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The Impact of Coal Mining on Ant (Formicidae) Abundance in Rice Field Areas, East Merapi, Lahat Regency, South Sumatra

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Abstract: The impact of coal mining pollution on rice fields located near mining areas can affect the health of communities that consume the harvested rice. Ants can serve as bioindicators of environmental pollution. This study aims to investigate the diversity of ants in rice fields located near and far from coal mining areas. The results show differences in ant diversity between rice fields near and far from the coal mining site. Ant species found in the rice field near the mining area included *Leptogenys chamela* (44 individuals), *Solenopsis invicta* (4 individuals), and *Camponotus texanus* (8 individuals). In contrast, in the rice field farther from the mining area, seven species were found: *Solenopsis invicta* (5 individuals), *Myopias emeryi* (71 individuals), *Tetraponera rufonigra* (37 individuals), *Paraponera clavata* (7 individuals), *Leptogenys chamela* (5 individuals), *Dolichoderus* sp. (1 individual), and *Camponotus texanus* (13 individuals). Ant abundance was higher in the rice field located farther from the coal mining area compared to the one located nearby.

Keywords: Ants, formicidae, diversity, mining, rice field.

Introduction

Lahat Regency is a developing region with productive coal mining operations and substantial coal reserves. This regency contributes 25%–30% of the coal production in South Sumatra, which reached 20 million tons in 2015, and holds 39% of the national coal reserves (BAPPEDA Lahat, 2016). Coal mining has had a positive impact on regional income; however, it also has negative effects on the environment. Coal mining is a major industrial sector that causes environmental pollution (Tiwary and Dahr, 1994). It generates large volumes of solid and liquid waste, with the industry capable of producing millions of liters of liquid waste daily (Singh, 1998).

Coal mining also poses a threat to local plantations. Rubber plantations, which are a primary source of income for the people in Lahat Regency, are at risk of contamination because they are often located near mining areas. This situation can lead to changes in abiotic factors in the plantations and affect the biodiversity of organisms living there, since waste from coal mining is often characterized by low pH and high concentrations of heavy metals (Wright et al., 2011).

Arthropods possess numerous characteristics that make them highly suitable as ecological indicators: they comprise diverse species, are present in most terrestrial ecosystems, contribute to various ecological interactions and ecosystem functions, have short life cycles, and are highly sensitive to changes in temperature and humidity (McGeoch, 1998; Maleque et al., 2009). Ants have often been used for ecological monitoring and have been shown to respond to various types of forest disturbances (Underwood and Fisher, 2006). In addition to their presence in most terrestrial ecosystems and their high diversity, ants are abundant and occupy multiple trophic levels (Alonso and Agosti, 2000).

Ants are considered suitable bioindicator species for biodiversity studies due to their

ecological significance in forest ecosystems (Alonso, 2000). Maryati (1996) reported that ants improve forest soil, aid the decomposition process, serve as a food source, and have a positive effect on tree regeneration in forests. Furthermore, ants have been used as biological control agents against insect pests in agriculture in many countries, such as Malaysia (Khoo and Chung, 1989), Thailand (Kritsaneeapiboon and Saiboon, 2000), Africa, and Papua New Guinea (Way, 1954). This study aims to investigate the abundance of ants (Hymenoptera: Formicidae) in rice fields in East Merapi, South Sumatra.

Materials and Methods

StudyArea

The study was conducted from June 2023 until completion. The research took place in East Merapi Subdistrict, Lahat, South Sumatra. Sampling was carried out through three survey visits at each station. The study area was divided into several stations, determined using a survey method. This area included two stations: a rice field zone located upstream or before the coal mining area (station A1), and a rice field zone located near the coal mining site (station A2).

Sampling Method

Surveys and explorations were conducted using a 1-kilometer line transect at each station. However, if the length of a station area did not allow for this distance, the transect was redirected with a 1-meter offset from the previous line. Many studies have shown that a combination of different methods often yields more accurate results, especially in evaluating ant community composition, compared to a single sampling method (Watanasit, 2003; Watanasit et al., 2003; Noonanant et al., 2005). Environmental factors measured in this study included soil pH, air humidity, air temperature, and light intensity.

Data were collected using direct hand-picking and insect traps. The type of trap used to capture ground-surface insects was the *pitfall trap*. The most commonly used methods for sampling ants include direct collection (Romero and Jaffe, 1989; Samson et al., 1997; Watanasit, 2003), leaf litter sampling (Levings, 1983; Brühl, 2001), and trapping techniques (Torres, 1984; Watanasit et al., 2000).

Data Analysis

Data analysis and interpretation were based on species richness (number of species found) and species abundance at each research station. Ant communities in the affected station were compared to those in the control station using the Shannon Diversity Index (H') and the Simpson Dominance Index (D) to evaluate differences in ant community composition across sampling sites. The influence of environmental factors on ant abundance was analyzed using multiple linear regression to assess both individual and combined effects of the environmental variables on ant abundance.

Results and Discussion

Rice Fields in East Merapi

Rice fields in West Merapi Subdistrict, Lahat Regency, are located near coal mining areas, making them susceptible to contamination from mining waste. In East Merapi, many rice fields are situated near or along transportation routes for coal transport. Understory vegetation was more abundant in rice fields located far from coal mining areas than in those near mining sites. This may be due to soil contamination, which hampers the growth and development of understory vegetation. Understory vegetation serves as a habitat for several organisms, especially ants. However, such vegetation such as herbs and shrubs can also interfere with rubber tree growth due to competition for water and soil nutrients. In addition, the temperature in rice fields near coal mining areas was found to be higher compared to those located farther away.

Table 1. Temperature of Ant Trap Locations at Station 1 and Station 2

Location	Trap No.	Temperature (°C)	Average (°C)
Station 1 (Rice Field Far from Coal Mine)	1	33.8	33.8
	2	33.9	
	3	34.2	
	4	35.0	
	5	34.0	
	6	33.9	
	7	33.0	

Location	Trap No.	Temperature (°C)	Average (°C)
	8	33.2	
	9	33.8	
	10	33.8	
Station 2 (Rice Field Near Coal Mine)	1	34.0	34.5
	2	34.0	
	3	34.0	
	4	34.0	
	5	35.9	
	6	35.0	
	7	34.0	
	8	34.9	
	9	34.4	
	10	35.2	

Ant Diversity in the Rice Fields of East Merapi

A total of 7 ant species comprising 195 individuals were found during the study. Three ant species were found in rice fields located near the coal mining area, whereas all 7 species were found in rice fields located farther from the mining site. Ant species such as *Myopias emeryi*, *Tetraponera rufonigra*, *Paraponera clavata*, *Leptogenys chamela*, and *Dolichoderus* sp. were found only in rice fields located far from the coal mine. Meanwhile, *Leptogenys chamela*, *Solenopsis invicta*, and *Camponotus texanus* were found in both locations. This indicates that ant diversity was higher in rice fields located farther from the coal mine compared to those near it.

Table 2. Diversity of Ant Species Found in Rice Fields Near and Far from Coal Mines

Species	Station A1 (Far from Mine)	Station A2 (Near Mine)
Leptogenys chamela	✓	✓
Solenopsis invicta	✓	✓
Camponotus texanus	✓	✓
Myopias emeryi	✓	X
Tetraponera rufonigra	✓	X
Paraponera clavata	✓	X
Dolichoderus sp.	✓	X

This discrepancy may be caused by various types of coal mining waste liquid, solid, and gas that can affect the surrounding environment even at considerable distances. Such waste can be distributed through rainwater or directly discharged into ecosystems. Noted that rice field conditions significantly influence ant diversity (Putra et al., 2017). For example, ant diversity is higher in organic than in inorganic rice fields. Environmental factors such as pH, organic matter content, nitrogen levels, organic carbon, and phosphorus levels can increase ant diversity and abundance (Adhi et al., 2017).

Explained that mining operations affect macrofauna in the surrounding environment (Machado et al., 2018). Stated that mining activities have both direct and indirect impacts on soil conditions (Evdokimova et al., 2024). Direct impacts are seen in soils closest to the mining area, where soil quality decreases due to pollutant accumulation such as coal dust and other particles. Indirect impacts occur in soils located further from the mining site, where pollutant accumulation is still detectable but decreases with distance.

This study reinforces the environmental impact of coal mining on surrounding areas, as evidenced by the lower ant diversity observed in rice fields near the mining site. The researchers also suggest that the low ant diversity in Station A2 may be due to changes in environmental conditions and nutrient availability, along with pollutant accumulation that restricts survival to only a few tolerant ant species.

Ants Species Description

Camponotus texanus

Camponotus texanus typically nests in dead branches (on living trees) and in oak tree trunks. Wheeler (1903) reported that three of its nests were collected from oak wood. A fourth nest was found in the crevice between two large rocks. They are also sometimes found nesting under rocks on rocky slopes. This species is very active and difficult to catch, and is limited to Texas, United States (Mackay, 2019).

Figure 1. *Camponotus texanus (*Personal doc, 2025)

Leptogenys chamela

Leptogenys chamela has a slender and elongated body shape that enables it to move quickly when hunting. It also possesses sharp and strong mandibles used for slicing prey. Generally, *Leptogenys* ants have a reddish-brown or glossy black body, with smooth surfaces and fine striation patterns. Additionally, they have a distinctive structure on their legs known as pectinate claws, resembling comb teeth, which aid in gripping surfaces and capturing prey (Lattke, 2011).

Figure 2. *Leptogenys chamela* (Personal doc, 2025)

Myopias

Myopias ants form small colonies, usually with fewer than 100 worker ants, and build nests in decaying wood or rocky soil. These ants possess an abdomen equipped with exocrine glands, venom glands, and Dufour's glands. They exhibit specialized hunting behavior, particularly targeting centipedes as food for their larvae. The ants paralyze their prey with a sting, decapitate the centipede, open its body, and allow the larvae to suck out the internal tissues until the prey is completely consumed (Billen et al., 2013; Ito et al., 2020).

Figure 3. *Myopias* (Personal doc, 2025)

Tetraponera rufonigra

Tetraponera rufonigra is an arboreal ant species with a painful sting that can cause severe anaphylaxis in individuals allergic to insect stings. It is morphologically characterized by a dark head and gaster, and a brown to bright orange body. This ant typically inhabits semi-deciduous forests, mangroves, urban parks, and gardens. It commonly nests in dead or living wood and exhibits aggressive behavior when its nest is disturbed. Colonies usually consist of 300–500 individuals. These ants are excellent climbers, frequently active in trees but also forage on the ground. They play a protective role for plants against herbivore attacks and feed on extrafloral nectar (Sabtu & Ab Majid, 2018; Sabtu & Ab Majid, 2017).

Figure 4. *Tetraponera rufonigra* (Personal doc, 2025)

Dolichoderus

Most *Dolichoderus* ant species nest underground or close to the ground surface. However, *D. pustulatus*, found in Florida and southern Georgia, nests in cavities of hardwood tree branches in swamps and wetlands. According to Johnson (1989), *Dolichoderus* lives in colonies with other

arboreal ants such as *Camponotus impressus*, indicating potential ecological interactions. Similarly, this study also found *Dolichoderus sp.* coexisting with *Camponotus texanus*. Anggraeni et al. (2014) explained that *Dolichoderus thoracicus* has potential as a biological control agent against Black Pod disease in cocoa plants in Central Sulawesi by collecting *Trichoderma sp.* spores on their bodies and spreading them on plants, thus inhibiting the pathogen *Phytophthora palmivora*.

Figure 5. *Dolichoderus* (Personal doc, 2025)

Solenopsis invicta

Solenopsis invicta, also known as the red imported fire ant, generally builds large mound-shaped nests on the ground surface with tunnel systems connecting chambers underground. Worker ants form small groups of around 200 individuals to care for the larvae. A colony can consist of hundreds of thousands of individuals in a single nest (Cassill et al., 2002). The eggs are small, oval-shaped, and maintain their size for about a week before developing into embryos and hatching into larvae (Petralia & Vinson, 1979).

Figure 6. *Solenopsis invicta* (Personal doc, 2025)

Paraponera clavata

Paraponera clavata is a large ant species with a complex and efficient stinger structure. It has four main components: venom gland (produces venom injected into the prey), sclerite (controls and directs the sting precisely), furcula (X-shaped structure used to stabilize and guide the sting), and gonostylus (channel for delivering venom into the prey). The venom is protein-based and hemolytic, causing intense pain and physiological effects in the prey (Hermann & Blum, 1966).

Figure 7. *Paraponera clavata* (Personal doc, 2025)

Ant Abundance in Merapi Timur Paddy Fields

This study identified seven ant species with a total of 195 individuals in the study area. Three ant species were found in paddy fields located near a coal mining site, totaling 56 individuals. Seven species were found in fields farther from the mining area, totaling 139 individuals. In paddy fields near the coal mining site, the following species were identified, *Leptogenys chamela* (44 individuals), *Solenopsis invicta* (4 individuals), *Camponotus texanus* (8 individuals). In paddy fields far from the mining area, seven species were found *Solenopsis invicta* (5 individuals), *Myopias emeryi* (71 individuals), *Tetraponera rufonigra* (37 individuals), *Paraponera clavata* (7 individuals), *Leptogenys chamela* (5 individuals), *Dolichoderus sp.* (1 individual) and *Camponotus texanus* (13 individuals).

The study results show that ant abundance is higher in paddy fields located farther from coal mining areas compared to those closer to the mines. This may be due to pollutants liquid, solid, and gaseous generated by coal mining, which can affect the surrounding environment and beyond. These pollutants can spread through rain or be directly discharged into the ecosystem. Species evenness is also higher in paddy fields farther from the coal mining site. Four species *Myopias emeryi*, *Tetraponera rufonigra*, *Paraponera clavata*, and

Dolichoderus sp. were not found in fields near the mine, indicating greater diversity and abundance in less polluted, more natural environments.

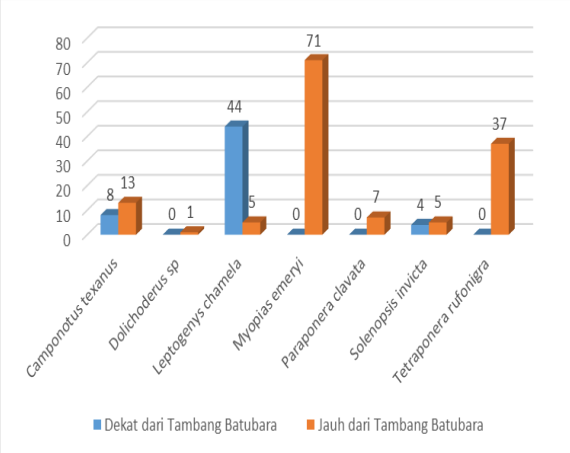

Figure 8. The Graph of Abundance of Ant in Paddy Field

Conclusion

Ant species found in paddy fields near the coal mining area include *Leptogenys chamela* (44 individuals), *Solenopsis invicta* (4 individuals) and *Camponotus texanus* (8 individuals). In contrast, seven ant species were found in paddy fields farther from the mining area *Solenopsis invicta* (5 individuals), *Myopias emeryi* (71 individuals), *Tetraponera rufonigra* (37 individuals), *Paraponera clavata* (7 individuals), *Leptogenys chamela* (5 individuals), *Dolichoderus sp.* (1 individual) and *Camponotus texanus* (13 individuals). The findings show that ant abundance and diversity are greater in paddy fields farther from coal mining areas. This is likely due to the absence of environmental pollutants from mining activities in these more natural areas.

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