,094	-0,079	0,389	0,003	
	0,364	0,648	0,859	0,809	0,840	0,301	0,995	
SQi	-0,392	0,019	0,384	-0,028	-0,025	-0,408	-0,211	**-0,779**
	0,296	0,962	0,308	0,942	0,950	0,276	0,586	0,013

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Cell Contents: Pearson correlation
                        P-Value
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Description: pH = the value of the degree of acidity, AGG = aggregate stability, SD = Soil Depth, C-org = C-organic total, qCO_2 = CO_2 respiration, ISM = Index Soil Makrofaona, WV = weight volume of soil, SQi = Soil Quality Index.

The results of correlation analysis showed that the indicator has a significant correlation with the soil quality index is a weighted volume of soil. Other indicators correlated respective with a lower value or insignificant. Soil macrofauna index values showed no significant correlation with the index of soil quality. Weight volume of soil is comparison between weight lump of soil and soil clod volume and stated in the g / cm3. Weight measurement volumes required as a guide to determine the soil density porosity of the soil. Volume weight value is influenced by soil texture (the finer the texture of the soil, the greater the value Weight volume of soil), soil depth, organic matter content, density, land management, land and mineral constituent structure type.

Conclusion

Keduang sub-watershed land improvements that have been made with agroforestry system have a diversity of fauna and a higher diversity index, so the development and survival of soil macrofauna more assured. Life of soil macrofauna in the sub-watershed Keduang not significantly affects the value of the quality of the soil in the sub-watershed Keduang. The indicators used should include soil fauna as a whole not just the soil macrofauna alone, so it is possible can significantly affect the value of the quality of the soil.

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