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Diversity of Earthworms (Oligochaeta: Annelida) in Reclamation Land at PT. Bukit Asam (Persero) Tbk. Tanjung Enim, South Sumatera

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Abstract *: The earthworms are in the restoration program first needs to know diversity and species that have the potential to restore ecosystem function. In this study, the aim is the researcher examined the diversity of earthworms in post-mining land at various ages of revegetated land, non-revegetated land, and natural land. The research was conducted at PT. Bukit Asam (Persero) Tbk, Tanjung Enim, South Sumatra. The methodology is used the quantitative research to find the result of this research. The result is The total number of individuals earthworms, and the highest density was found on 23-year-old revegetated land and natural land.*
Keywords *: earthworm; diversity; reclamation land*

I. Introduction

Coal mining is one of the activities of utilizing natural resources that have the potential to damage the environment, both water, soil and air. Exploitation of coal usually begins with peeling soil and cover plants, then excavating. Furthermore, coal is transported to stock piles (Sukandarrumidi 2006). After mining, the top soil is not returned to its original location or stacked for several years. The soil layer is then returned to its original location or spread to another place after mining is finished. This process causes the mixing of top soil with dumping and other mining materials (tailings), so that soil conditions become heterogeneous (Topp et al. 2001).

Restoration is the return of ecosystem functions in post-mining land. Restoration is usually focused on vegetation revegetation and more manageable soil surface fauna (Majer et al. 2007). Reconstruction of appropriate plant communities is very important in restoring damaged soil ecosystems. Efforts to restore ecosystem structure and function, cannot succeed without the ecological function of the plant community. Community improvement efforts are needed to accelerate ecological succession, recolonization of indigenous fauna and restoration of ecosystem functions (Frouz et al. 2007). Mining activities cause land to be disrupted. Soil fauna is the main focus in efforts to restore ecosystem function (Top et al. 2001).

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Earthworms are candidates for good soil fauna in the initial restoration of mining land. Sculion & Malik (2000) reported that earthworms influence the characteristics of the soil surface, especially in increasing aggregate and carbon stability. Emmerling & Paulsch (2001) also reported the ability of earthworms in land improvement efforts, namely the activity of

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digging and mixing soil (bioturbation), so that macro pores formed, regulating the movement of water and air along with other microbiota in the soil. Earthworms can increase the stability of humidity and temperature at the surface soil horizon which plays an important role in efforts to improve land.

The role of earthworms in improving soil structure, such as soil aggregate formation and soil pores, has been widely reported. Earthworms used for rehabilitation of soil texture, must meet several conditions, namely tolerant to extreme environments, have ecological plasticity, the ability to penetrate compact soil, and the ability to spread. It is recommended that the restoration efforts be used for multi-species earthworms (Garcia & Fragoso 2002).

Saptaningrum (2001) reported on post-tin mining land on Bangka island, high sand content (%) (in the first year) and gradually declined until the 15th year after being mined. Clay and dust levels are very low (%) at the beginning after mining and gradually increase until the 15th year. pH, organic C, total N, available P increase with the length of time after mining. The value of cation exchange rates increased from the 5th year after mining.

In the United Kingdom and Eastern Europe it is reported that earthworms that have survived the accumulation process at the mine opening, can re-colonize within 10-30 years (Huttl & Weber 2001). Frouz et al. (2007) reported that in Central Europe, the density of soil macrofauna in post-mining reclamation land was higher than for natural post-mining land. Earthworms were significantly different at the three ages (15, 23 and 40 years) observed. The dominant epigeic earthworms were Dendrobaena octaedra and Lumbricus rubellus. In the reclaimed land endogeic earthworms were also found. In Austria Dunger & Wanner (2001) reported the development of soil fauna in post-mining land for 46 years revegetation. The groups of epigeic earthworms found were Dendrobaena octaedra, D. rubidus rubidus and Lumbricus rubellus rubellus. Anesic groups found were Lumbricus terrestris, while the endogeic groups found were Aporrectodea caliginosa caliginosa, A. rosea rosea, and Octolastion tyrtaeum. Two species of earthworms, namely Allobophora chkorotica and Octolasion cyaneum are found in small amounts and are only found at certain times.

So far, the use of earthworms in the restoration program has not been carried out on a large scale. The use of local earthworms are in the restoration program first needs to know diversity and species that have the potential to restore ecosystem function. In this study, we examined the diversity of earthworms in post-mining land at various ages of revegetated land, non-revegetated land, and natural land. The research was conducted at PT. Bukit Asam (Persero) Tbk, Tanjung Enim, South Sumatra.

PT. Bukit Asam (Persero) Tbk. is a State-Owned Enterprise (BUMN) which was established on March 2, 1981 based on Government Regulation No. 42 of 1980. The company is based in Tanjung Enim, Muara Enim Regency, South Sumatra Province. The company is located about 3 km northwest of the city of Tanjung Enim, in Lawang Kidul District, Muara Enim Regency, South Sumatra. Geographically, the location of PT. Bukit Asam (Persero) Tbk. located at position 3042'30 "LS to 4047'30" LS and 103043'00 "BT to 103050'10". PT. Bukit Asam (Persero) Tbk. consists of two mining units, namely the Tanjung Enim mining unit (UPTE) located in Tanjung Enim and the Ombilin mining unit (UPO) located in Ombilin. PT. Bukit Asam (Persero) Tbk. has 8 Mining Authorities, one of which is the mining authority of Air Laya.

II. Methodology

This research was conducted from September 2011 to January 2012 at PT. Bukit Asam (Persero) Tbk, Tanjung Enim, South Sumatra. Earthworms were collected from six types of land, namely 6-year-old revegetated land (Tembe), 12 years (MTS), 20 years (Suban), 23 years (Petai water), non-revegetation (Mahayung 1), and natural land (Mahayung 1) (Figure 1; Appendix 1).

The identification of earthworms was carried out in the Biosistematic and Animal Ecology Section of the Department of Biology, FMIPA IPB. Soil analysis was carried out in the Department of Soil Science and Land Resources of the Faculty of Agriculture, IPB. Earthworms were collected in four revegetated land types, namely revegetated land aged 6, 12, 20 and 23 years. Earthworms are also collected from non-revegetated land and natural land. At each sampling location the coordinates are measured with GPS.

The earthworms found are taken by hand sorting (Bartlett 2010). All collected earthworms are put into sample bottles which have been given 70% alcohol and labeled. Identification of specimens is based on Sim & Easton (1972) and Blakemore (2002) with the help of a stereo microscope.The environmental factors measured are pH, humidity (RH), temperature, litter dry weight, and vegetation.

The morphological and anatomical characters of the earthworm species found were described. Analysis of earthworm data includes diversity, density, relative density, and frequency of presence of a species. Worm diversity was calculated by the Margalef species richness index (DMg), Shannon-Wiener diversity index (H '), Fisher diversity index alpha (α), and Pielou (J') evenness index. The similarity of earthworm species between locations was calculated by similarity of qualitative Jaccard species (CJ) (Magurran 1987).

The formulas used are as follows:

a. Density Species (D)

$$\text{D species A} = \frac{\sum \text{individual species A}}{\text{Large } (m^2)}$$

b. Relative density of species

$$\text{RD species A } (\%) = \frac{\text{Density species A}}{\text{Sum D species}} \text{ x } 100$$

c. Relative Frequency species (Rf)

$$\text{Rf species A } (\%) = \frac{\sum \text{plot found species A}}{\text{Sum } \sum \text{plot}} \text{ x } 100$$

d. Margaleft's Species wealth index (D_{Mg})

$$\text{DMg} = \frac{S - 1}{\log (N)}$$

Description: S = number of species, N = number of individuals

e. Shanon-wiener's Diversity index (H')

$$H' = \sum_{i=1}^{n} pi \ln pi$$

Description: pi = ni / N, ni = number of individuals per species, N = number of individuals.

f. Fisher alpha's Diversity index

$$S = \alpha \log^{e} = (\frac{1 + N}{\alpha})$$

g. Pielou's Average Index

$$J' = \frac{H'}{\ln S}$$

Description: N = number of individuals

h. Jaccard's Qualitativ similarity

$$CJ = \frac{j}{a + b - j}$$

Description: j = total number of species found in two habitats, a = total number of species at location a, b = total number of species at location b.
The relationship between the number of individuals with environmental analysis with Pearson (P), and principal component analysis (PCA), uses PRIMER 5 and R.2.12 programs.
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III. Discussion

3.1 Description of Earthworms

The earthworms identified are adult earthworms which are characterized by the presence of clitules in the anterior part. In this study four species of earthworms were found, namely Pontoscolex corethrurus, Polypheretima elongata, Pheretima sp, and Amynthas pauxillula. The earthworm family found was Glossoscolecidae and Megascolecidae.

Pontoscolex corethrurus

Pontoscolex corethrurus was observed with a body length of 6-11.5 cm (Figure 1a), prostomium prolobus type, saddle shaped clitula (Figure 1b) in segments 13-20, 14-21 or 15-22. Lumbricine seta type, which has 8 sets per segment, which is spread in the dorsal section. Dorsal holes in this species were not identified. The position of male and female holes is not clearly observed. This worm has 3 pairs of sperm holes, which are in the 6/7-7 / 8-8 / 9 segment. Hole positions are in segments 7-9. Spermases are segmented 6-8 or 7-9, lacking diverticula and accessories (Figure 1c). Spermateka P. corethrurus does not have nephridia. Stomach is in segment 6 (1d image). This species has no prostate.

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(a)

(b)

(c)

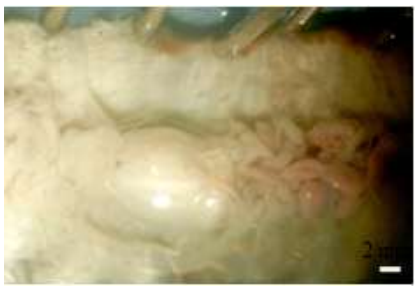
(d)

Figure 1. Morphology and anatomy of *P. corethrurus:* body 6-11.5 cm (a), saddle-shaped clitula (b), 3 pairs of specimens without diverticula (c), and bounch in segment 6 (d).

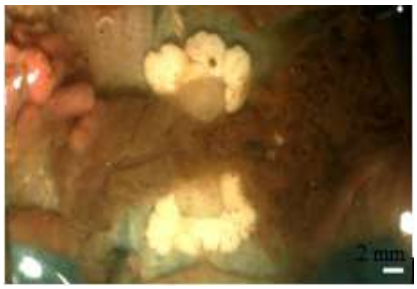
Polypheretima elongata

Polypheretima elongata has a body length of 7.5-11 cm, the prostomium type prolobus or proepilobus, have a ring clitulem, which is in segments 14-16 (Figure 2a). Seta perichaetine types which has more than 8 sets per segment, and spread using segments. The Single dorsal of holes are located in the middle of the segment, usually not at the top and back. Dorsal's hole in the locking process to connect to the outside environment to protect the body in the process of respiration. The first dorsal of hole is in the 10/11 segment or 12/13 in this species. It has a hole in the 18th segment and one hole in the 14th segment. This species does not have any holes. P. elongata does not have any ingredients. The stomach is located in the segment after 7/8 or 8/9 (Figure 2b). The prostate is racemose, which is equipped with a copulation pouch. P. elongata has no caeca (Figure 2c).

(a)



(b)



(c)

(d)

Figure 2. Morphology and anatomy of Pheretima sp .: prostomium epilobus (a), 4 pairs of spherical holes (b), spermas equipped with diverticula and nephridia (c), and prostate equipped with copulation bag (d).

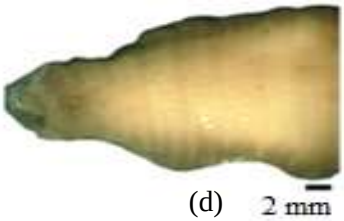
Amynthas pauxillula

Amynthas pauxillula has a body length of 6.7-9 cm (Figure 3a), prostomium epilobus type (Figure 3b), ring-shaped clitula, in the 14-16 segment. Seta perichaetine types, usually spread in each segment. There is one dorsal hole in the center of the segment, the first dorsal hole in the 11/12 segment. This genus has a pair of male holes in segment 18, and one female hole in the 14th segment (Figure 3c). The spheres are intersegmental, holes are sensitive to 3 pairs in the ventral segment 4 / 5-5 / 6-6 / 7 (Figure 3d). The first equipment hole in the 4/5 segment. Teka pairs in three segments. Spermateka 3 pairs are located in segments to 4-6 or 5-7, equipped with diverticula, accessories, but no nephridia (Figure 3e). Stomach is between segments to 7/8 or 9/10 or 10/11. This species has a prostate, tubular racemose, without pockets of copulation (Figure 3f).

(a)

(b)

(c)



(d)

(e)

(f)

Figure 3. The morphology and anatomy of Amynthas pauxillula: body length 6.7-9 cm (a), prostomium epilobus (b), 18 segment male holes and female holes in segment 14 (c), spermateka holes (d), spermens without nephridia (e), and prostate without copulation pouch (f).

3.2 Diversity of Earthworms

The total number of earthworm individuals collected from the two times taken was 698 individuals. Retrieval in September found 33 individual adult worms and 186 juvenile individuals. Taking in January found 260 individual adult worms and 219 juvenile individuals. Earthworms were not found on location 5 (non-revegetated land) (Table 1). In the September collection, only Pontoscolex coretharurus (Glossoscolecidae) was found. In January, the earthworm found is Amynthas pauxillula, Pheretima sp. and Polypheretima elongata (Megascolecidae) (Table 2). The number of individual earthworms in September was 219 individuals, while in January 479 individuals.

Table 1. Species, number of individuals, genus of earthworms in observations in September 2011 and January 2012

Total individual / genus / species	**Total individual**	
	September	January
N (Total individual)	219	479
Total genus (individual)	1	4
Total species (individual)	1	4

Table 2. Species and number of individual earthworm on revegetation land; non-revegetation; and natural land

Location (the field of age)	**Species**	**Earthworm**	
		∑ individual	Persentage (%)
Non-revegetation	-	-	-
R-6 years age	*Pontoscolex corethrurus*	4	0,015
	Amynthas pauxillula	8	0,030
R-12 years age	*Pontoscolex corethrurus*	45	0,173
R-20 years age	*Pontoscolex corethrurus*	69	0,265
R- 23 years age	*Pontoscolex corethrurus*	76	0,292
	Polypheretima elongata	1	0,003
	Pheretima sp.	1	0,003
Natural soil	*Polypheretima elongata*	41	0,157
Total	260	1	0,015

R = land revegetation

The dominant earthworm found at the study site is Pontoscolex corethrurus which is almost found in every location. Amynthas is only found on 6-year-old land, while Polypheretima and Pheretima are found on 23-year-old land and natural land.

On revegetated land, ages 6, 12, 20, 23 years and natural land were found to be 44, 112, 196, 294 and 229 individuals respectively. The highest number of species (3 species) was found on 23-year-old revegetated land and natural land, followed on 6-year-old revegetated land (2 species), and 12 and 20-year-old revegetated land (1 species) (Table 3).

Table 3. Number of individuals (N), genus (G), species (S), species richness, diversity index, and earthworm evenness index (J ') on various types of land

Parameter	**Total of Individual and Diversity**						
	Non-R	R-6 years	R-12 years	R-20 years	R-23 years	L.Natural	
N	0	44	112	196	294	229	875
S	0	2	1	1	3	3	4
G	0	2	1	1	3	3	4
Density (Ind/m^2)	0	2,75	7	12,25	18,37	14,31	9,11
Frequency found	0	0,19	0,44	0,5	1	1	0,52
D_{Mg}	0	0,52	1,27	1,32	2,63	2,76	7,23
α	0	0,72	1,65	1,67	3,63	3,91	11,51
H'	0	0,83	1,9	1,8	2,61	2,65	3,73
J'	0	0,75	0,98	0,87	0,94	0,95	0,95

R = revegetated land, Non-R = non-revegetated land, Natural = natural land, N = number of individuals, S = species type, G = genus, DMg = species richness Margalef, α = fisher diversity index, H '= Shannon-Wiener species diversity index and J '= Piolue evenness index.

The highest density of earthworms (18.37 ind / m2) was found on 23-year-old revegetated land, followed by natural land (14.31 ind / m2), and the lowest was found on 6-year-old revegetated land (2.75 ind / m2). The frequency of high earthworms (16 plots) was found on 23-year-old revegetated land and natural land. The lowest frequency of earthworms found (3 plots) was found on 6-year-old revegetated land. The results of the diversity index analysis showed that the diversity of high earthworms was found in natural land locations (DMg = 2.76, α = 3.91, and H '= 2.65), followed by 23 years of revegetation (DMg = 2.63, α = 3.63, and H '= 2.61). The lowest diversity of species was found on 6-year revegetated land (DMg = 0.52, α = 0.72, and H '= 0.83) (Table 4). The highest evenness was found in the 12-year revegetation location (0.98), followed by natural land (0.95).

Based on the results of the analysis of species density (K), the highest density (5.93 ind / m2) in P. corethrurus on 23 years revegetated land, followed by revegetated land aged 20 years (4.31). The lowest density (0.06 ind / m2) in Polypheretima elongata and Pheretima sp., Was found on 6-year-old revegetated land. The highest relative density (97.93%) in P. corethrurus on 23-year revegetated land, followed on natural land (73.21) in Polypheretima elongata, and 6-year revegetated land (66.66%) on A. pauxillula. The lowest relative density (1.03) in Polypheretima elongata and Pheretima sp. on 23 years old revegetated land. The highest frequency was highest in P. corethrurus (81.25%) on 23-year revegetated land, followed by natural land (75%). The lowest relative frequency (6.25%) was found in A.

pauxillula and P. elongata on 6-year-old revegetated land, and in P. elongata and Pheretima sp. on 23-year-old land (Table 4).

Species similarity between locations is known from the qualitative Jaccard value (CJ). From the results of the similarity index analysis it is known that at 12 years the revegetated land has a high species similarity (CJ = 1) with 20 years old revegetated land. The same results also occur on 23-year-old revegetated land with natural land locations (CJ = 1). The similarity of the lowest species (CJ = 0.25) was found on 6-year-old revegetated land with 23-year-old revegetated land and natural land locations (Table 5).

Table 4. Density of species (K), relative density (KR), and relative frequency (Fr) of worm species in each study location.

Location	Species	Relative Density and Frequency		
		K	KR	Fr
Non-R	*P. corethrurus*	-	-	-
	A. pauxillula	-	-	-
	P. elongata	-	-	-
	Pheretima Sp.	-	-	-
R-6 years	*P. corethrurus*	2,25	33,33	6,25
	A. pauxillula	0,5	66,66	6,25
	P. elongata	-	-	-
	Pheretima Sp.	-	-	-
R-12 years	*P. corethrurus*	2,81	50	43,75
	A. pauxillula	-	-	-
	P. elongata	-	-	-
	Pheretima Sp.	-	-	-
R-20 years	*P. corethrurus*	4.31	50	50
	A. pauxillula	-	-	-
	P. elongata	-	-	-
	Pheretima Sp.	-	-	-
R-23 years	*P. corethrurus*	5,93	97,93	81,25
	A. pauxillula	-	-	-
	P. elongata	0,06	1,03	6,25
	Pheretima Sp.	0,06	1,03	6,25
L Natural	*P. corethrurus*	0,68	19,64	75
	A. pauxillula	-	-	-
	P. elongata	2,56	73,21	43,75
	Pheretima Sp.	0,25	7,14	18,75

R = revegetated land, Non-R = non-revegetation, L. Natural = natural land, K = species density, KR = relative species density (%), Fr = Relative frequency of species (%).

Table 5. Qualitative Jaccard diversity index (CJ) of earthworms between locations

Location	Similaritas Jaccard					
	R-6 years	R-12 years	R-20 years	R-23 years	Non-R	Natural Soil
R-6 years	1	0,5	0,5	0,25	0	0,25
R-12 years		1	1	0,33	0	0,33
R-20 years			1	0,33	0	0,33
R-23 years				1	0	1
Non-R					1	0
L. natural						1

R = revegetated land, Non-R = non-revegetation, L. Natural = natural land.

Environmental factors at the study site were on 20-year-old revegetated land with a high soil pH (6.55), 12-year-old revegetated land having the lowest soil pH (6.18). High soil moisture (43.51%) in the location of natural land, the lowest humidity (25%) was found on non-regenerated land. The highest temperature (34.12oC) was found on the lowest non-revegetated land (26.4oC) at the site of natural land. Litter dry weight was highest (223.75 g) on 23-year-old revegetated land and lowest (13.75 g) on non-revegetated land (Table 6).

Table 6. Average environmental factors measured at the study site

Field Factor	Similaritas Jaccard					
	R-6 years	R-12 years	R-20 years	R-23 years	Non-R	Natural Soil
pH	6,29	6,18	6,55	6,35	6,37	6,30
rH(%)	34,75	31,62	29,06	42,68	25	43,51
Temp (°C)	29,81	28,95	29,37	27,43	34,12	26,4
B. s	79,25	23,68	39,78	223,75	13,75	170,40

Faculty. Ling = environmental factors, R = revegetation land, pH = soil pH, rH = soil moisture (%), temperature = soil temperature, and B.s = litter dry weight (g).

3.3 Diversity of Earthworms with Environmental Factors

The results of the Pearson correlation analysis showed that the number of individual earthworms significantly negatively correlated with soil pH (p = 0.0383) and temperature (p = 0.00000030). The individual number of earthworms significantly positively correlated with soil moisture (p = 0.0000060), litter dry weight (p = 0.0035), total N (0.01) and porosity (0.05) (Table 7).

Table 7. Pearson Correlation (P) between the number of individual earthworms with environmental factors and their probability values (p)

Parameter	Total individual	
	corelation	Value (p)
pH	-0,211	0,0383
earth	0,444	0,0000060
temprature	-0,494	0,00000030
Nett	0,295	0,0035
C-organik (%)	0,75	0,08
N-total (%)	0,88	0,01
sand (%)	0,67	0,14
dast (%)	0,57	0,23

clay (%)	0,06	0,89
density (g/cm^3)	0,39	0,43
Porosit (%)	0,80	0,05
Pirit (%)	-0,31	0,54

From the results of scatter plots it is known that the number of individual earthworms is found high at pH 6.0-6.5, humidity 40-55% and temperature = 26oC-27.5oC (Figure 4). The results of PCA analysis between the number of individuals and environmental factors are described in biplot (Figure 8). From the PCA's biplot is known that the number of individuals is negatively correlated with temperature and pH, positively correlated with litter, RH, porosity, N-total, organic C, dust, sand, clay, density and pyrite. The main components are 1 (PC1) and main components 2 (PC2) cover 80%.

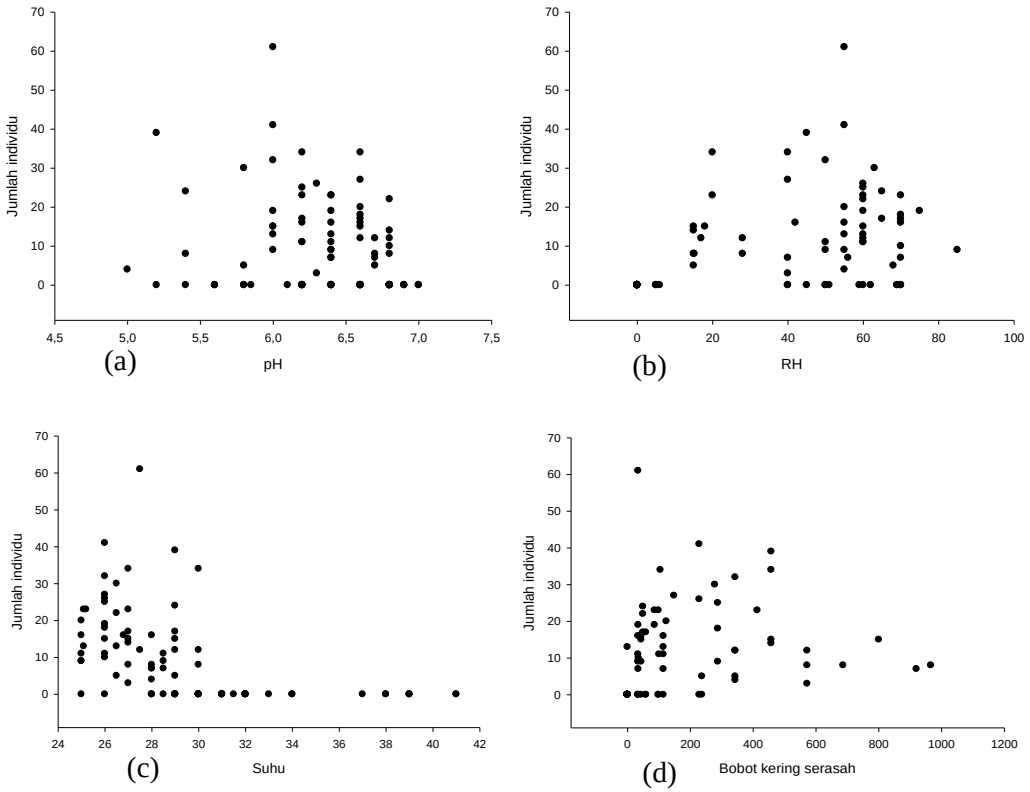


Figure 4. Relationship between the number of individuals to environmental factors: (a) pH, humidity (b), temperature (c), and dry weight of litter (d).

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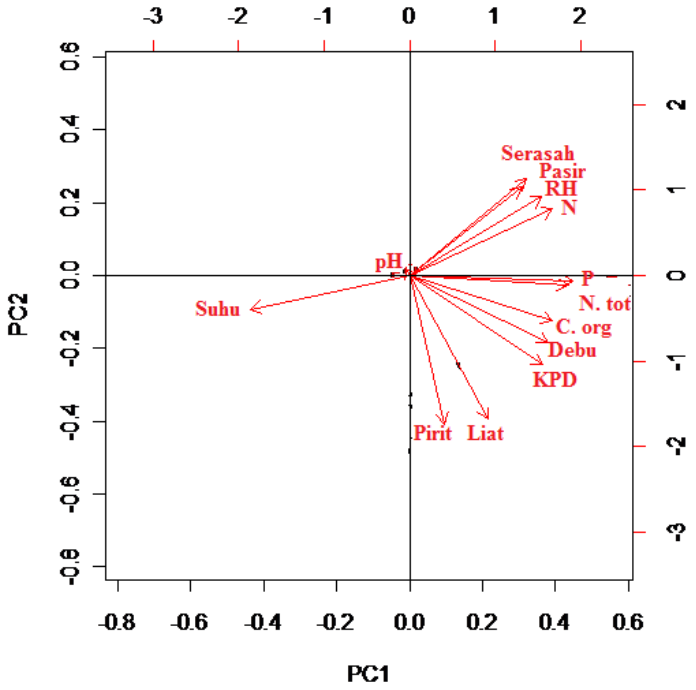

Figure 5. Biplot analysis of the main components of the study variables and locations. N = number of individual worms, litter = litter dry weight, KPD = soil density, N.tot = total nitrogen, and C.org = soil organic carbon.

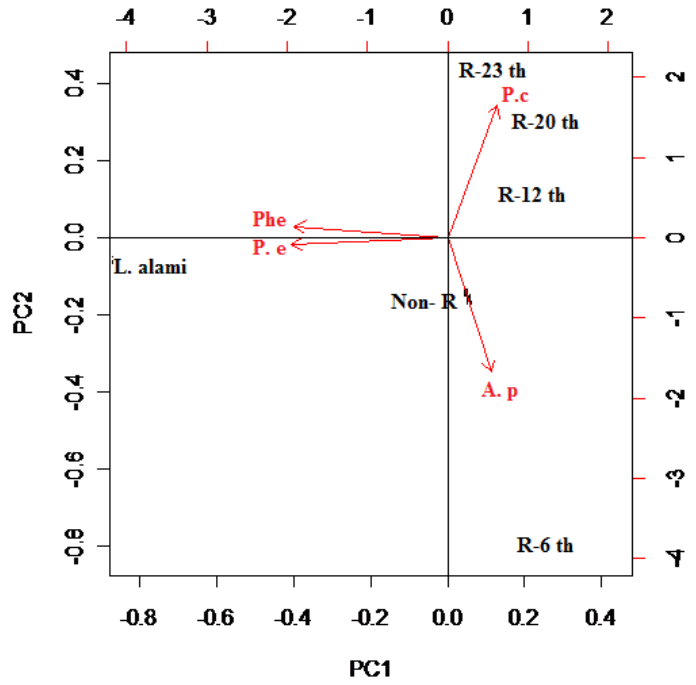

Figure 6. Biplot analysis of the main components of the study variables and locations. P.c = Pontoscolex corethrurus, A.p = Amynthas pauxillula, P.e = Polypheretima elongata, Phe = Pheretima sp ,.

IV. Conclusion

PCA analysis between species and sampling locations was depicted in a biplot (Figure 9). From this biplot it is known that Amynthas pauxillula earthworm species is dominantly found on 6-year revegetated land. On revegetated land 12, 20 and 23 years the dominant species found is Pontoscolex corethrurus, and on natural land is Phretima sp. and Polypheretima elongata. They are with main component 1 (PC1) and main component 2 (PC2) covering 89%. The proportion of the main component variants can be seen in (Appendix 1).

Four species of earthworms were found, namely P. corethrurus, A. pauxillula, P. elongata, and Pheretima sp. post mining area PT. Bukit Asam (Persero) Tbk. Tanjung Enim, South Sumatra. The worms included in the epigeic group were A. pauxillula, P. elongata, and Pheretima sp., While P. corethrurus was included in the endogeic group. The total number of individuals, and the highest density was found on 23-year-old revegetated land and natural land. The highest number of species was found on 23-year-old revegetated land and natural land. Environmental parameters that significantly influence earthworms are pH, temperature, soil moisture, litter, total N and porosity.

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