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Impact of Litter Quality and Earthworm Populations on Seruk Spring Forest's Soil Characteristic

(Pengaruh Kualitas Serasah dan Populasi Cacing Tanah pada Karakteristik Tanah Hutan Sumber Seruk)

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ABSTRACT

Seruk spring, located in Batu, East Java, is a spring with four different Land Use Systems (LUS) in its surrounding area, comprising a mixed, a pine, an eucalypt, and a bamboo forests. Over time, there have been changes in land use around the area of Seruk Spring. This results in a decrease in the environmental quality, and even in the spring's water discharge. As spring serves as an important part of people living in the immediate vicinity, this research aimed to determine the differences in litter quality, earthworm populations, and soil porosity at each LUS. Litter was measured in each area and analyzed in the laboratory to determine its biomass and quality. Earthworm populations and biomass were measured with the iron box method, while the soil porosity and organic matter were based on secondary data from the previous research. The correlation among all the parameters was analyzed with Principal Components Analysis (PCA) using PAST 3 software. The results showed that the bamboo forest had the most suitable land-use system around spring, based on the highest litter thickness and its quality in the area. The different qualities of each LUS provided diverse advantages for the spring ecosystem. The presence of the bamboo forest around the spring area should be conserved, to maintain the quality of the ecosystem and the sustainability of the spring area itself.

1. Introduction

Land-use change is currently a serious and widespread environmental problem, as it causes various negative effects on the ecosystem services (Polasky, Nelson, Pennington, & Johnson, 2011; Borrelli et al., 2017; Batunacun, Nendel, Hu, & Lakes, 2018). One example that needs attention is the reduction of the conservation area around springs. Changes in natural conditions around the springs result in a decrease in the recharge area of the spring water table, which can cause the spring to become dry (Mishra, Khare, Gupta, & Shukla, 2014; Astuti, Sahoo, Milewski, & Mishra, 2019). Conserving the condition of the spring area and all its supporting parameters needs to be done to maintain the sustainability of the spring for human welfare. Several parameters that can be used to evaluate Land Use Systems (LUS) that are most suitable for conserving springs including the thickness and the quality of litter which affects the level of soil fertility, as well as the presence of soil macrofauna, which affects soil porosity and which makes it easier to absorb water and the process of litter decomposition Yusnaini, Niswati, Arif, & Nonaka, 2008; Yulistyarini & Sofiah, 2011).

Litter decomposition is an ecosystem process that plays an important role in global carbon dynamics and balance. The process of litter decomposition, which also produces CO_2

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into the atmosphere, is affected by global warming (Ott, Rall, & Brose, 2012). Changes in evapotranspiration and other environmental factors such as soil moisture have a direct effect on the decomposition process. Generally, the process of litter decomposition occurs more rapidly in warmer temperatures. Changes in the plant community can also affect the litter decomposition and all its input into the soil. Springwater is one of the ecosystems that may also be affected by climate change. The vegetation in the surroundings of the spring plays a role in the hydrological process and water storage in the soil (Song, Zhou, Gu, & Qi, 2015).

Vegetation, soil, and water is a complex integration that affects each other to maintain the productivity of the terrestrial ecosystem (Zhang, Xie, Fan, & Zhen, 2010). Forest land conversion has resulted in the reduction of one of the soil functions that as water storage. Some soil properties which are related to the water balance components, such as water storing capacity, infiltration, and pore stability are affected by land use and plant species that grow in the area. Species growing in the area might affect the water cycle and balance in the system (Yagüe, Domingo-Olivé, Bosch-Serra, Poch, & Boixadera, 2016). One of the vegetation roles in water balance in the soil is to provide organic materials. It is known that organic materials can improve the availability of nutrient elements in soil, which will improve the biophysical conditions of the soil.

Land vegetation generally absorbs more water because surface litter reduces the effects of raindrops beating, and organic materials, micro-organisms, and plant roots tend to increase soil porosity and stabilize soil structure resulting in a higher infiltration rate. Soil physical characteristics are important, especially in the process of water absorption into the soil. The conversion of natural tropical ecosystems may accelerate the degradation of the soil, or even to groundwater storage (Pudjiharta, 2010; Siringoringo, 2014). Forest conversion into intensive farming was also known to have a great impact on biodiversity (Kanianska, Jad'ud'ová, Makovníková, & Kizeková, 2016).

The richness of plant species indirectly affects litter decomposition due to the number of fauna species and the activity of soil microbes (Tresch et al., 2019). In tropical climates, earthworms in the ecosystem play a role in the process of decomposition and nutrient cycling in the soil (Singh, Schädler, Demetrio, Brown, & Eisenhauer, 2019). The earthworm presence and their community structure also give a big effect on the soil structure, gas dynamics, water flow, and C/N ratio in the soil (Bertrand et al., 2015). Their presence is also significant in introducing organic matter into mineral soils and forming humus (Ponge, 2013). Earthworms are considered soil engineers, as they impact soil properties and most of which give benefits to the soil. In this case, the earthworms will be much related to the litter produced by the vegetation and have a crucial impact on the nutrient cycle for the soil quality. Moreover, through its casts deposited on the surface of the soil, earthworms will create a rough surface to decrease run-off and erosion, and the tunnel they created provides high soil porosity simultaneously (Blouin et al., 2013).

In Indonesia, research on earthworms has not been widely conducted, especially those related to their indirect benefits on a spring's conservation. Earthworm research in Indonesia was mostly related to their benefits to the agricultural area (Nurhidayati, Arisoesilaningsih, Suprayogo, & Hairiah, 2012), earthworm as bioindicator on polluted soil (Joko, Anggoro, Sunoko, & Rachmawati, 2017), and their benefit to reclamation in the mining area (Nugroho, Widuri, & Sayektiningsih, 2018). The activity of earthworms will also benefit the absorption of rainwater into the soil which will maintain the groundwater and water flow regulation (Dewi & Senge, 2015). It maintains the existence of a water source so that the water source can continue to benefit human beings. Therefore, the role of earthworms in the conservation area around a spring needs to be explored more. There are several LUSs in the recharge area of Seruk spring, including bamboo, forest area, eucalypt, and pine LUS. The land cover area of the pine LUS is the most extensive area covering approximately 51.72% or 10.27 ha of the recharge areas (Yulistyarini & Sofiah, 2011). The large pine LUS might affect water conservation. The presence of vegetation plays a considerable role in the availability of leaf litter and roots that can affect the physical, chemical, and biological properties of the soil so that it can create a good ecological environment for the hydrological balance of the spring in the area. However, although the impact of forest land-use change has been widely observed, the activity of forest land-use change nowadays is still happening.

Previous studies conducted in the conservation area around the spring in Batu City were mostly related to the vegetation composition, or the characteristic of the soil Yulistyarini, Solikin, Sofiah, & Laksono, 2009; Yulistyarini, 2011; Yulistyarini & Sofiah, 2011; Fiqa, Yulistyarini, & Arisoesilaningsih, 2018). Comprehensive research on vegetation relationships (represented by the resulting litter), soil macro biota, and soil characteristics, has never been carried out. This research is expected to provide new information regarding the correlation between these parameters for the decreasing number of spring conservation efforts in Batu City. This study aimed to compare the differences in litter quality, soil macrofauna, and soil characteristics in four types of forest surrounding the Seruk spring, to give more consideration regarding the effect of land cover in the conservation of the spring recharge areas.

2. Methodology

2.1. Study Site

This research was conducted in the Seruk Spring recharge area, Toyomarto, Pesanggrahan Village, Batu City, East Java. Geographically, the Seruk Spring is located at 07°53'02.7" S and 112°30'15.4" E, with an altitude of 1,233 meters above sea level. There are four types of forest surrounding the spring (Figure 1), which consists of pine (*Pinus merkusii*) forest (10.27 Ha), eucalypt (*Eucalyptus alba*) forest (1.97 Ha), bamboo forest (*Dendrocalamus asper, Gigantochloa atter*, and *Gigantochloa apus*) (1.80 Ha) and mixed forest more than 20 species of trees (dominated by *Trema orientalis, Ficus virens*, and *Ficus racemosa*) (0.44 Ha) (Yulistyarini & Sofiah, 2011).

2.2. Data Collection

Litter thickness was determined using a ruler from the forest floor. Biomass and litter quality were measured based on the taken plots with a size of 0.5 x 0.5 m each, with three times replication, in every observed area. The wet weight of the litter was weighed and dried furnace for 48 hours at 80°C (Hairiah, Ekadinata, Sari, & Rahayu, 2011), then the biomass of the litter was determined in each hectare. The quantities of lignin, polyphenol, cellulose, and ashes were determined with the Van Soest and Wine method (Van Soest & Wine, 1968), based on the separation of the different compounds of the material using specific reactive. The analysis process was conducted in Soil Biology Laboratory, Faculty of Agriculture, Brawijaya University.

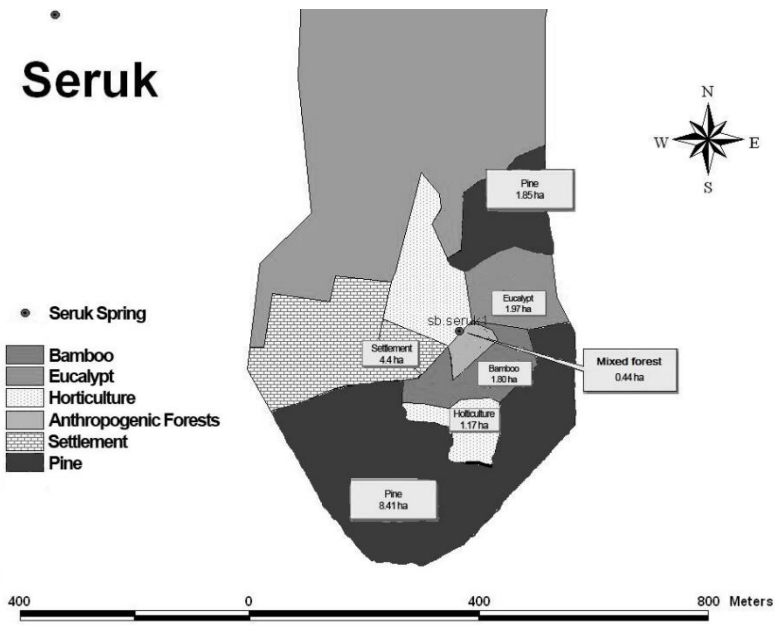

Figure 1. The Land Use System (LUS) around Seruk Spring, Batu City

Earthworm sampling was conducted in the morning. The sampling process was started by putting a steel frame measuring 20 x 20 x 10 cm into the ground (Lavelle & Spain, 2001). Excavated soils around the frame were done to limit the movement of earthworms elsewhere. Soil and earthworms' samples were taken from a depth of 0-10 cm, 10-20 cm, and 20-30 cm with three times replication. Samples of earthworms were taken manually (hand sorted) and then set in the biomass. The parameters observed were the biomass (g/m^2) and the density (individual/m^2) of earthworms.

Soil characteristics (porosity and soil organic matter), were obtained from secondary data based on the previous research. Bamboo forest and mixed forest are the native ecosystems of the recharge area, while the other two are artificial ecosystems.

2.3. Data Analysis

Analyses of variance (ANOVA) were performed to determine the differences among the four LUS (the presence of earthworm, litter quality and thickness, soil porosity, and organic matter) using the Tukey test at the level of 5% probability. The standard error of the mean for values for each land use was calculated using the three replicated samples. These analyses were carried out using the statistical software MINITAB 14. Principal Components Analysis (PCA) was done for further data analysis using PAST 3. The result was used to determine how vegetation covers impacted the environment.

3. Result and Discussion

Research results showed that bamboo forest was the most suitable LUS located around the water spring, due to its litter thickness, soil organic matter, and porosity. Based on Figure 2, showing the litter thickness measurements at the four different LUS, it was indicated that the bamboo forest area had the thickest litter compared to the other three areas. The litter thickness in the bamboo area reached about 3.68 cm, which was significantly higher than that in the pine area (1.61 cm), eucalyptus (1.17 cm), and mixed forests (2.85 cm).

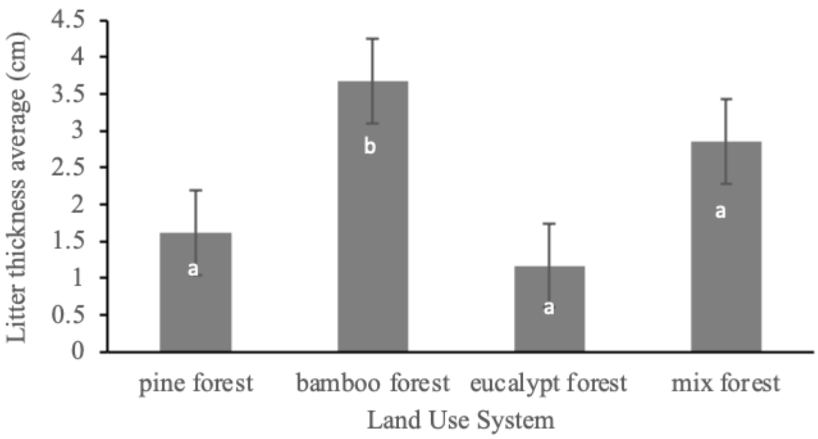

Figure 2. The thickness of litter on a variety of vegetation cover in the recharge area of Seruk Spring, Batu City with significant different of (p<0.05: a<b)

Figure 3 shows the quality of the litter thickness, in which the highest content of polyphenols was found in eucalypt LUS with a value of 20.05%. This was significantly different compared to the levels of polyphenols in the mixed, pine, and bamboo forests, with the value of 2.45%, 3.18%, and 2.42%, respectively. The highest lignin content was discovered in litter in the pine area that reached 32.25%. This was significantly different compared to the lignin content in the mixed forest (28.39%) and the eucalyptus forest (26.64%). The lowest lignin percentage was contained in the bamboo forest, which amounted to 16.39%. Litter in the bamboo forest had the highest cellulose content with 63.79%. This was significantly different compared to the cellulose contained in the pine forest litter (47.86%). The levels of cellulose in the pine forest litter were not significantly different when compared to that in the eucalyptus forest (45.22%). However, the mixed forest had significantly different levels of cellulose in a litter (40.18%), while the levels of cellulose in the litter in the mixed and the eucalyptus forests were not significantly different. The litter with the highest ash content was found in the bamboo forest, reaching 27.70%, which was significantly different from the ash content found in the mixed (15.44%), the pine (9.62%), and the eucalyptus (11.35%) forest (Figure 3).

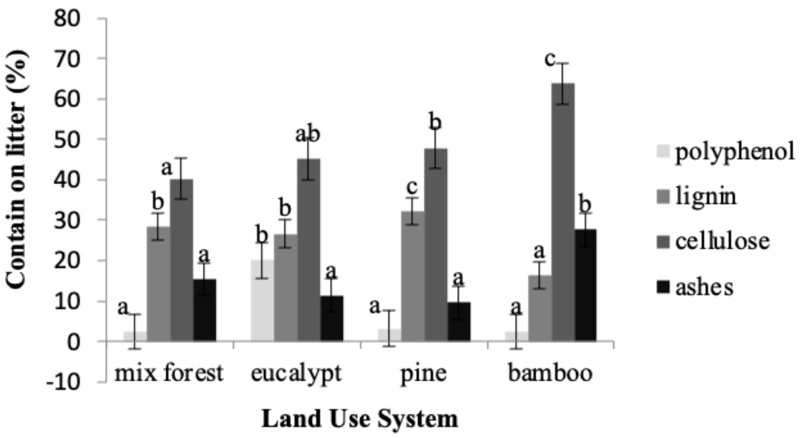

Figure 3. The content of litter on some land cover area in the recharge area of Seruk Spring, Batu City; significant different (p<0.05: a<b)

Table 1 shows that the highest worm density was found in the eucalypt forest, which was 150 individual/m^2. The bamboo forest area, on the other hand, had the lowest density of 25 individual/m^2. Similarly, the highest earthworm biomass was also found in the eucalyptus forest area (123.75 g/m^2), and the lowest was found in the bamboo forest area (50 individual/m^2) as shown in Table 1. Table 1 also indicates the value of soil porosity in each area, consisting of the mixed forest area (50.43%), the eucalypt forest area (55.45%), the pine forest area (64.13%), and the bamboo forest area (56.06 %), with no significant differences in all of the LUS. However, the pine forest area had the highest percentage that was followed by the bamboo forest area. In line with soil porosity, soil organic matters in the pine and bamboo forest areas also greater than those in the mixed and eucalyptus forest areas (9.05% and 7.09%) to (2.39% and 3.165%).

Experimental research conducted in sugarcane fields in Malang Regency showed that earthworms will be found in areas with high organic matters (Nurhidayati et al., 2012), but this condition was not found in this study. However, research conducted in the peat forest in Central Kalimantan showed a similar result, where the area with a high litter thickness was not a preferred habitat for earthworms (Maftu'ah & Susanti, 2009). Therefore, the number of earthworms found in the bamboo forest area tended to be low.

LUS that might conserve the spring recharge area better than the others was bamboo LUS. The bamboo forest produced the highest litter thickness in the area (Figure 2) and had the highest soil organic matter and soil porosity (Table 1), which was significantly different from the other forest area. The bamboo forest, which had high cellulose and ashes on its litter (Figure 3), benefited the environment. A high litter thickness, as well as cellulose and ashes contained in the litter, gave a positive impact on the soil organic matter and soil porosity (Figure 4). The differences in the land cover system will affect both the quality of litter inputs, quantity, and sustainability. Litter of the various plant species will have a changing effect on the process of litter decomposition. It is reported that bamboo litter undergoes slow decomposition because as a woody monocot, bamboo has a higher density of wood and cellulose fibers (Liu et al., 2015).

The results from the main component analysis performed on litter quality, earthworm populations, and soil characteristics in four different LUS, were grouped into two main components. This was indicated by the value of eigenvalue >1. The two new components explained 87.32% (the first component was 64.71% and the second component was 22.61%) of the observed variables. The first component had relatively greater information than the second component. Based on the above component analysis, the following was the eigenvalue value of each component (Table 2). Component one provided more information than component two. Cellulose was the litter content component that had the most influence on component one (PC1). Polyphenols were the litter content components that had the most influence on component two (PC2). However, Figure 3 showed that the most closely correlated variables in the eucalypt forests were the earthworm's density and biomass, whereas in the bamboo forest LUS was ashes and cellulose. For the decomposers, in the process of digestion, decomposing cellulose was preferable to decomposing lignin (Talbot & Treseder, 2012).

Table 1. The mean value of earthworms' density and biomass with soil organic matters and porosity in each LUS

Land cover	The Density of earthworms (individual m^{-2})	Biomass of earthworms ($g\ m^{-2}$)	Soil organic matter (%)*	Porosity (% vol)*
Mix forest	50^{b}	110^{b}	2.92^{a}	51.53^{a}
Eucalypt	150^{c}	123.75^{b}	3.17^{a}	55.83^{b}
Pine	50^{b}	33.75^{a}	7.09^{b}	52.50^{ab}
Bamboo	25^{a}	25^{a}	8.56^{b}	62.47^{c}

Remarks: Different notation showed significantly different values ($p<0.05$: a<b); * (Yulistyarini, 2011)

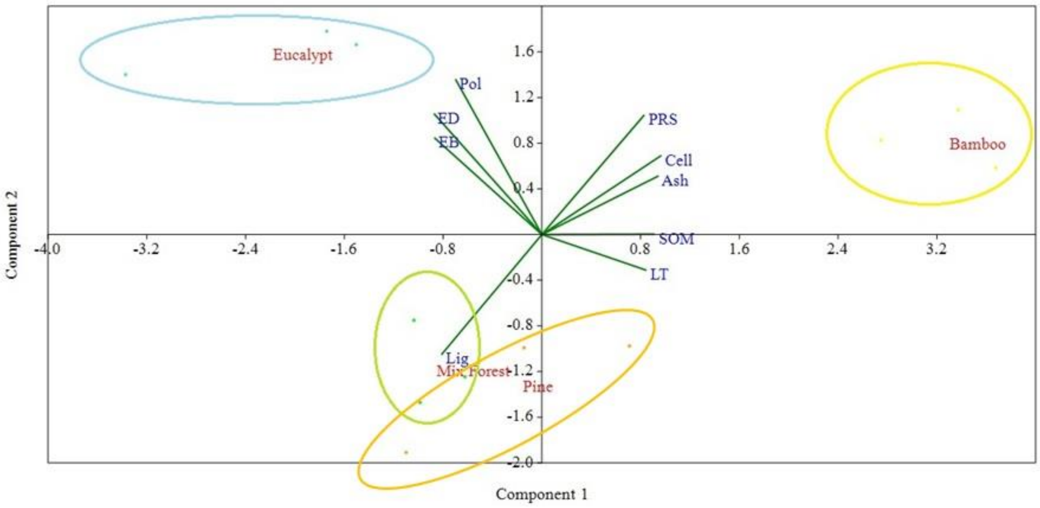

Figure 4. Correlation between litter, soil macrofauna, and soil characteristics in Seruk Spring recharge area (PC 1: 64,709% and PC 2: 22,606)

Table 2. Eigenvalue on litter quality, earthworm's population, and soil characteristic in four different LUS

	PC 1	PC 2
Eigenvalue	**5.82378**	**2.0345**
% variance	**64.709**	**22.606**
Variable		
Litter Thickness	0.3256	-0.12022
Lignin	-0.31345	-0.4053
Polyphenols	-0.26974	0.52441
Ashes	0.3638	0.19774
Cellulose	0.37262	0.26659
Earthworm Biomass	-0.33556	0.32675
Earthworm Density	-0.33681	0.40806
Porosity	0.31964	0.40351
Soil Organic Matter	0.35153	0.0011036

Thick litter in the bamboo forest supported the hydrological function of the recharge area of the spring. As stated by Lu, Liu, Hwang, & Wang (2007), the abundance the abundance of bamboo fine roots serves not only as a source of organic material that helps the development of soil structure, but also forms channels for water movement at the root of the mildew. Therefore, LUS bamboo has been recommended for recharge spring area management (Yulistyarini & Sofiah, 2011). Bamboo adds a great amount of organic matter to the soil (Uluocha, Udeagha, & Umeojiakor, 2016). The presence of canopy cover, basal area, lower plants, and litter will increase soil organic matter, so the soil will contain many microorganisms. This will invite the micro and macrofauna soil, which in turn will speed up the process of mineralization and the decomposition by soil microorganisms will run faster.

The rate of litter decomposition in the mixed forest consisting of various plant species increased compare to that with one plant species only, due to the presence of additional substances from the exudate in the mixed forest litter. This rate of decomposition can change faster or slower, or interact positively or negatively than expected (Ge et al., 2013). The mixture of various species of litter causes the transfer of nutrients between litter components, due to differences in the quality of the litter content (Pan et al., 2020).

Based on the tree density, the pine LUS had the highest density of trees than any other LUS. However, the litter of some pine species, eucalypt species, and the natural forest had no significant different decay time that can be referred to (Demessie, Singh, Lal, & Strand, 2012). This is made sense that the level of litter thickness in the three areas is not significantly different as reported in this study. A thick layer of litter will increase soil organic matter since its thickness is associated with the process of decomposition and mineralization, in addition to other functions such as protecting soil from erosion and avoiding soil from direct rainwater (Fiqa & Sofiah, 2011; B. Zhang, Wang, Yao, & Bi, 2013; Li, Niu, & Xie, 2014). However, ecological interactions by the soil microbial community are also impacted by secondary metabolites released by the surrounding vegetation. Pine and eucalypt produce secondary metabolite, and this might give an effect on the soil microbial living in the area and working as litter degrading agents in the area.

Litter consists of various organic compounds that are relatively different between plant species (Krishna & Mohan, 2017). From the four observed area, the lowest litter quality was found in the eucalypt forest due to polyphenols and lignin contained in its litter which was very high with 20.05% and 26.64%, respectively. This indicates a slow decaying litter. The other area was the pine forest. Pine litter contains polyphenols which are relatively good (3.18%), whereas lignin content was categorized as high (32.25%). The lignin percentage in the pine forest in this study was similar to that reported by Rahman & Motiur (2012) which was about 29.3%-37%. Lignin is a chemical compound (together with cellulose) that negatively influences the rate of decomposition due to its compound that is quite resistant to the decomposition process Rindyastuti & Darmayanti, 2010; Rahman & Motiur, 2012). The highest polyphenol (tannin) contained in the litter in eucalyptus LUS with 20.05%.

However, based on the research in Korea during the ten-weeks decomposition of leaves, pine needles reduced mass was only 23.6%-30.4% (Chae et al., 2019). It shows that the pine litter needs a long time to decompose. Litter quality has become one of the important factors that regulate the rate of litter decomposition (Zhang, Zou, & Siemann, 2017), which varies according to the plant species.

Different LUS showed significant different results on earthworms' density, biomass, and soil organic matter, while porosity in the four study areas did not show any significant differences. The same result was also indicated in the research conducted by Chotimah, Wasis, & Rachmat (2020) in Bogor. The eucalypt forest had the highest earthworm density and biomass, in contrast to the bamboo forest which had the lowest density, while the two other areas had the same earthworm density. Paoletti (1999) also obtained a similar research result, where the biomass of earthworm in the tropical forest was higher than the earthworm biomass in the coniferous forest (pine forest), but the earthworm density in the coniferous forest was higher than that in the tropical forest. However, the species richness of earthworms in the tropical forest was higher than the other LUS. The earthworms in the pine forest were found in large numbers but the biomass was lower than that in the mixed forest area.

Eucalypt is planted side by side with grass used by farmers as animal feed. The application of fertilizer is carried out regularly by farmers to maximize the growth of fodder grass. This what has caused the density and biomass of earthworms in the eucalypt area to increase. This also happened to the research conducted by Haynes, Dominy, & Graham (2003) which found that earthworms gather in the area of animal feed grass plantations, due to fertilization applied in the area. The earthworm is a key species that can indicate the soil conditions in an area. Its presence, quantity, and density are used as indicators of the soil quality in the area (Blouin et al., 2013).

The value of soil porosity in each area as follows, mixed forest area (51.53%), eucalypt forest area (55.83%), pine forest area (52.50%), and bamboo forest area (62.47 %). The bamboo forest showed the highest percentage followed by the pine area. In line with soil porosity, soil organic matter in the bamboo forest and the pine forest area was also greater than that in the mixed forest and the eucalyptus forest (8.56% and 7.09%) to (2.92 % and 3.17%). The pine LUS was located next to agricultural land which is also likely to be fertilized periodically (See Figure 1). This might be the cause of the large amount of soil organic matter found in the pine area. (Six, Bossuyt, Degryze, & Denef, 2004) indicated that litter, earthworms, soil porosity, and soil organic matter had a coherent relationship.

The differences in physical properties and chemical characteristics of soil can cause differences in furthering the ability of soil water. Increasing the quality of soil organic matter due to the availability of litter can support the stability of soil physical properties, such as soil porosity. Soil macropore has a large role in the rate of water absorption into the ground, and this condition will also help to conserve water as well.

4. Conclusion and Recommendation

4.1. Conclusion

The bamboo forest was the most suitable land-use system (LUS) around the spring for recharge area. This was based on the highest soil organic matter and porosity due to the thickness and quality of litter in the area. The eucalypt forest had the highest earthworm density and biomass. Each LUS had advantages in terms of each characteristic that might give a good impact on the Seruk Spring.

4.2. Recommendation

To maintain the existence of the water sources, conservation efforts should be carried out more thoroughly. The existence of various types of LUS around the area needs to be preserved provided they support the sustainability of the water source. Similar research needs to be conducted in other water source areas, to discover the similarities or differences in patterns in different areas.

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