The Changes of Earthworm Population and Chemical Properties of Tropical Soils under Different Land Use Systems

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ABSTRACT

Local Rice Cultivars Grown On Tidal Swampland Near Coastal Area in South Kalimantan (E. Purnomo, M.L. Setiawan, N. Yuliani, E. Atmaja, M. Wahyuni, A.R. Saidy, and M. Osaki): Hilly area Sumberjaya, West Lampung Province, South Sumatra, Indonesia, is one of the Province where deforestation increasing in the past 30 years as a result of the implementation of agricultural systems, especially coffee plantation. it is important to study the soil fauna in these natural relicts. Six sites (3 naturals and 3 managed systems) were studied in order to identify earthworm species communities, using the hand sorthing method and soil chemical parameters (pH, avail-P, org-C., tot-N, and cation exchange capacity (CEC). Two species were found (*Pheretima* sp. and *Pontoscolex* sp.). All land use systems had very similar soil chemical characteristics, there can be characterised as acidic (pH between 3.6 and 5.0). A high content of organic carbon was in natural sites (bush 4.0 % and primary forest 3.9 %), and a low content was in managed sites (coffee plantation 2.1 %). Total nitogen (0.37 %) and CEC (21.84 Cmol-c kg^{-1}) was in primary forest. However, the earthworm densities were significantly lower under primary forest than in the other sites. The acidity component explained mainly the lowest earthworm population at the primary forest (soil pH 3.6). The use of succession forest (bush) and mix farming showed a positive effect on soil fertility

Keywords: Earthworm, landuses, soil fertility.

INTRODUCTION

During the last 30 years, the practice of agriculture has become more intensified. In Lampung, Southern Sumatra – Indonesia, coffee is one of the main export commodities, mainly planted intensively in the western mountainous areas of Lampung with topography of 60 ^{o} slope. In this area, high intensity rainfall caused considerable run off and soil erosion from the coffee plantation area on rainy season. Intensive agriculture may increase soil erosion and leaching of nutrients.

Several changes of soil quality occur when virgin soil is cultivated. In the tropics, deforestation has been long considered to be lead to the degradation of soil properties related to soil fertility. Besides soil chemical and physical parameters, we also included soil biological parameters, such as earthworm community to compare soil fertility in different land use systems.

Soil fertility depends on physical, chemical and biological soil attributes (Huerta *et al*., 2007). Earthworms, as ecosystem engineers (Jones *et al*., 1994), play an important role in organic matter decomposition dynamics (Lavelle and Martin, 1992) and influence the supply of nutrients in several ways (Syers and Springett, 1984). Their presence can be used as a soil quality indicator (Klemens, 2003) and high diversity is usually present in soils with high organic matter content. Pashanasi et al. (1992) has been shown well correlation between earthworm abundance and the productivity of cropped plants in the tropical region .

Although earthworm are the major component of soil fauna communities in most of natural ecosystem the humid tropics (Lavelle et al., 1992) and probably the most important component of the soil fauna in terms of soil formation and nutrient cycling. Distribution of earthworm is irregular and is affected by various factors such us soil temperature, moisture, pH, texture, bulk density, organic matter and C/N ratio play a vital role in their distribution (Edwards 1983; Ismail *et al*., 1990). Changing in the soil habitat as well as direct

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damaged induced by fire, may obviously affect the ecology of soil organisms. Burning has induce mortality of these organisms in soil surface, and therefore essentially eliminated their activities, though such effects have usually been temporary, reversing in few years. To a great extent, the population and activity of soil organisms was also affected by the intensive agriculture. Furthermore, deforestation in the tropical regions has long been considered to lead to the degradation of the earthworm activities (Aoki, 1973). Earthworm is one of the important organisms in the soil that susceptible to the faint change of environmental, especially moisture, temperature and amount of litter supply.

Earthworms are known to live very closely to their sources of food (Lee, 1995). A high amount of litter accumulation might be increase the earthworm population. Population of earthworm usually increase with the availability of organic matter, and in many temperate and even tropical forest, earthworm have the capacity to consume the total annual litter fall. Such a total turnover of organic litter fall has been calculated for an an English mixed woodland (Satchel, 1967), an agricultural system in maize crops (Angel *et al*. 2004), an organic matter content of different land uses system (Haynes *et al*. 2003), a Nigerian tropical forest (Madge, 1969) and tropical rain forest of Indonesia (Yusnaini et al., 1999; Matsumoto et al., 2000, Yusnaini *et al*., 2002).

Deforestation in the tropical regions has long been considered to lead to the degradation of the soil properties related to soil fertility. Earthworm is one of the important organisms in the soil that susceptible to the faint change of environmental, especially moisture, temperature and amount of litter supply (Aoki, 1973). Some reports have published about the survey of soil fauna in the tropical regions (Yusnaini et al., 2002; Matsumoto *et al*., 2000; Watanabe, 1984). Species and ecology of earthworm in the tropical region have reported in detail (Lavelle, 1988). However, some important problems remain unsolved. These include population, life cycle and ecology of earthworm under different land-use, vegetation, and seasonal change in tropical region. We chose earthworms because they are one of the most important macro-decomposer groups in the tropics (Swift *et al*., 1979). The abundance and diversity of earthworm has used as indicator of soil fertility (Stork and Eggleton, 1992). Earthworms play an important role in the turnover of organic matter in soil and in building and maintaining a good soil structure (Lavelle, 1988). They, therefore, are essential for improved utilization of added organic and thus for plant growth, especially in an extensive agriculture system, such us organic farming which is based on nutrient release from turnover of organic material.

The purpose of this study was to survey soil fertility by soil chemicals and population of earthworms from different types of land uses at Sumberjaya, West Lampung, South Sumatra, Indonesia. In order to identify the potential use of earthworms for increasing soil fertility, in this work we focused on studying the relationship between soil properties and earthworm abundance.

MATERIAL AND METHODS

Study site and surveyed methods

Study site was conduct in several land use change in Hilly area Sumberjaya, West Lampung Province, South Sumatra, Indonesia include primary forest, bush area, deforest area, coffee plantation (old and young), and mix farming. Primary forest was located along the upper part and the peak of the hills, between 800-1200 m above sea level. All disturbed sites were next to the primary forest site and located on the lower slopes of the area. The area under bush re-growth had been covered by secondary forest until it was slashed in 1999 and since then, this area has been left to bush re-growth. Deforested area, which had also been covered by secondary forest, was slashed and burned 6 months before soil sampling made. Coffee plantation divided with different age, young coffee plantation (<2 years) and old coffee plantation (>20 years). Mix farming garden located in the neighbourhood of coffee-planted areas, which provide fruits (mostly banana, papaya), nuts, resins and other tropical products. In the area, the wet season extends over 7-9 months while the dry season over less than 2 months. Annual rainfall was approximately 1.500-2.000 mm and mean temperature was 22-25^{o}C.

Soil Sampling

Soil samples were collected at all land use systems at dry season (September 2001). For soil chemical analysis, soil take in separate in three layer (1-10, 10-20 and 20-30) from 4 replications at the different land use systems. Soil chemical analysis includes soil pH (Extraction in water (1:

2.5 ratios), organic carbon (Walkley and Black methods), total nitrogen (Kjeldahl methods), available P (Bray 1), and CEC (NH4OAc pH 7.0).

Earthworms were taken using quadrants of 25 x 25 cm^2 and 30 cm deep soil monoliths that are divided into three layers, 0-10 cm, 10-20 cm, and 20-30 cm. In each sampling plot soil inside the quadrates were dig out in 0-10 cm, 10-20 cm, and 20-30 cm depth, spread on polyethylene sheet and then earthworm were collected by hand sorting (Springett, 1981). Four sampling point at each location were 5 m apart along a random transect. The survey had been conducted at dry season (September 2001).

RESULTS AND DISCUSSION

Soil Chemical

Deforestation in the tropical regions has long been considered to lead to the degradation of soil properties related to soil fertility. In a Hilly area of Sumberjaya, Lampung Province, South Sumatra, clearing and cutting the primary forest by slash and burn method for the monoculture plantation, e.g coffee, paddy field, vegetables, make the soil chemical change (Table 1). Soil organic carbon, and total nitrogen, were high when the soil was covered by forest vegetation (primary forest), and decreased when the primary forest was opening by slash and burn. More over cation exchange capacity (CEC) was higher in the primary forest than others land use system. High CEC could use as indicator of soil fertility. The soils that have high CEC indicate that soil has enough capacity for adsorption and exchanges cation. As a result, the nutrient, especially cation not easily lost by erosion.

In the all of land uses system, soil chemical content (soil pH, organic C, total N, avail-P, and CEC) were higher in the upper depth layer (0-10 cm). All soils were very acidic with pH values of 3.6–5.0 (Table 1). Their cation exchange capacity (CEC) varied between 9.66 and 21.84 cmol kg^{-1} and the highest CEC was in the upper depth of 0-10 cm in primary forest. Organic matter content decreased in all systems with increasing soil depth. In the upper depth of 0–10 cm the organic matter content not differ significantly between the bush, primary forest, and mix farming (4.0 %, 3.9 %, and 3.5 %, respectively). The significantly higher organic matter content in these areas is probably caused by a higher amount of leaf litter and dead roots entering the system during the year.

Table 1. Effect of deforestation in hilly area of Sumberjaya on the soil chemical properties.

Land uses	Soil Layer (cm)	Org-C (%)	Soil pH	Tot. N (%)	Avail-P (ppm)	CEC (Cmol-c kg^{-1})
Primary Forest	0-10	3.9 ± 0.2	3.6 ± 0.2	0.37 ± 0.1	11.43 ± 3.2	21.84 ± 0.2
	10-20	1.7 ± 0.3	3.6 ± 0.1	0.21 ± 0.1	8.49 ± 3.0	17.88 ± 1.4
	20-30	1.3 ± 0.3	3.6 ± 0.1	0.10 ± 0.0	3.78 ± 1.5	12.03 ± 0.1
Deforest area	0-10	3.1 ± 0.6	5.0 ± 0.3	0.19 ± 0.1	3.63 ± 0.8	13.14 ± 1.4
	10-20	2.1 ± 0.6	4.5 ± 0.4	0.13 ± 0.0	3.39 ± 0.4	11.76 ± 0.2
	20-30	1.4 ± 0.3	4.3 ± 0.2	0.12 ± 0.0	1.45 ± 0.5	9.66 ± 1.1
Young Coffee	0-10	2.6 ± 0.2	4.6 ± 0.2	0.22 ± 0.0	8.25 ± 0.7	13.38 ± 0.2
	10-20	2.3 ± 0.3	4.3 ± 0.2	0.17 ± 0.0	9.28 ± 0.9	12.03 ± 1.9
	20-30	2.0 ± 0.1	4.2 ± 0.2	0.18 ± 0.0	1.81 ± 1.0	9.75 ± 2.2
Old Coffee	0-10	2.1 ± 0.3	3.5 ± 0.0	0.26 ± 0.1	12.90 ± 1.6	17.82 ± 1.3
	10-20	1.3 ± 0.1	3.7 ± 0.1	0.16 ± 0.1	9.81 ± 0.7	16.83 ± 0.6
	20-30	1.1 ± 0.1	3.6 ± 0.1	0.09 ± 0.1	7.33 ± 1.2	15.75 ± 1.7
Mix Farming	0-10	3.5 ± 0.1	4.2 ± 0.4	0.22 ± 0.0	21.09 ± 2.3	15.90± 1.7
	10-20	2.7 ± 0.4	4.0 ± 0.3	0.19 ± 0.0	11.97 ± 2.5	14.70 ± 2.0
	20-30	2.2 ± 0.4	3.9 ± 0.2	0.15 ± 0.0	3.63 ± 1.0	14.88 ± 0.5
Bush	0-10	4.0 ± 0.1	4.7 ± 0.2	0.28 ± 0.0	5.05 ± 1.3	18.03 ± 0.1
	10-20	3.2 ± 0.2	4.3 ± 0.2	0.23 ± 0.0	4.53 ± 0.5	15.21 ± 2.0
	20-30	2.7 ± 0.2	4.1 ± 0.2	0.24 ± 0.0	2.46 ± 0.5	15.33 ± 0.1
Imperata cylindrica	0-10	2.2 ± 0.4	4.2 ± 0.3	0.16 ± 0.0	22.64 ± 3.6	16.02 ± 0.9
	10-20	2.2 ± 0.2	4.0 ± 0.1	0.16 ± 0.0	20.50 ± 5.5	14.94 ± 0.7
	20-30	2.2 ± 0.3	3.9 ± 0.2	0.10 ± 0.0	4.07 ± 1.1	14.31 ± 0.9

The content of extractable phosphorus in the upper 5 cm of the soil was significantly higher under mix farming area (21.09 ppm) and *Imperata cylindrica* (22.64 ppm) than in the soils of the other land use systems. The lowest of extractable P was in deforest area (3.63 ppm) (Table 1).

Earthworm Population

Land use change in the hilly area forest from primary forest by slash and burn methods to the another land use does not make the change of earthworm Family. In all of land use systems, the diversity of earthworm was low, with only two family earthworms found *Pheretima*, and *Pontoscolex* (Table 2).

However, the population number of earthworm are different from among land use systems. The population number of earthworm was higher in *Imperata cylindrica* area than that of others land use. The earthworm abundance was higher in the up

Table 2. Effect of deforestation on earthworm population in a Hilly Area of Sumberjaya.

Land use	Soil Layer (cm)	Earthworm spesies	Earthworm number (individu m^{-2})
Primary Forest	0-10	-	0
	10-20	-	0
	20-30	-	0
Deforest area	0-10	*Pheretima* sp.	144
		Pontoscolex sp.	85
		Others	26
	1-20	-	
	20-30	-	
Young Coffee	0-10	*Pheretima* sp.	107
		Pontoscolex sp.	96
		Others	16
	10-20	*Pheretima* sp.	37
		Pontoscolex sp.	16
	20-30	*Pheretima* sp.	5
Old coffee	0-10	*Pheretima* sp.	32
		Pontoscolex sp.	11
		Others	11
	10-20	*Pheretima* sp.	11
	20-30	-	
Mix Farming	0-10	*Pheretima* sp.	59
		Pontoscolex sp.	22
		Others	5
	10-20	*Pheretima* sp.	10
		Pontoscolex sp.	5
	20-30	-	
Bush	0-10	*Pheretima* sp.	139
		Pontoscolex sp.	91
		Others	11
	10-20	*Pheretima* sp.	37
		Pontoscolex sp.	16
		Others	5
	20-30	-	
Imperata cylindrica	0-10	*Pheretima* sp.	165
		Pontoscolex sp.	139
		Others	21
	10-20	*Pheretima* sp.	43
		Pontoscolex sp.	32
		Others	11
	20-30	-	

layer (0-10 cm) than that of second (10-20 cm) and third layer (20-30). The highest density of earthworms was found in the *Imperata cylindrica* at the up layer (165 individuals m^{-2}), and the lowest in the soils under primary forest (Table 2). *Pheretima*, sp. is the earthworm species dominant in all of land use change.

The same as earthworm number, earthworm biomass was higher in *Imperata cylindrica* area, followed by young coffee plantation and deforest area (Table 3). *Pheretima* sp. more abundance and bigger than *Pontoscolex* sp.

Table 5. Effect of deforestation on earthworm biomass in a Hilly Area of Sumberjaya.

Land use	Soil Layer (cm)	Earthworm spesies	Earthworm biomass g m^{-2}
Primary Forest	0-10	-	0
	10-20	-	0
	20-30	-	0
Deforest area	0-10	*Pheretima* sp.	22
		Pontoscolex sp.	13
		Others	4
	10-20	-	
	20-30	-	
Young Coffee	0-10	*Pheretima* sp.	24
		Pontoscolex sp.	22
		Others	4
	10-20	*Pheretima* sp.	8
		Pontoscolex sp.	3
	20-30	*Pheretima* sp.	1
Old coffe	0-10	*Pheretima* sp.	5
		Pontoscolex sp.	2
		Others	2
	10-20	*Pheretima* sp.	2
	20-30	-	
Mix Farming	0-10	*Pheretima* sp.	9
		Pontoscolex sp.	3
		Others	1
	10-20	*Pheretima* sp.	2
		Pontoscolex sp.	1
	20-30	-	
Bush	0-10	*Pheretima* sp.	11
		Pontoscolex sp.	7
		Others	1
	10-20	*Pheretima* sp.	8
		Pontoscolex sp.	3
		Others	1
	20-30	-	
Imperata cylindrica	0-10	*Pheretima* sp.	17
		Pontoscolex sp.	15
		Others	2
	10-20	*Pheretima* sp.	8
		Pontoscolex sp.	6
		Others	2
	20-30	-	

Although, in the primary forest has a high soil organic carbon content (3.9 %), earthworm was not found. This is probably by the lowest of soil pH in primary forest. Abundance and biomass of earthworm was partly explained by the organic matter component and partly by acidity. Decreasing acidity, earthworm decreased, especially *Pheretima* sp. Different results in tropical rainforest Tobasco Mexico, earthworm densities was more abundant in the forest with had a high content in organic carbon (Huerta *et al*., 2007).

CONCLUSIONS

Soil quality is defined as the capacity of a soil within ecosystem boundaries to sustain biological productivity, maintain environmental, and promote plant and animal health. Descriptive and analytical measurement of the physical, chemical, and biological properties are sometimes used to characterized soil quality. Indicators of soil quality are needed to measure the change in soil function that occur because of alteration in management.

In our experiment, we assess the earthworm abundance and soil chemical change includes soil pH, T-N, O-C, Avail-P, and CEC to indicate changes in soil quality cause of deforestation in a hilly area. The soil chemical properties includes, T-N, O-C, avail-P and CEC were highest in the primary forest, however no earthworm was found at the primary forest. The lowest earthworm in primary forest due to the lowest pH in that area. Organic matter and soil acidity are the soil chemical parameters that show the most important influence in soil biota, especially earthworm population.

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