EARTHWORM POPULATION AT THE POST COAL MINING FIELD IN EAST KALIMANTAN, INDONESIA

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EARTHWORM POPULATION AT THE POST COAL MINING FIELD IN EAST KALIMANTAN, INDONESIA. Coal mining activities in Indonesia result in heavy soil degradation and significant decrease in earthworm population. This study aims to explore the population of earthworms at different ages of the plant in the post coal mining rehabilitation areas. PT. Kideco Jaya Agung, East Kalimantan. In this study, 5 samples (30 cm x 30 cm, 20 cm depth) of soil were collected from 5 rehabilitation sites. Sites were selected based on age after rehabilitation: 2, 4, 6, 8 and 10 years after replanting, and sampled with 20 m distances between samples to determine earthworm population. The depth of litter layer and species of plants were also recorded at each site. Chi square analysis was conducted to determine the significance of earthworm density in rehabilitation sites at different ages, while correlation analysis was conducted to determine correlation between litter thickness and the number of earthworms found in the research sites. Only 2 species of earthworms were found in this study; their abundance increased in line with the age of rehabilitation areas. The number of earthworms (density) at 10 years after rehabilitation was almost similar to that in the natural forests. In conclusion, planting tree species producing significant amount of litter might stimulate the earthworm community and initiate succession. It might also take more than 10 years to return to the previous state for the earthworms in terms of density after land rehabilitation of the coal mining areas is conducted.

Keywords: Coal mining, earthworm, litter, rehabilitation

POPULASI CACING PADA LAHAN BEKAS TAMBANG BATUBARA DI KALIMANTAN TIMUR, INDONESIA. Aktivitas pertambangan batubara di Indonesia telah menyebabkan kerusakan tanah yang parah dan menurunkan tingkat populasi cacing tanah. Penelitian ini bertujuan untuk mempelajari populasi cacing tanah di berbagai umur tanaman rehabilitasi pada lahan bekas tambang batubara, di PT Kideco Jaya Agung, Kalimantan Timur. Pada penelitian ini, untuk mengetahui populasi cacing dilakukan dengan mengambil sampel tanah pada lahan rehabilitasi dengan umur tanaman 2, 4, 6, 8, dan 10 tahun, sebanyak 5 sampel setiap tingkatan umur dengan ukuran 30cm x 30cm, kedalaman 20cm. Jarak antar sampel 20m. Ketebalan serasah juga diukur pada setiap sampel yang diambil. Analisis chi square dilakukan untuk mengetahui tingkat signifikansi kerapatan cacing pada setiap tingkatan umur rehabilitasi, sedangkan analisis korelasi dilakukan untuk mengetahui hubungan jumlah cacing dengan ketebalan seresah. Hasil penelitian menunjukkan bahwa hanya ditemukan 2 jenis cacing tanah dari semua lahan rehabilitasi, dimana jumlah populasi meningkat pada tiap tingkatan umur tanaman rehabilitasi. Namun demikian, populasi cacing pada lahan rehabilitasi dengan umur tanaman 10 tahun hampir sama dengan jumlah populasi cacing tanah pada hutan alam. Secara umum, penanaman pohon yang menghasilkan banyak serasah mampu menstimulasi peningkatan populasi cacing tanah dan menginisiasi suksesi. Selain itu, diperlukan waktu lebih dari 10 tahun bagi lahan bekas tambang batubara agar kerapatan cacing tanah kembali, seperti semula setelah dilakukan rehabilitasi.

Kata kunci: Tambang batubara, cacing tanah, serasah, rehabilitasi

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I. INTRODUCTION

The most common method in extracting coal in Indonesia is open pit mining. In this method, soil surfaces including its vegetation are removed before the coal is extracted (Endriantho, Ramli, Hasanuddin, & Hasanuddin, 2013). This method is often applied in this country because the abundant coal deposits are located closely to the earth surfaces. Although this method is considered to be the cheapest, open pit mining method results in several problems; heavy soil damage and soil compaction due to heavy vehicle activities (Haigh et al., 2015); soil erosion and sedimentation because of direct rainfall exposure to the open soil surfaces (Zhao et al., 2013); and an increase in toxic heavy metal in the soil, resulting in significant decrease of soil fauna population (de Quadros et al., 2016).

The open pit mining method in coal extraction also produce on acid mine drainage due to weathering processes in the dumping areas, leading to the oxidation of sulphide minerals, known as pyrite (FeS_2), which is in turn reducing soil fauna population (Simate & Ndlovu, 2014). Furthermore, a review conducted by Arnold and Williams (2016) reported that open pit mining could also create irreversible disturbances to biotic and abiotic ecosystem components including soil faunas. Thus, open pit mining method to extract coal results in negative consequences to the soil environment including earthworms and other soil faunas.

Earthworms could improve soil fertility and quality due to their role in litter decomposition and burrowing activities. In post mining areas, earthworms play important roles in improving and returning the soil quality in the rehabilitation areas. A study conducted by Pagenkemper et al. (2015) reported that earthworm activities improve soil properties such as bio-porosity, resulting in more favourable soil condition for the plants to grow. Moreover, Arnold and Williams (2016) reported that earthworms and other soil macro-faunas in the post mining rehabilitation areas are able to improve the macropore configuration, nutrient cycling and hydrological processes.

In addition, earthworm population could also be an indicator for restoration accomplishment in some restoration projects, as reported by Le Bayon, Bullinger-Weber, Gobat, and Guenat (2013), Barton and Moir (2015), Finngean, O'Grady, and Courtney (2018). It means that earthworm recolonization in the post mining rehabilitation areas is an essential feature in the post coal mining rehabilitation areas. Boyer and Wratten (2010) concluded that earthworms play important roles in accelerating restoration process and re-establishing the ecosystem functions in the post coal mining rehabilitation areas. Therefore, it is important to determine the earthworm population dynamics in the rehabilitation areas including in the post coal mining.

So far, research in earthworm population dynamic in the post coal mining areas have rarely been conducted in Indonesia. Mainly, studies related to coal mining impacts in Indonesia focus on rehabilitation methods and strategies (Ardika, 2013; Endriantho et al., 2013; Lizawati, Kartika, Alia, & Handayani, 2014); plant species selection for rehabilitation (Mawazin & Susilo, 2016; Susilo, 2016); vegetation structure and succession (Riswan, Harun, & Irsan, 2015; Soegiharto, Zuhud, Setiadi, & Masyud, 2017); and social aspects of coal mining activities (Apriyanto & Harini, 2013; Hidayat, Rustiadi, & Kartodihardjo, 2015). Meanwhile, Wibowo and Slamet (2017) conducted a study to determine soil macrofauna diversity in the post mining areas, however, the study was conducted in the post silica mining areas. In addition, Hilwan and Handayani (2013) studied the diversity of soil mesofauna and macrofauna in the post tin mining areas. Thus, studies focussing on earthworm population dynamic in the post coal mining areas are essential. This paper determines the population dynamics of earthworms at different ages of rehabilitation plants in the post coal mining rehabilitation areas in a coal mine in East Kalimantan, Indonesia. This study was important to determine the duration of earthworm population to recover from heavily degraded soil and the factors influencing the recovery processes.

II. MATERIAL AND METHOD

A. Study Site

This study was conducted in a coal mine operated by the company PT. Kideco Jaya Agung, East Kalimantan, Indonesia, which was the third largest coal mining company in Indonesia (Figure 1.) The company has been established in 1982 and began to produce coal in 1993, while the rehabilitation of coal mining areas has been conducted since 1995 (Kideco, 2016). The research sites were located at five rehabilitation areas determined by the age of rehabilitation plants, which are managed by the company. However, although the company has conducted the rehabilitation activities since 1995, which meant that the company have some 17-years old rehabilitated areas, and it was hard to find some rehabilitated areas with plants more than 10 years of age because accurate locations were not provided.

Before the mining activities were conducted, the previous landscape in Kideco mining concession areas were dominated by primary and secondary tropical forests. This was the common features of pre-mining landscape in East Kalimantan, Indonesia. The company's total concession areas is about 23,000 ha located on dedicated forest areas granted from the Ministry of Forestry after applying concession scheme of forest areas. However, based on the regulations, the company could not occupied all of the concession areas and obliged to rehabilitate the damaged areas before returning the concession areas back to the government.

B. Methods

The earthworm collection was conducted in December 2012 by applying a purposive sampling method in the rehabilitation areas at different ages; 2, 4, 6, 8 and 10 years, which were determined by the time after rehabilitation. In this study, there were at least two main considerations in deciding and locating the samples: accessibility and safety. Some locations might no longer be accessible because there was no road maintenance. This was due to the coal extraction was finished. In addition, some locations were not save even if they were accessible because they were too close to the coal extraction activities using heavy vehicles.

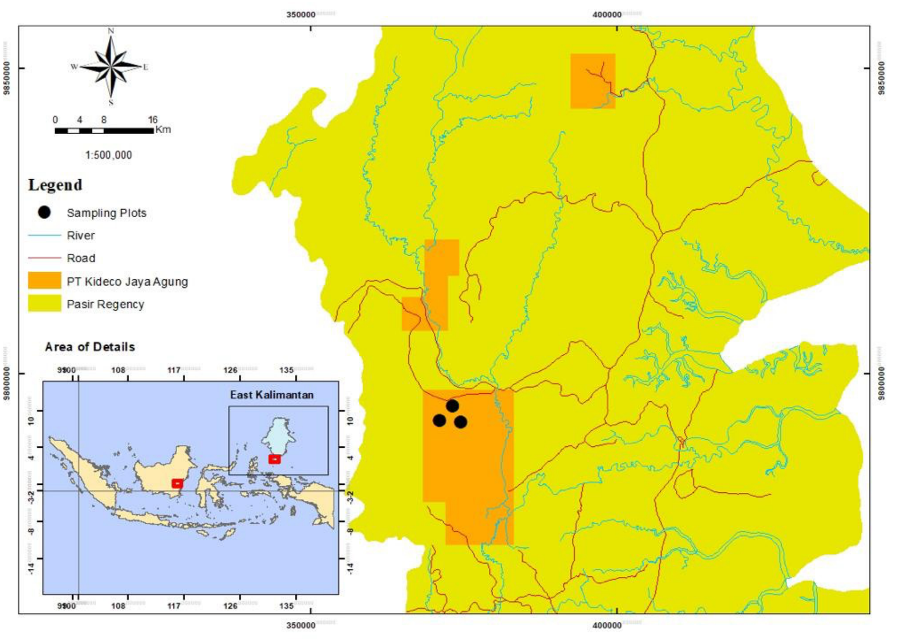

Figure 1. The Kideco company site location

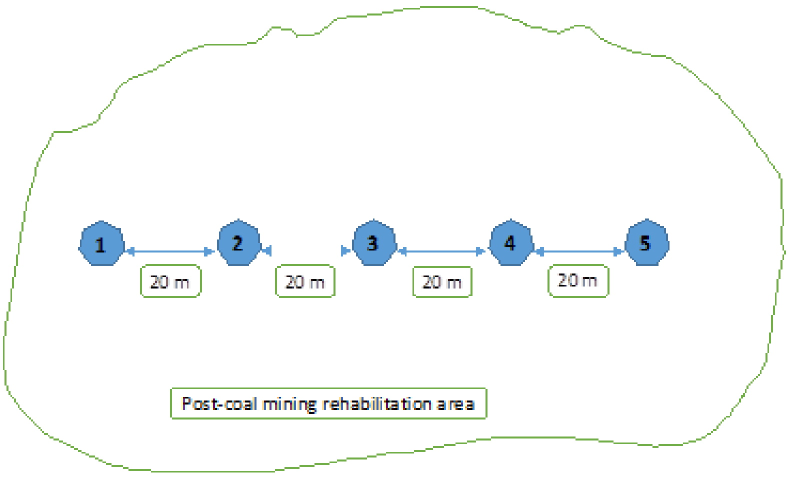

Figure 2. Illustration of sample placement at each of the rehabilitation area

The information about the age of the rehabilitation was obtained from the company's internal documents. To reduce the variability between rehabilitation sites, the study sites were placed as close as possible to each other using map provided by the company. For example, one year old rehabilitation areas should be as close as possible with 2 years old rehabilitation areas. This method was also applied in several earthworm and other soil biota studies (García-Pérez, Alarcón-Gutiérrez, Perroni, & Barois, 2014, Birkhofer et al. 2012).

In each of the five rehabilitation areas, transects were established and five soil samples were collected, with 20 m apart along the transect (Figure 2). Thus, in total of 25 samples were collected, each measuring 30 cm x 30 cm square, with 20 cm of depth (a soil block). The earthworms in each of the soil blocks were manually counted by hand-sorting in the field. In this method, each of the soil blocks was spread on a white paper and then, the earthworms were collected. Then, the earthworms were inserted in a bottle of formalin preservative liquid for later identification in the laboratory. Meanwhile, the litter depth was also measured at 3 points for each of the samples.

The hand-sorting method to count earthworms in this study had been applied in some soil macro fauna studies. This method has been acknowledged and standardized in Europe (Römbke, Sousa, Schouten, & Riepert, 2006) and it had several advantages in applying in the field; cheap and reliable (Schmidt, 2001; Smith, Potts, & Eggleton, 2008). However, the hand-sorting method had also some critics as it needs more human resources and less efficient (Jimenez, Lavelle, & Decaëns, 2006; Schmidt, 2001), therefore methods such as wet sieving to improve the accuracy was developed. Nevertheless, the extra methods to improve the accuracy were unable due to the limited transportation facilities. Especially, for the rehabilitation areas which have been abandoned for long period of time, there was no road maintenance, resulting in difficulties to access the areas.

C. Analysis

Taxonomic identification was conducted in the laboratory of *Balitek* KSDA (Research Institution of Natural Resources Conservation Technology) based on book entitled: *'Biologi Tanah: Ekologi dan Makrobiologi Tanah'* (Soil Biology: Ecology and Soil Macro-biology) written by Hanafiah, Anas, Napoleon, and Ghofar (2005). However, the taxonomic identification of the earthworms found in this research was only conducted up to the genus level determined from the morphological characteristics of the animals. Earthworm identification up to the species level was unable to be conducted due to limited resources in the laboratory. As a consequence, the determination of the earthworm's characteristics (ecotype) in detail based on the type of food and how to find the food could not be conducted. Furthermore, although larger size of squaresamples (30 cm x 30 cm) was applied to prevent disturbances, instead of 25 x 25 cm as suggested by Smith et al. (2008), it was unable to measure the length and diameter of the earthworms; length and diameter because the animals were in incomplete shape due to disturbances in the transporting process of the materials.

Chi square (X^2) statistics analysis was conducted to determine the significance of earthworm density in rehabilitation sites at different ages using a software "S plus 8". Based on a book entitled "*Statistika untuk Penelitian*" (Statistics for Research) written by Sugiyono (2005), chi square analysis is a non-parametric statisticto analyze data, which was obtained by counting, not measuring. Here, it was considered that the earthworms found in the point sample were counted. Moreover, at some point samples, earthworm was not found, which resulted in zero values. Therefore, non-parametric statistics were suitable for the statistic analysis in this study. Hypothesis used in this analysis were:

H_0: There was no significant difference in the earthworm density found at rehabilitation sites at the different ages

H_1: There were significant differences in the earthworm density found at rehabilitation sites at the different ages

In addition, statistics analysis using Microsoft Excel software was also conducted to determine correlation between litter thickness and the number of earthworms found in the research sites in chronological sequences.

III. RESULT AND DISCUSSION

A. Earthworm Abundance at the Different Ages of Rehabilitation Areas

Results showed that only two genus of earthworms were identified, which belong to two families in the coal mining rehabilitation areas in all ages of the rehabilitation areas (Table 1). The population of earthworms found in the ten years old rehabilitation areas was almost five times higher than the population of earthworms found in the two years old rehabilitation areas. There was a trend that the total number of earthworms found increased in accordance with the age of the rehabilitation areas. It was confirmed in the Chi square (X^2) analysis, which showed that there was a significant difference in earthworm density at rehabilitation sites from the age of 2, 4, 6, 8 and 10 years in this study. At 0.05 significance level ($\propto = 0.05$), X^2 value was 74.4, compared to X^2 table 9.488. As a result, H_0 was rejected and H_1 was accepted. Therefore, it can be said that there was a significant increase in the earthworm density in the rehabilitation sites from the age of 2 years to 10 years.

In this study, *Pheretima* sp. was the dominant earthworm species found in this research because this species was found in the rehabilitation areas at all ages of the rehabilitation. *Pheretima* sp. was a species of earthworm, which could widely be found in several parts of Asia such as China (Fang, Liu, Zhou, Yuan, & Lam, 2014), Thailand (Iwai, 2017), Philippines (Aspe & James, 2018), Vietnam (Nguyen, Tran, & Nguyen, 2014) and

Table 1. The average population density of earthworms found in 2 to 10 years old rehabilitation areas in the post coal mining rehabilitation areas

Type of genus	Family	2 years	4 years	6 years	8 years	10 years
		Density (animal/m^{-2})				
Pheretima sp.	Megascolecidae	16	9	49	60	78
Lumbricus sp.	Lumbricidae		4	9		
	Total density	**16**	**13**	**58**	**60**	**78**

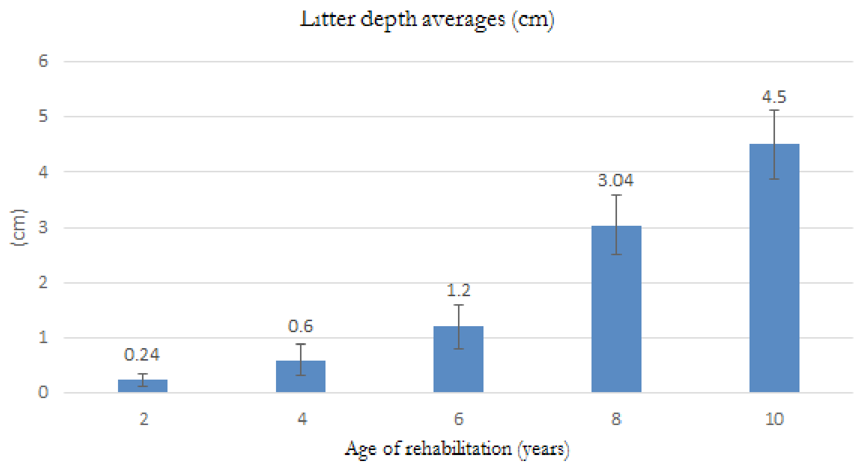

Figure 3. Litter layer depth at the different ages of the rehabilitation areas in the post coal mining rehabilitation areas

Table 2. Rehabilitation plant species planted in the concession areas of a coal mining company

Age of rehabilitation plants	Species
2	Sengon (*Falcataria moluccana*), sengon buto (*Enterelobium cyclocarpum*)
4	Sengon (*Falcataria moluccana*)
6	Sengon (*Falcataria moluccana*)
8	Akasia (*Acacia mangium*), sengon (*Falcataria moluccana*)
10	Sengon (*Falcataria moluccana*)

Malaysia (Teng et al., 2013). On the other hand, *Lumbricus* sp. could only be found in four and six years of age of the rehabilitation areas. This might be due to the characteristic differences between *Pheretima* sp. and *Lumbricus* sp. A study conducted by Anwar (2013) reported that *Pheretima* sp. was a geophagus earthworm species, characterized by soil as the main source of food and its capability in inhabiting low pH and low organic matter soil environment, which were the main feature of ultisol type of soil. Meanwhile, it was reported that *Lumbricus* sp. could be found in most parts of Europe (Milutinović, Tsekova, Milanović, & Stojanović, 2013). Hendrix et al. (2008) reported that *Lumbricus* sp. was native to Europe. However, this species was also introduced from Europe to several regions such as North America (Shartell, Lilleskov, & Storer, 2013; Stojanović, Tsekova, & Milutinović, 2014), Australia (Martinsson et al., 2015) and Asia (Hendrix et al., 2008). Therefore, *Lumbricus* sp. could be categorized as non-native earthworm species in Indonesia.

Meanwhile, the litter depth of the rehabilitation plants at the age of two to ten years was presented in Figure 3. From the results, the litter depth increased in accordance with the age of the plants in the rehabilitation areas. The litter in the 10 years old rehabilitation sites was more than 20 times thicker than the litter in the two years old rehabilitation plant sites. This might be related to the type of species planted in the rehabilitation areas, which were fast growing plant species (Table 2). This type of plant species might be able to produce significant amount of litter in relatively short period of lifetime. A review conducted by Krisnawati, Kallio, and Kanninen (2011) by comparing the growth of *Acacia mangium* in several studies reported that, this species produced about 12–17 tonnes/ha of biomass at the age of one year, which then the production was significantly increasing to

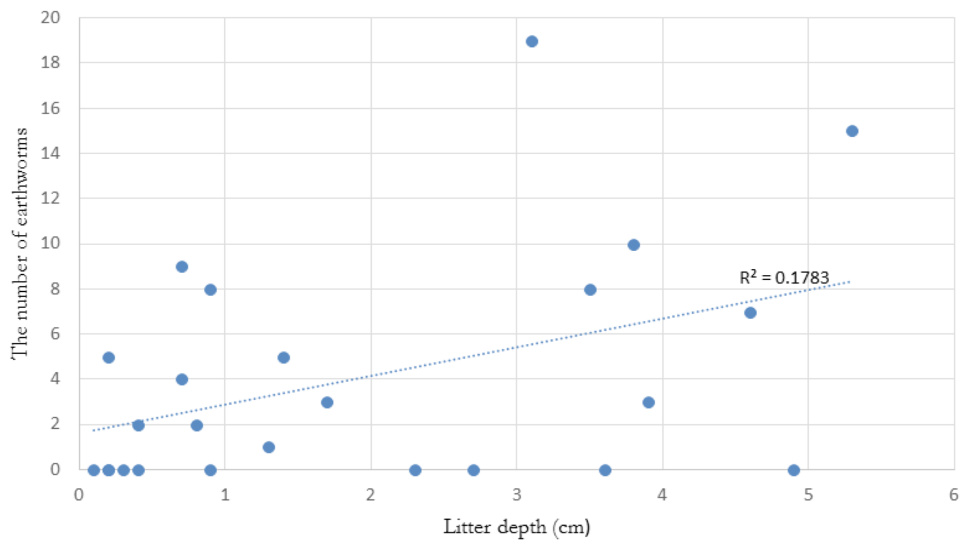

Figure 4. Relationships between litter depth and the number of earthworm found in the research sites

83–241 t/ha at the age of 10 years. In addition, Munawar and Suhartoyo (2013) reported that *Falcataria moluccana* produced 10.6 tonnes/ha litter. This indicated that fast growing plant species generated significant amount of litter, resulting in thick litter layer on the soil surfaces.

Figure 4 showed the relationship between earthworm population and litter depth in the post mining rehabilitation areas. The result of correlation analysis showed that correlation coefficient (R) between litter depth and the number of earthworms was 0.422, indicating that there was a positive linear correlation, in which the increase in litter depth was followed by the increase in the number of earthworms. On the other hand, the litter depth increased in accordance with the age of rehabilitation plants. Here, the production of litter increased as the rehabilitation plants grew. However, the correlation analysis showed that correlation determination (R^2) between the number of earthworms and litter thickness was only 0.17, indicating that there was a low correlation between the number of earthworms and litter thickness. It indicated that the increase in litter quantity were not the dominant factor causing the increase in earthworm population in the rehabilitation sites.

B. Factors Causing Increasing Earthworm Population in Rehabilitation Areas

In this study, litter quantity was an important factor that influenced the population of earthworms in the soil by providing favourable habitat for the earthworm as well as source of food. A study conducted by Abakumov, Cajthaml, Brus, and Frouz (2013) reported that rehabilitation plants accelerated C and N content in the soil, decreasing pH and increasing the amount of humic and fulvic acids, which in turn accelerating soil biotas colonization. Yatso and Lilleskov (2016) reported that leaf litter and soil type were essential factors influencing earthworm population growth. Meanwhile, Zhao et al. (2013) conducted a study by investigating the chronosequence impact of vegetation in the open cast coal mining areas from 1 to 13 years. The study revealed a significant increase in organic matter produced by the plants. The study also concluded that litter accumulation could initiate the succession in the post coal mining rehabilitation areas. Therefore, combined with the food availability, the litter thickness created favourable environment for the earthworm population to grow.

Food availability was a primary factor in influencing the earthworm population in the post coal mining areas. This was also confirmed by Hlava, Hlavová, Hakl, and Fér (2015), who had conducted a study about succession in post opencast mining area. The study found that the population of earthworm in the forestry reclamation areas was higher compared to the population of earthworm in the agricultural reclamation areas, due to high food availability in the forest reclamation areas. The other research conducted by Emmerling (2014) reported that earthworm population in the 3 years un-cultivated area was higher than the earthworm population in the cultivated maize area due to the high availability of harvest residues as a source of food. Meanwhile, Kuntz et al. (2013) also reported that population of earthworm in reduced tillage farming system was higher than earthworm population in the conventional farming system because the food availability in the reduced tillage was more abundant.

On the other hand, the increasing population of earthworms in the study sites also had positive effects to the plants in the rehabilitation areas. The soil quality increased due to earthworm movement and activities in the soil, improving growth of the rehabilitation plants. A study conducted by Frouz, et al. (2013) concluded that earthworm bioturbation improved the soil development resulting in positive impact to the trees in the post mining afforested sites. In addition, a review conducted by Jouquet, Blanchart, and Capowiez (2014) reported that earthworms had several important roles in the post mining restoration; de-compacting soil, influencing water infiltration to control erosion, and improving soil organic matter. Therefore, there were mutual relationships between earthworms and trees in the rehabilitation areas.

The other factor causing an increase in earthworm population in this study was possibly earthworm invasion from the surrounding areas. This was possible because the concession areas of PT. Kideco mining company were surrounded by secondary and primary forests. Meanwhile, a study conducted by Russell, Farrish, Damoff, Coble, and Young (2016) reported that earthworm started to appear at reclamation sites as early as 2-8 years after afforestation in Illinois, US, while Frouz, et al. (2013) showed that earthworms were found at reclamation sites after 2-5 years. However, the earthworm population in the native forests located near to the research sites were not determined due to inaccessible locations. Consequently, information about earthworm population in reference sites could not be presented. Although coal extraction using open cast mining method certainly created significant impacts on the soil micro and macro-faunas, detailed information about to what extent coal mining extraction makes some impacts to the earthworm population was not yet available.

C. Comparison of Earthworm Populations

Information about population and density of earthworms in the post coal mining rehabilitation areas in Indonesia was limited, therefore the population and density of earthworm in this study could only be compared with that population and density of earthworm in other habitats or land-uses. Several studies had shown that forest land use changes to other purposes such as agriculture and mining areas decreased the earthworm population in the soil (Agustina, 2016; Sri Dwiastuti, Sajidan, Suntoro, & Setyono, 2013). However, a study conducted by Hairiah et al. (2004) reported that forest land use change to coffee based agroforestry increased the earthworm population.

Compared to the other land uses, the density of earthworms in the 10 years old rehabilitation areas in the post coal mining areas in this study was slightly higher than that density of earthworms in the undisturbed forests, which was 78 animals/m^2 in this study compared to 75 animals/m^2 in the undisturbed forest (Table 3). Nevertheless, by considering to the other land use as a comparison, it could be said that after 10 years of rehabilitation activities, the density of earthworm population was almost similar to that earthworm density in the undisturbed forests. Therefore, it took more than 10 years in terms of earthworm density to return to the previous state after disturbances as a result of

Table 3. The number of species and density of earthworms in several land uses

Land use types	Density (animal m^{-2})	References
Undisturbed forests	75	F. X. Susilo, Murwani, Dewi, and Aini (2012), Hairiah et al. (2004)
Mixed coffee agroforestry	149	Hairiah et al. (2004)
F. moluccana plantation	16	S Dwiastuti and Suntoro (2011)
Peat < 50 cm thick with rubber plantation	183	Maftu'ah and Susanti (2009)
Post tin mining rehabilitation areas	82	Handayani (2009)

coal mining activities in the forest landscape in this study.

Several studies were conducted to determine earthworm population recovery in the mining rehabilitation areas in other regions. Indicated by the characteristics and amount of biomass, a study conducted by Dunger and Voigtländer (2009) reported that it took more than 50 years for the earthworm population to return to the pre-disturbance level after reclamation of post mining was conducted, finding 7 earthworm species. The other study reported that the rate of earthworm abundance increased by 3 individuals/year/m^2 and reaching 142 individu/m^2 after 21 years of restoration program which was started in Northern Illinois, US (Wodika, Klopf, & Baer, 2014). This number was similar to the native prairie located near to the study site.

D. Earthworm Re-colonization in The Post Coal Mining Areas: Is It Successful?

From the two genus of earthworms found in this study, *Pheretima* sp. could be considered to be a successful colonizer in the post mining environment particularly in East Kalimantan, Indonesia compared to *Lumbricus* sp. According to Eijsackers (2011), there were several characteristics for earthworms as a successful species colonizer; (1) the number of times a species could come first in the habitat, (2) habitat range in which a species was capable to establish, (3) endurance of a species living in a range of environmental conditions, and (4) species dominance in number or biomass at early successional stage. In this study, *Pheretima* sp. had already been found in the 2nd year of rehabilitation areas, which was very early stage of colonization. This species also dominated at all stages of the rehabilitation time. Moreover, the fact that *Pheretima* sp. was found in the 2nd year of the rehabilitation time indicated that this species was able to live in hard conditions. The early stage of post rehabilitation was characterized by high temperature due to open areas and direct sunlight to the soil surfaces. At this stage, the soil surfaces were not covered by the plants' canopies.

However, recognizing the factors on how *Pheretima* sp. could survive and dominate the post mining habitat in this study were difficult because only a few factors could be observed. According to a review conducted by Eijsackers (2011) adapted from Bradshaw (1993), there were several factors influencing the success of earthworm as colonizers; (1) dispersal, (2) establishment and (3) population growth. In the post mining areas, the dispersal of *Pheretima* sp. might be occurred actively by top soil spreading before rehabilitation was conducted. Before coal extraction was conducted, the topsoil layer, which potentially contained earthworm was removed and retained for rehabilitation purposes. From the review, it was also discussed that the establishment of earthworms was influenced by biological characters such as reproduction, cocoon size and cocoon survival capacity, while earthworm population growth was influenced by maturation time combined with environmental factors such as moisture, pH and C/N ratio. However, because the species identification could only be conducted up to genus level, factors influencing the establishment of *Pheretima* sp. in this study could not be discussed.

E. Management Implication

From this study, it could be seen that litter layer had played some important roles to the earthworm population; providing food and favourable environment. Therefore, it is important for the company to select species of trees that can produce more litter layer on the soil surface. Based on the legal regulation, coal mining companies are also suggested to plant fast growing species of plants when the rehabilitation is conducted. Then, it is enriched with local species of plants after 2 or 3 years of rehabilitation. Because they can grow fast, these fast growing species of plants are able to produce more litter on the soil surface. However, in East Kalimantan, fast growing species of plants are commonly exotic species. This type of species are threatening conservation efforts by altering forest structure in the future. Thus, it is important for the government to create some regulations mandating the coal mining companies using native plant species that produce more litter in the rehabilitation areas.

IV. CONCLUSION

In conclusion, there was a significant increase in earthworm population in accordance to the age of rehabilitation in the post coal mining areas in this study. There were only two genus of earthworm found in this study, indicating low species diversity in the research sites. Meanwhile, *Pheretima* sp. could be considered to be a successful colonizer in the post mining environment particularly in East Kalimantan, Indonesia compared to *Lumbricus* sp. Moreover, the increase in earthworm density has a positive correlation with the litter thickness on the soil surface. However, litter thickness was not the single factor causing increasing population of earthworms in this study. In the early stage of rehabilitation of coal mining areas, it is important to plant tree species which could produce significant amount of litter to stimulate the earthworm population to increase and initiate succession. Subsequently, the rehabilitation plants will have some benefits from the increasing earthworm population in the soil. Finally, it took more than 10 years in terms of earthworm density to return to the previous state after disturbances as a result of coal mining activities in the forest landscape in this study.

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