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Diversity of Soil Surface Insects in Coal Post-Mining Land of PT. Bukit Asam Tbk in Tanjung Enim

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Abstract: Coal mining activities carried out openly can harm the environment. One of the environmental damages that occurs is the loss of habitat for soil-level insects. This research was conducted to identify the diversity of soil surface insect species in the post-coal mining land of PT. Bukit Asam Tbk Tanjung Enim IUP Banko Barat at various ages of reclamation. Soil surface insect samples were collected using the pitfall trap method, which was carried out for 1x24 hours. The results showed that the highest presence of soil surface insect species occurred in individuals aged 6 years, with a total of 128 individuals, and was dominated by the order Hymenoptera. The species found are *M. insertus, M. minimum, O. smaragdina, P. clavate, S. Invicta* and *Gryllus* sp. The species diversity index in post-coal mining land aged 6 years, namely 1.51, is classified as moderate. The lowest presence of soil surface insects occurred in 2 years, with a total of 24 individuals. The species diversity index in post-coal mining land aged 2 years, namely 0.85, is relatively low. Thus, the research results show that the diversity of surface soil insects is influenced by the age of reclamation. The longer the land is managed, the higher the index of diversity of soil surface insect species in post-coal mining land.
Keywords: Post-Mining, Reclamation, Soil Surface Insects

1. Introduction

Most coal mining activities are conducted in forest areas designated as concession areas. Coal mining can be executed through various methods, one of which is an open system. Mining coal openly with intensive land exploitation has a more significant negative impact on environmental damage, rendering the land unproductive [1]. The resulting environmental damage includes land degradation [2], decreased soil productivity, soil compaction, erosion [3], and the loss of habitat for biodiversity, particularly soil surface insects [4].

Soil surface insects are integral components of biodiversity, providing numerous benefits. They play a crucial role in ecosystems, contributing to activities such as vegetation growth [5]. The diversity of soil surface insects varies across different fields, a phenomenon attributed to distinct environmental conditions in each area [6]. The presence of surface insects is strongly influenced by these environmental conditions, making them a valuable parameter for assessing soil quality and serving as bioindicators of soil fertility [7].

Restoration of post-coal mining land is essential to mitigate the decline in soil surface insect populations resulting from coal mining activities [8]. According to Minister of Energy and Mineral Resources Regulation No. 07 of 2014, which pertains to the Implementation of Reclamation and Post-mining in Mineral and Coal Mining Business Activities [9], every mining company is mandated to manage and monitor the mining environment. This responsibility encompasses post-mining reclamation and rehabilitation activities.

Land reclamation is an endeavor aimed at restoring damaged land. Additionally, reclamation is undertaken to enhance and maximize the benefits of natural resources by planting vegetation [10]. Through these reclamation efforts, the goal is to reestablish habitat for surface insects on post-coal mining land. The objective of this research is to identify the diversity of soil surface insect species on PT. Bukit Asam Tbk Tanjung Enim's post-coal mining land at various stages of reclamation.

2. Material and Methods

2.1. Materials

The research was conducted at PT. Bukit Asam Tbk Tanjung Enim IUP Banko Barat, Muara Enim, South Sumatra, in July 2023. Sampling was performed on post-coal mining land aged 2, 3, 4, 5, and 6 years, as well as on land that had not undergone coal mining, serving as a natural or control condition (Figure 1).

(a) (b)

Figure 1. Research location (a). land that has not yet been mined for coal, (b). post-coal mining land PT. Bukit Asam Tbk IUP Banko Barat

The materials used in this research were water, liquid detergent, and 70% ethanol. The tools used in this research were plastic cups (14 oz), PVC pipes (13 cm), toothpick, plastic plate (9 inches), small sample cups (25 ml), tweezers and block millimeter paper.

2.2. Methods

The soil surface insects were sampled using a purposive random sampling method, with a focus on each different revegetation plant on PT. Bukit Asam Tbk Tanjung Enim IUP Banko Barat's post-coal mining land. The sampling employed the pitfall trap method, which entails capturing soil-level insects using a trap system consisting of plastic bottles and PVC pipes inserted into the soil parallel to the surface. These traps were left in place for 24 hours, and filled with a detergent solution to capture soil surface insects at the research location. The collected soil surface insects were then preserved in small sample cups filled with 70% alcohol and labeled for subsequent identification.

2.3. Data Analysis

The data analysis involved identifying the diversity of soil surface insect types in PT. Bukit Asam Tbk IUP Banko Barat's post-coal mining land using key insect determination [11]. Subsequently, an analysis of species diversity index (H'), species richness index (DMg), and species abundance index (E') was conducted.

2.3.1. Species Diversity Index (H')

The species diversity index is calculated using the formula (Shannon-Wiener) as follows [12].

$$H' = -\sum Pi \ In \ Pi$$

$$Pi = ni/N$$

Information:
H = Diversity index
ni = Number of individuals of a species
N = Number of individuals of all species

The magnitude of the species diversity index according to Shannon-Wiener is defined as follows [13].

a. Value H'>3 shows that the abundance of species diversity is high
b. Value 1≤H'≥3 indicating that species diversity is moderate
c. Value H'<1 indicates that species diversity is little or low

2.3.2. Species Richness Index

In this research, the species richness is measured using the Margalef species index. The categories for determining species richness based on the Margalef index are as follows: if DMg<3.5, richness is considered low; if 3.5<DMg<5, it indicates medium richness, and if DMg>5, it signifies high richness. The calculations can be performed using the following formula [14].

$$\mathrm{DMg} = \frac{(s-1)}{\ln N}$$

Information:
DMg = Margalef richness index
S = Number of species discovered
N = The number of individuals of the entire species

2.3.3. Species Evenness Index

In this study, the species evenness is assessed using the Evenness type index. To determine the level of species evenness in a community, the E value is employed, with the condition that if E'<0.3, the species evenness is classified as medium. Conversely, if E'≥0.6, the species evenness level is classified as high. The calculations can be carried out using the following formula [15].

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

Information:
E' = Evenness index
H' = Species diversity index

S = Number of species

3. Results and Discussion

3.1. *Presence of Soil Surface Insects*

The research results indicate that the number of surface insect species on post-coal mining land is influenced by the duration of land management. Seven species of surface insects were identified on PT Bukit Asam Tbk Tanjung Enim IUP Banko Barat's post-coal mining land. The number of insect species found increases with the length of plant management on post-mining land. Details of soil surface insects found in post-coal mining land are presented in Table 1.

Table 1. Soil surface insect species found in post-coal mining land PT. Bukit Asam Tbk Tanjung Enim IUP Banko Barat.

Ordo/Famili	Species	Number of Species Found					
		Not Mined Yet	6 years	5 years	4 years	3 years	2 years
Hemiptera							
Plataspididae	*Menecles insertus*	2	3	-	-	-	3
Hymenoptera							
Formicidae	*Monomorium minimum*	44	11	11	9	-	-
	Oecophllya smaragdina	37	43	30	15	12	16
	Paraponera clavata	24	13	9	8	6	5
	Solenopsis invicta	63	48	22	-	6	-
Lepidoptera							
Arctiidae	*Lophocampa argentata*	4	-	-	-	-	-
Orthoptera							
Gryllidae	*Gryllus* sp.	19	10	5	7	5	-
Number of Individuals		193	128	77	39	29	24
Number of Species		7	6	5	4	4	3

Description (-) : No soil surface insect species were found

Table 1 illustrates that the number of surface insects on post-coal mining land ranged from 3 to 6 species. The highest number of species was observed on post-mining land aged 6 years, totaling 128 individuals from 6 species of revegetation plants were observed. Conversely, the lowest number of species was recorded at the age of 2 years, with 24 individuals from 1 species of revegetation plants observed. In unmined land, 7 insect species were found, totaling 193 individuals from 10 species of plants were observed.

One insect species, L. argentata, is exclusively found on land that has not undergone coal mining. Another species, M. minimum, is specific to fields planted for more than two years. Two species, O. smaragdina and P. clavate, are present in both land before and after coal mining. Notably, the dominant surface insects identified consist of four species belonging to the order Hymenoptera (Figure 2).

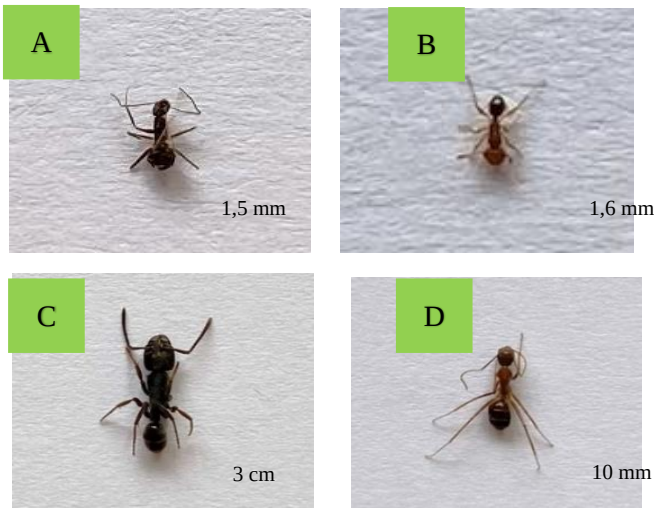


Figure 2. Soil surface insect species in post-coal mining land at the West Banko IUP in the order Hymenoptera (A) *Monomorium minimum*, (B) *Solenopsis Invicta*, (C) *Paraponera clavate* and (D) *Oecophllya smaragdina*

Three additional species of soil surface insects were discovered on PT. Bukit Asam Tbk Tanjung Enim IUP Banko Barat's post-coal mining land. These three insect species belong to three different orders: Hemiptera, Lepidoptera, and Orthoptera (Figure 3).

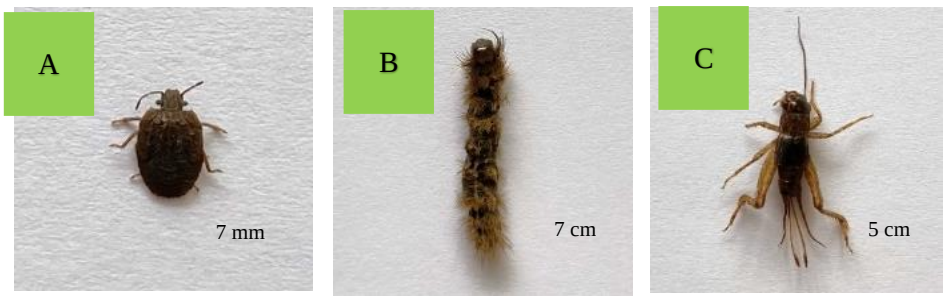
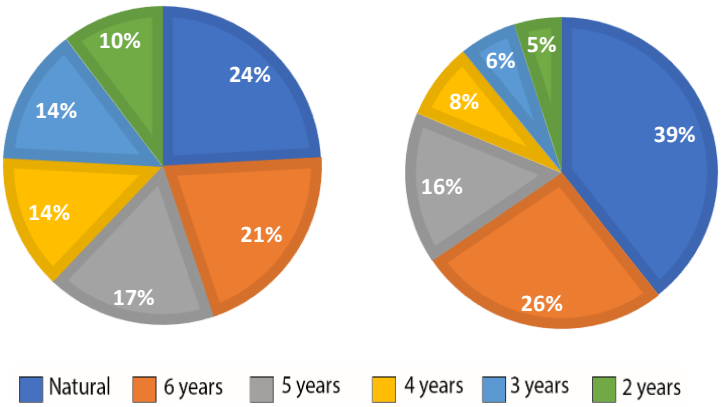


Figure 3. Soil surface insect species in post-coal mining land PT. Bukit Asam Tbk Tanjung Enim IUP Banko Barat in other order (A) *Menecles insertus*, (B) *Lophocampa argentata*, (C) *Gryllus* sp.

The number of species and individuals on PT. Bukit Asam Tbk Tanjung Enim IUP Banko Barat's post-coal mining land, ranging from 2 to 6 years old, is illustrated in the circular diagram (Figure 4). A relationship exists between the number of species and the count of individuals found; as the number of insect species increases, so does the count of individuals. Notably, the number of species and individuals in land that has not undergone coal mining is higher than in other post-coal mining areas.



(a) Number of Species (b) Number of individuals

Figure 4. (a) percentage diagram of the number of soil surface insect species, (b) percentage diagram of the number of individual soil surface insects of post-coal mining land at PT. Bukit Asam Tbk Tanjung Enim IUP Banko Barat.

In Figure 4(a), it is evident that the percentage of soil surface insect species on post-coal mining land ranges from 10% to 21%. The highest percentage is observed in the 6-year-old land, while the lowest is found in the 2-year-old land. Land that has not been mined for coal shows a percentage of 24%. This indicates that the restoration process conducted on the 6-year-old land is approaching its natural state. This can be seen from the results of observations of the number of species found in 6-year-old post-coal mining land. There were 6 insect species found, while in observations on land that had not yet been coal mined, 7 species of ground surface insects were found, thus the insect species in the 6-year-old post-mining land are already diverse.

In Figure 4(b), the percentage of individual insects on post-coal mining land ranges from 5% to 26%. The highest percentage is observed in the 6-year-old land, while the lowest is found in the 2-year-old land. Land that has not been mined for coal shows a percentage of individuals at 39%. This indicates that the number of individuals in the 6-year-old land has started to approach a natural state.

The existence of surface insects can be influenced by environmental factors, both abiotic and biotic. Such as soil, water, sunlight, temperature, and even the surrounding plants [16]. Post-coal mining land that is 6 years old has undergone a land restoration process starting from the soil on the land. Land restoration is carried out using revegetation plants and the use of bokashi fertilizer to help accelerate plant growth. So that the soil conditions on the land can support a habitat for the existence of surface insects.

3.2. Index of Diversity, Richness, and Evenness of Surface Insect Species

The results of the study showed that surface insect species in the post-coal mining land of PT. Bukit Asam

Tbk IUP Banko Barat has a different diversity index at each reclamation age. Insect species are analyzed based on the species diversity index (H'), species richness index (DMg), and species evenness index (E'). The diversity index in each post-coal mining land is influenced by the age of land management and can be seen in Table 2.

Table 2. Index of diversity, richness, and evenness of insect species land surface on post-coal mining land PT. Bukit Asam Tbk Tanjung Enim IUP Banko Barat.

Index	Research Location (year)					
	Not Mined Yet	6 years	5 years	4 years	3 years	2 years
Species Diversity (H')	1,62	1,51	1,42	1,38	1,32	0,85
Species Richness (DMg)	1,14	1,03	0,92	0,81	0,89	0,62
Species Evenness (E')	0,83	0,84	0,88	0,99	0,95	0,78

In Table 2, it is evident that the biodiversity index increases with the advancing age of land management. The longer the period of land management, the higher the value of species diversity on PT. Bukit Asam Tbk Tanjung Enim IUP Banko Barat's post-coal mining land. The species diversity index in post-coal mining land ranges from 0.85 to 1.51, with the highest diversity observed at the age of 6 years and the lowest at the age of 2 years. The species diversity in post-coal mining land is classified as moderate. In contrast, land that has not been mined for coal shows a species diversity index of 1.62.

The species richness in post-coal mining land, as shown in Table 2, ranges between 0.6 and 1.03. The highest species richness index is observed at the age of 6 years, while the lowest is at the age of 2 years. Species richness in post-coal mining land is relatively low. In comparison, the species richness index in land that has not yet been coal mined is 1.14. This indicates that as land management duration increases, the species richness on that land also increases [17]. The species evenness in post-coal mining land is detailed in Table 2, and there is no significant difference observed at each reclamation age. The species evenness index ranges from 0.78 to 0.99. The highest species evenness is observed at the age of 4 years, while the lowest is at the age of 6 years. The species evenness index on land that has not yet been coal mined is 0.83. This indicates that the evenness of species in post-coal mining land is not significantly influenced by the age of land reclamation.

The number of species and individuals of soil surface insects found in PT. Bukit Asam Tbk Tanjung Enim IUP Banko Barat's post-coal mining land has a close relationship with land management. Field observations reveal that as the post-coal mining land management period extends, the number of species and individuals on the land increases. Specifically, a reclamation age of 6 years exhibits a greater number of species and individuals compared to a 2-year age.

Environmental factors play a crucial role in determining the presence of surface insects at each reclamation age. The environmental conditions vary from 2 to 6 years of age. Temperature and humidity of the ecosystem are key environmental factors influencing the presence of soil surface insects. Soil temperature is a determining factor for the presence and density of soil surface insects and can influence the decomposition level of soil organic matter. Meanwhile, air humidity plays a significant role in the water content of soil-level insect bodies and their life cycles [14].

The abundant presence of insects in a land is closely tied to the availability of food and the suitability of environmental conditions. The abundant presence of insects plays a crucial role in soil processes, such as breaking down organic matter. The rapid decomposition of soil organic matter not only supports more fertile plant growth but also contributes to an increased presence of soil surface insects [18].

The availability of ground surface insect food can come from plant debris and wild plants on the land. Based on observations, revegetation plants, and enrichment plants used on post-coal mining land that is 6 years old have a greater variety of species than on land that is only 2 years old. Plant species used include *Acacia mangiun*, *Adenanthera pavonina*, *Alstonia Scholaris*, *Melaleuca orientalis*, *Pterocarpus indicus* and *Swietenia macrophylla*. The dominant soil surface insect species in PT. Bukit Asam Tbk Tanjung Enim West Banko IUP's post-coal mining land belongs to the order Hymenoptera, especially in areas with older reclamation ages, such as 6 years. Insects from the order Hymenoptera are highly sensitive to habitat disturbance [19]. The post-coal mining land, having undergone coal mining activities, experiences disturbed habitat conditions. This disturbance can lead to a more abundant presence of species and individuals from the order Hymenoptera in land that has not been subjected to coal mining.

Chemical elements also play a role in influencing the presence of surface insects on PT. Bukit Asam Tbk Tanjung Enim IUP Banko Barat's post-coal mining land. The pH value of the soil significantly affects the life of surface insects [16]. The measured soil pH levels in post-coal mining land of PT. Bukit Asam Tbk Tanjung Enim IUP Banko Barat ranges between 3.32

and 4.58, falling into the sour to very sour category. This pH value can result in imbalanced nutrient availability, leading to a less abundant presence of insects on the surface of the soil.

In this study, the species diversity index (H') of soil surface insects in post-coal mining land at PT. Bukit Asam Tbk Tanjung Enim IUP Banko Barat exhibits a medium diversity index. The species diversity index is influenced by the duration of land management. As the land management period increases, the species diversity index also tends to increase, and vice versa. High or low species diversity index values are influenced by the number of identified species and individuals [20]. The higher the number of species found, the greater the diversity value, indicating a more stable community on the land.

Species richness refers to the number of species in a given area; the greater the number of species found, the higher the richness index. In post-coal mining land PT. Bukit Asam Tbk Tanjung Enim IUP Banko IUP, the species richness index is classified as low. One factor that can influence the species richness index on land is the presence of litter. Litter on the land surface provides increased availability for species belonging to the order Hymenoptera [21].

The species evenness index in post-coal mining land PT. Bukit Asam Tbk Tanjung Enim IUP Banko IUP is close to 1. This indicates that all species exhibit a similar level of evenness at each reclamation age. The species evenness index is valuable for assessing the balance in the distribution of surface insects on the land. If a land contains many abundant species, the evenness index will be high, whereas land with few species will show a low evenness index [13].

The primary factors influencing the diversity index, richness, and evenness of species include damage to natural habitats such as land conversion, chemical pollution, and climate change [22]. Coal mining has a profound impact on altering the landscape and land cover. Therefore, the restoration process of post-coal mining land becomes crucial to returning the land to its original state. In such conditions, soil surface insect species are likely to be fewer, exhibiting moderate to low species diversity.

4. Conclusion

Post-coal mining land PT. Bukit Asam Tbk Tanjung Enim IUP Banko Barat reveals that the highest presence of surface insects, approaching natural conditions, occurs at a reclamation age of 6 years. The soil surface insect species identified were six, totaling 128 individuals, and were predominantly from the order Hymenoptera. The species found are *M. insertus, M. minimum, O. smaragdina, P. clavate, S. Invicta* and *Gryllus* sp. The diversity index of soil surface insect species in post-coal mining land at the age of 6 years is classified as moderate. This indicates that the diversity index of soil surface insect species is positively correlated with increasing reclamation age. The longer the land management period, the greater the diversity index of soil surface insect species in post-coal mining land.

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