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The Effect of Mulching Technology to Enhance the Diversity of Soil Macroinvertebrates in Sengon-based Agroforestry Systems

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ABSTRACT

Soil macroinvertebrate are strongly influenced by environmental factors. The change of agronomic technology may affect their role in maintaining soil fertility and crop production. The aim of this study was to know the effect of technology of mulching to enhance diversity of soil macroinvertebrate in *sengon*-based agroforestry system. Field experiment was arranged in randomized block design with treatment i.e. with and without organic matter mulching. Sweet potato used as tested intercrop. Collection of soil macroinvertebrate was carried out using a hand sorting and pit-fall trap methods. Result of the study showed that application of maize residue as mulch enhanced diversity index of surface and deep soil macroinvertebrate, i.e: 0.215 and 0.214 (by 44% and 73% respectively compared no mulching). Organic mulching technology can support diversity of beneficial soil macroinvertebrates.

Key words: agroforestry, soil macroinvertebrates, sengon *(Paraserianthes falcataria),* mulching.

INTRODUCTION

Land degradation is an important part of global crisis. Rising population pressure and urbanization, combined with land degradation, soil salinization, and global warming have been causing food insufficiency. Controlling the land degradation and their rehabilitation programes may enhance land productivity and contribute to human needs (Edgerton, 2009; Kumar, 2008). Soil biodiversity conservation is an important part of agricultural dan silvicultural management to maintain their production. There are intercorrelation between soil biodiversity, especially soil macroinvertebrates with crop production (Sugiyarto, 2004). Soil macro-invertebrates influence soil processes, which may affect both the physical and chemical fertility of soils (Lavelle and Pashanasi, 1989). Soil macro-invertebrates contribute to the maintenance and productivity of agrosystems. Okwakol (1994) observed a declining trend in fauna biomass and soil chemical properties, indicating that soil macrofauna had a direct effect on soil properties. Soil macroinvertebrates maintain soil physical, chemical and biological fertility by immobilization, humification, biocontrol processes and play role as decomposer as well as soil engineer to encourage crop production (Lavelle et al., 1994; Hagvar, 1998).

Soil macroinvertebrates belong to soil macrofauna with have no vertebrates. The macrofauna consists of animals with body longer than 4 mm or wider than 2 mm, which are visible to the naked eye (Gorny dan Leszek, 1993). In total, more than 20 taxonomic groups are involved including arthropods, mollusks and earthworms. The Coleopteran or beetles tend to the most diverse (Brown et al., 2001). They can be further divided into three groups, which play different roles in the ecosystem: the epigeics, anecics and endogeics (Lavelle et al., 1994). The epigeics live and feed on surface litter including saprophagous arthropods and pigmented small earthworms, as well as predators of this group (chilopods, ants and some coleopteran). Anecics on the other hand feed on surface litter but build subterranean burrows and nests that provide shelter. They consist of some large pigmented earthworms and the majority of termite species. The endogeics live in the soil and consist mainly of termites and unpigmented earthworms. Based on their behavior and sampling technical, soil macroinvertebrates are differed to below-ground or deep soil macroinvertebrates and above ground or surface soil macroinvertebrates (Adianto, 1993; Sugiyarto, 2004).

In organic matter decomposition processes, soil macroinvertebrates contribute to fragmentation/

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comminution and facilitate to bacteria and fungi in mineralization processes (Lavelle et al., 1994). Soil macroinvertebrates also play role in nutrient transportation or distribution, enhancing properties of soil structure and soil forming. So they are important to maintain soil fertility and soil healthy (Adianto, 1993; Foth, 1994; Brown et al., 2001). Soil macroinvertebrates diversity show intercorrelation with ecosystem function, but there little information and no profound interest to their conservation (Lavelle et al., 1994; Hagvar, 1998).

Soil communities, especially soil macroinverte-brates, are strongly influenced by environmental factors, and any change in land use may change their communities (Wallwork, 1970). From the moment a natural system is modified by human activities for agricultural purposes, major changes occurred the soil environment and to the flora and fauna populations and community present (Brown et al., 2001). Simple correlation analysis indicates that soil macrofauna diversity was closely related with soil organic content, soil humidity, domination of ground vegetation and level of light penetration (Sugiyarto, 2000). Surface soil macrofauna diversity at forest habitat, especially at pine stands, were higher level than at cultivated plants habitat (Sugiyarto et al., 2002). *Schefflera aromatica* showed best influence to increase soil mesofauna diversity, compared with other forest stand at Jobolarangan forest area (Sugiyarto et al., 2001). Land-use changes from mixed forest to sengon plantation in monoculture and agroforestry system degrade diversity of macroinvertebrates. The soil macroinvertebrate in *sengon* plantation (non-agroforestry) system and in *sengon*-based agroforestry system, i.e: 0.16 and 0.09 (decreased 47% and 70%, respectively, compared with mix forest (Sugiyarto, 2004).

The effects of clearing, however, and of change in land use, on soil macroinvertebrates have not been widely quantified (Lal, 1987). The tropical rain forests, for instance, are known for their richness. Soil invertebrates diversity and abundance are strongly depend on environmental factors, especially quality and quantity of organic matter as food source and maintaining physic-chemical environment stability (Maftu'ah et al., 2002; Sari et al., 2003). The combination of the various practice adopted by farmers at a particular site are important in determining the soil fauna community and provide an important entry point and opportunity for managing their populations, enhancing their beneficial activities and reducing their negative effects on soil fertility and agricultural production (Brown et al., 2001). Organic matters management system is the key-factor in soil macroinvertebrates conservation.

Mulching is one of agronomical technology to ensure organic matter supply. To support organic matter supply in mulching technology, there is important to develop intercropping system, especially agroforestry system, with produce more crops residue. Agroforestry, or woody perennial-based mixed species production systems, has the potential to arrest land degradation and improve site productivity through interactions among trees, soil, crops, and livestock, and thus restore part, if not all, of the degraded lands. Food production either directly (producing food grains, root crops, fruits, and vegetables) or indirectly (improving soil conditions and thereby promoting understorey crop productivity especially on degraded sites) constitutes the central theme of most smallholder agroforestry practices (Kumar, 2008). There are many intercrop species producing crops residue in *sengon* (*Paraserianthes falcataria*)-based agroforestry system at Jatirejo forest resort, district of Kediri, East Java. Maize (*Zea mays* L.) is the most dominant intercrop potentially as source of crops residue (Sugiyarto et al., 2007).

The aim of this research is to study the affectivity of mulching technology in enhancing soil macroinvertebrates diversity at the *sengon*-based agroforestry system. The source of mulch is maize crop residue. Tested intercrop/ understorey species is sweet potato (*Ipomoea batatas*).

MATERIAL AND METHODS

The research was carried out in *sengon* plantation at Jatirejo forest resort, district of Kediri, East Java. The field experiment was arranged in randomized complete block design with treatment i.e: with and without organic matter mulching in four replicates. Dry maize crop residue was used as mulch with doses be equally 15 mg/ha. Soil was plowed and made pile in the same direction with *sengon* plantation line. The experiment block area was (3 x 5) m^2. Distance of these block area were 100 cm. Sweet potato used as test intercrop arranged in population be equally 67.134 plant/ha.

Collection of soil macroinvertebrate was carried out using a hand sorting method for deep soil macroinvertebrates and pit-fall trap method for surface soil macroinvertebrates in 4^{th}, 8^{th}, 12^{th}, 16^{th}, and 20^{th} weeks after planted. Samples which be collected was quantified and identified in laboratory of Biology, Faculty of Mathematics and Natural Sciences, Sebelas Maret University, Surakarta, Central Java referred to Burges and Raw (1967), Wallwork (1970), Borror et al., (1992), Gorny and Leszek (1993), and (Suin, 1997).

Soil macroinvertebrates diversity value found expression in modified Simpson diversity index (Sugiyarto, 2004) with equation:

$$D = (1\text{-}\Sigma\ (pi)^2\ (qi);$$

D: diversity index

pi: sum of individual in one species/sum of individual in total species

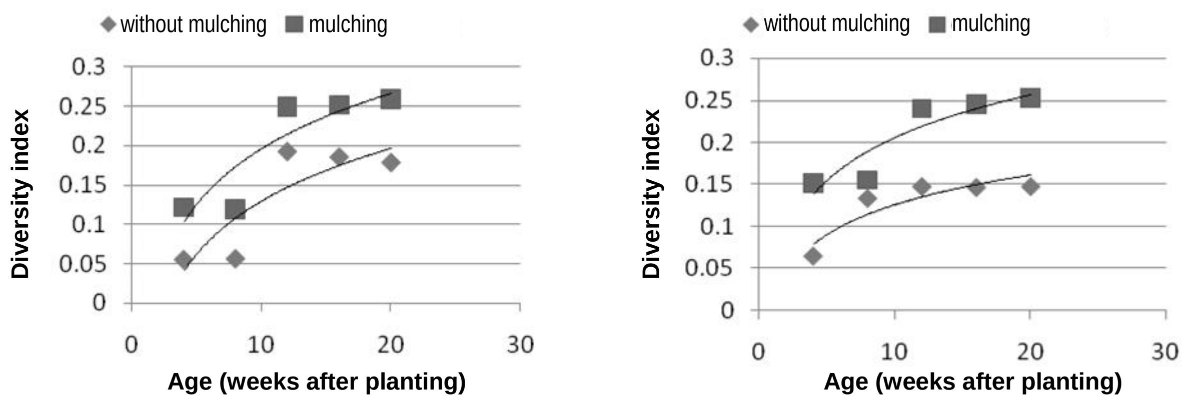
qi: sum of species in one observation unit / sum of species in all observation unit

RESULTS AND DISCUSSION

Soil is a living entity, comprising an inseparable mixture of solid, liquid and gaseous phases, and diverse fauna and flora, the below ground biodiversity. It is capable of supporting biological growth, and is in equilibrium with its environment. Soil macroinvertebrates is little part of below ground biodiversity but take important role in soil function, especially in organic matter decomposition processes and fixed up soil physical properties. Their existence showed different response to their environment, but their population tend to increase by rising of organic matter available (Crossley et al., 1992). High soil macroinvertebrate diversity and quantity were showed in complex/mixture of different organic matter or low quality (high C/N ratio) of organic matter. Sugiyarto et al*.* (2007) stated that maize, *sengon* and elephant grass residue affected higher population of soil macroinvertebrates than sweet potato and *papaya* residue application.

Result of this research showed that age of sweet potato as intercrop in *sengon*-based agroforestry system affected soil macroinvertebrates diversity (Figure 1). Increasing of sweet potato age is followed by enhancing of soil macroinvertebrates diversity index, especially on mulching application. Diversity index of surface soil macroinvertebrates increase from 0.092 on fourth week after planted to 0.228 on twentieth week after planted (enhancing 148% respectively). In the same case diversity index of deep soil macroinvertebrates increase from 0.107 on fourth week after planted to 0.210 on twentieth week after planted (enhancing 96% respectively). At without mulch application treatment showed that after twelfth week after planted both surface and deep soil macroinvertebrates diversity index tended to stable or decreased.

Covering level of intercrop at different age and mulching may be act as the major factor supported soil macroinvertebrates existence. This phenomenon explained that soil macroinvertebrates need above-ground vegetation and mulch as source of food and to protect from environmental disruption, i.e: predator, high light intensity, high temperature, force of rainfall and running off, etc. Brown et al. (2001) mentioned that common agricultural practices giving positive effect on the soil biota, i.e. organic matter (mulch, manure, etc.), less physical disturbance (tillage), green manure, soil covers, crop rotations, liming, fertilization and organic agriculture. Sugiyarto et al*.* (2007) showed that most of soil macroinvertebrates tend to avid risk of open space or high light intensity. Faunal populations often decline when natural habitats are cleared (Watanabe et al*.*, 1983). Work in the Mabira Forest Reserve in Uganda showed that forest clearance and cultivation have deleterious effects on soil macrofauna communities (Okwakol, 1994, 2000). In a few instances, however, faunal densities and diversity increase following clearing of forest or woodland. Okwakol (1994) reported soil macrofaunal density of 1247 m^{-2} in cleared and uncultivated site compared with 863 m^{-2} in the natural forest. Most of the gain was attributed to a dramatic increase in the density of termites as well as increase in the density of predatory surface-active fauna such as spiders, ants and centipedes. This trend was partly attributed to the abundant food supply for wood and litter feeding species. Collins (1980) has showed that type of vegetation has often been shown to be a major determining factor of soil fauna abundance. As land conversion occurs, the above-ground biodiversity is reduced. This impacts the associated soil macrofauna thus lowering the biological capacity of the ecosystem for self regulation. Zake et al*.* (1994) noted that banana plantations also supported estimated weight biomass of 4.55 g m^{-2} and macrofauna biomass formed a relatively similar trend to that of organic matter and banana yield.



A B

Figure 1. Surface (A) and deep (B) soil macroinvertebrate diversity index in *sengon*-based agroforestry system with and without mulching application.

This research showed that surface soil macroinvertebrates more responsive to the environment alteration than deep soil macroinvertebrates one. Differ with surface macroinvertebrates, beside be protected by above-ground material, deep soil macroinvertebrates also protected by soil itself. More, the surface soil macroinvertebrates, especially most of insects, chilopods and arachnids, can migrate to another habitat to escape or avoid some disruption. In a survey of termites in natural forest, a cleared but not cultivated site and six sites cultivated for over different periods distinct differences between systems were observed. Twenty-four species, including *Odontotermes amanicus* (Sjostedt) and *Microtermes luteus* (Harris), both not previously identified in Uganda, were recorded in natural forest (Okwakol, 2000). Forest clearance resulted in drastic reduction in the number of species to about 40% of what existed in natural forest while cultivation led to further reduction to <20%. Clearance of forests has both direct and indirect effects on termites as disturbance removes vegetation, destroys nest sites, alters the soil environment and food sources and leads to exposure to predators and parasites (Black and Okwakol, 1997). Scientists have begun to quantify the causal relationships between (i) the composition, diversity and abundance of soil organisms, (ii) sustained soil fertility and associated crop production, and (iii) environmental effects, including soil erosion, greenhouse gas emissions and soil carbon sequestration (Lavelle et al*.*, 1997).

This research result showed that mulching technology with maize residue enhanced both surface-and deep soil macroinvertebrates diversity index in *sengon*-based agroforestry system (Table 1). By mulching application surface soil macroinvertebrate diversity index enhanced from 0.149 to 0.215 (increase 44% respectively), and deep soil macroinvertebrate diversity index enhance from 0.124 to 0.214 (increase 73% respectively). This results reflected multifunction of mulch. It enhance soil macroinvertebrates directly, and also supported more expansive sweet potato growth giving good protection and source of food for soil macroinvertebrates. This showed the important role of mulch to support existence of most species of soil macroinvertebrates like the previous researcher finding (Maftu'ah et al., 2002; Sari et al., 2003). Maize residue is a low quality organic matter that decomposed slowly. Their supplies as mulch give longtime protective function for soil macroinvertebrates. On the contrary, sweet potato and *sengon's* residue on this system supplied a lot of food for soil macroinvertebrates and nutrient to ensure the vegetation growth. All of this service factors created suitable environment for soil macroinvertebrates (Sugiyarto et al., 2007).

Table 1. Soil macroinvertebrates diversity index in sengon-based agroforestry system with and without mulching application treatments.

Treatment	Soil macro-invertebrates diversity index	Dominate soil macroinvertebrates
Without mulch	0.149 (Surface)	*Odontomachus* sp.
	0.124 (Deep)	*Pontoscolex corethrurus*
With mulch	0.215 (Surface)	*Lobopelta ocellifera*
	0.214 (Deep)	*Pontoscolex corethrurus*

By mulching technology, diversity index of deep soil macroinvertebrates enhanced more dramatically than surface soil macroinvertebrates (Table 1). These indicated that mulch give long-term beneficial to amelioration of soil environment by food-web regulation. Like the previous discussion that deep soil macroinvertebrates are more stable community than surface soil macroinvertebrate. Beside creating a suitable physic-chemical environment, mulching increased surface soil macroinvertebrate potentially as food source for various deep soil predators. So directly, the increasing of surface soil macroinvertebrates population and diversity enhance diversity of deep soil macroinvertebrate. Sugiyarto (2004) concluded that there was positive intercorrelation between surface-and deep soil macroinvertebrate diversity index.

Earthworm (*Pontoscolex corethrurus*) as a soil fertility indicator dominated to deep soil macroinvertebrate community, both with and without mulching application. This species is a decomposer as well as soil engineer. On other hand, there was a difference dominancy of surface soil macroinvertebrate in mulch treatment (*Lobopelta ocellifera)* and no mulch treatment (*Odontomachus* sp.) (Table 1). *Odontomachus* sp. is a phytophage species potentially as pest, but *L. ocellifera* is a predator species potentially as biocontrol agent. These gave evidence that mulching can support to the diverse of beneficial soil macroinvertebrates. Brown et al*.* (2001) mentioned two main types of classification of soil macrofauna according their function in the soil and crop system, i.e: beneficial group (sapro-, copro-, and necrophages as decomposers or mineralizer; geophages as bioturbators and predators as biocontrol agents) and adverse group (phytophages as parasites or pests). Availability of crop residues as mulch, in other hand, may be able to be alternative food source for some phytophages so it can reduce the intensity of pest herbivory activity.

CONCLUSIONS

Enhancing soil macroinvertebrate diversity on *sengon*-based agroforestry system can be optimized by returning of intercrop residue in mulching technology. Application of maize residue as mulch enhanced diversity index of surface-and deep soil macroinvertebrate, i.e. from 0.149 and 0.124 to 0.215 and 0.214 (by 44% and 73% respectively compared no mulching). Organic mulching technology can support to the diverse of beneficial soil macroinvertebrates.

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