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THE ABUNDANCE OF ANTS (FORMICIDAE) IN COFFEE PLANTATIONS OF MERAPI, LAHAT DISTRICT

Pengaruh Parameter Fisikokimia terhadap Kelimpahan Makrozoobentos di Sungai Kungkilan, Sumatera Selatan

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ABSTRACT

Ants are widely used as ecological indicators in agricultural landscapes, yet community responses can vary across local environmental gradients. This study assessed ground-active ant assemblages in coffee plantations in Merapi, Lahat (South Sumatra, Indonesia) at sites categorized as near versus far from a coal-mining area, using pitfall traps and community-level metrics. Mean temperatures during sampling were nearly identical between site categories (near 30.54 °C; far 30.56 °C). Ant assemblages showed contrasting patterns in richness and abundance: far sites contained six taxa but a lower total number of individuals (117), while near sites contained three taxa but higher total abundance (209). Species composition differed markedly, with far sites dominated by Solenopsis invicta and near sites dominated by Leptogenys sp. and Myopias emeryi. Diversity indices reflected these patterns: Shannon diversity was higher far from the mine (0.8906) than near (0.7215), while Simpson dominance was slightly higher far (0.5607) than near (0.5219), and evenness was higher near (0.6567) than far (0.4971). These findings indicate an association between distance class and ant community structure in coffee plantations, characterized by higher richness but stronger dominance at far sites and higher abundance but lower richness at near sites; however, conclusions about mining impacts should remain cautious given the observational design.

Keywords: *Ants, Coffee plantation, Community Composition, Coal Mining*

ABSTRAK

Semut sering digunakan sebagai indikator ekologi di lanskap pertanian, namun respons komunitasnya dapat bervariasi mengikuti gradien lingkungan lokal. Penelitian ini mengevaluasi komunitas semut aktif-permukaan (ground-active) di kebun kopi di Merapi, Kabupaten Lahat (Sumatera Selatan, Indonesia) pada lokasi yang dikategorikan dekat dan jauh dari area tambang batubara, menggunakan pitfall trap serta metrik komunitas. Suhu rata-rata selama pengambilan sampel hampir sama pada kedua kategori lokasi (dekat 30,54 °C; jauh 30,56 °C). Komunitas semut menunjukkan pola kontras antara kekayaan jenis dan kelimpahan: lokasi jauh memiliki enam taksa tetapi jumlah individu total lebih rendah (117), sedangkan lokasi dekat memiliki tiga taksa tetapi kelimpahan total lebih tinggi (209). Komposisi spesies juga berbeda jelas, dengan lokasi jauh didominasi Solenopsis invicta dan lokasi dekat didominasi Leptogenys sp. serta Myopias emeryi. Indeks keanekaragaman mendukung pola tersebut: indeks Shannon lebih tinggi pada lokasi jauh (H′ = 0,8906) dibanding dekat (H′ = 0,7215), sementara dominansi Simpson sedikit lebih tinggi pada lokasi jauh (D = 0,5607) dibanding dekat (D = 0,5219), dan kemerataan lebih tinggi pada lokasi dekat (E = 0,6567) dibanding jauh (E = 0,4971). Hasil ini menunjukkan adanya keterkaitan antara kategori jarak dan struktur komunitas semut di kebun kopi, ditandai kekayaan jenis lebih tinggi namun dominansi lebih kuat pada

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lokasi jauh, serta kelimpahan lebih tinggi namun kekayaan jenis lebih rendah pada lokasi dekat, namun interpretasi dampak tambang belum menunjukan hubungan sebab akibat, karena desain penelitian bersifat observasional.

Kata kunci: *Semut, Kebun Kopi, Komposisi Komunitas, Tambang Batubara*

INTRODUCTION

Ants (Hymenoptera: Formicidae) are a ubiquitous and ecologically dominant insect group in terrestrial ecosystems, and their communities often show consistent shifts along environmental gradients and disturbance regimes (Tiede et al., 2017; Andersen, 2019). Because ants are widespread and taxonomically diverse, relatively straightforward to sample, and tightly linked to soil and vegetation processes (e.g., soil turnover, nutrient cycling, and plant–ant interactions), they have long been used in terrestrial monitoring and impact assessment (Underwood & Fisher, 2006).

Conceptual frameworks emphasise that disturbance effects on ants are often indirect, operating via changes in habitat structure and “openness”, and that community responses depend on functional composition and ecological context (Andersen, 2019). Empirical work also shows that ant assemblages can shift in community structure (e.g., species richness and relative-abundance structure) and functional attributes along environmental and land-use gradients, which makes ants useful for comparing ecological condition across sites and management regimes (Underwood & Fisher, 2006; Tiede et al., 2017).

In tropical agroforestry systems such as shade-grown coffee, ants can contribute to ecosystem functioning by shaping arthropod food-web interactions and influencing pest (and sometimes disease) dynamics. Ant assemblages also tend to track management-driven changes in vegetation structure and microclimate, with diversity often declining under more intensive, low-shade systems; consistent with broader evidence that ant-mediated pest control and plant protection are frequently stronger in shaded cropping systems than in simplified monocultures (Philpott & Armbrecht, 2006; Anjos et al., 2022).

Evidence from coffee landscapes shows that ant-mediated pest control depends on landscape structure measured at multiple spatial scales (e.g., forest and coffee cover, and proximity to forest fragments/edges), supporting the view that ant-related services integrate signals across both local and landscape contexts (Aristizábal & Metzger, 2018). More broadly, ant biodiversity in tropical agroforestry systems often declines with management simplification or intensification, which makes ant communities informative for evaluating ecological condition in working landscapes; moreover, changes in ant occurrence/activity and richness can serve as practical indicators of environmental change and linked ecosystem processes such as predation (Philpott & Armbrecht, 2006; Tiede et al., 2017)

Mining is a globally important pressure on biodiversity, affecting species and ecosystems through multiple pathways including habitat loss and degradation, infrastructure expansion and fragmentation, and contamination of land and water. Coal mining can also alter soil physicochemical properties and, in some settings, is associated with elevated concentrations of metals in mine spoils and mine-affected soils (Khan et al., 2024). Long-term field evidence further suggests that responses of soil invertebrates to elevated metal concentrations can be taxon-specific: community-level diversity may show limited change at concentrations within regulatory limits, but sensitive groups and processes such as litter decomposition can decline under higher Cu/Zn loads (Creamer et al., 2008).

South Sumatra is a major coal-producing region, and Lahat Regency is among the areas where coal mining operates alongside agricultural land uses, creating potential for fine-scale mosaics of farms located at varying proximity to mining activity. Within Merapi Subdistrict (Lahat, South Sumatra), a recent local study in rice fields reported differences in ant richness and abundance between sites near versus farther from coal mining areas, suggesting that ant communities may vary across similar proximity gradients in the same broader landscape (Teristiandi & Yuliana, 2025).

However, patterns observed in one crop system (e.g., rice paddies) cannot be assumed to transfer directly to another (e.g., coffee) because microhabitat, ground cover, litter depth, shade, and farm management can influence ant activity and capture rates. Therefore, coffee plantations in the Merapi landscape provide an important additional context to evaluate how ant assemblages differ across proximity to mining activity while avoiding over-interpretation of causality.

Accordingly, the objectives of this study are: (i) to describe ant species composition and abundance in coffee plantations across two proximity categories (near vs far from mining activity). Because the study measures a limited set of environmental variables (temperature and ant assemblage data) and does not experimentally manipulate mining-related exposures, we frame our inference as a comparative biodiversity assessment rather than a definitive test of mining impacts.

By providing baseline evidence from coffee plantations in Merapi, Lahat, this work complements local agroecosystem research and supports future studies that integrate broader environmental measurements (e.g., soil chemistry) to more directly evaluate mechanisms underlying observed community differences.

MATERIALS AND METHOD

Study area

The survey was conducted in coffee plantations of Merapi Subdistrict, Lahat Regency, South Sumatra (Indonesia). This region (tropical climate) features smallholder coffee. Two types of plantation sites were selected based on distance to a coal mine: Far plots (located on the upstream side of the Merapi Subdistrict, approximately several kilometers from active mining) and Near plots (situated adjacent to the coal mining area). Each zone included multiple similar coffee farms.

Sampling design

In each zone with Near (A1-A9) vs Far (B1-B9), nine sampling points (plots) were established. At each point, one pitfall trap was installed. Pitfall traps consisted of 8–10 cm diameter plastic cups buried flush with the soil surface and partly filled with a 50% ethanol solution as a preservative. Traps were left open for 48 hours (sampled in the morning of day 3) to accumulate ground-foraging ants. Pitfalls operate continuously and effectively capture active ants over this period. The temperature at each trap was measured with a portable thermometer.

Species identification and abundance.

Captured ants were preserved in ethanol and later sorted and identified to genus level under a stereomicroscope. For each sampling point, the number of individuals of each ant species was recorded. All counts from the nine points in a zone were summed to obtain the total abundance per species in that zone.

Data Analysis

Ant abundance data from each pitfall trap were organised into a species-by-sample table, using the number of individuals per ant taxon as raw counts. For each sampling point, we calculated total abundance and taxon richness (the number of taxa recorded). We then quantified community diversity using the Shannon–Wiener diversity index, dominance using Simpson’s dominance index together with and evenness index. All indices were calculated consistently across samples to enable direct comparison between site categories (near vs. far from mining activity) while keeping the interpretation focused on observed community patterns rather than inferring unmeasured environmental mechanisms.

RESULT AND DISCUSSION

Ant Abundance Patterns and Composition

The bar chart (Figure 1) summarises clear differences in species-level composition and dominance between distance classes. Across far-from-mine plots, a total of 117 individuals were recorded, distributed across six taxa: Solenopsis invicta (85), Leptogenys sp. (20), Camponotus sp. (6), Tetraponera rufonigra (3), Myopias emeryi (2), and Paraponera sp. (1). This indicates strong numerical dominance of S. invicta in the far sites (85/117 ≈ 72.6% of individuals). In contrast, near-mine plots contained 209 individuals, but only three taxa were detected: Leptogenys sp. (131), Myopias emeryi (75), and Camponotus sp. (3). S. invicta, T. rufonigra, and Paraponera sp. were not recorded in this group in the sampling period represented by the dataset.

Numerically, the near sites were dominated by Leptogenys sp. (131/209 ≈ 62.7%) and M. emeryi (75/209 ≈ 35.9%), with Camponotus sp. contributing a small fraction (3/209 ≈ 1.4%). Taken together, the figure shows a turnover in dominant taxa: far sites were dominated by S. invicta, whereas near sites were dominated by Leptogenys sp. and M. emeryi, alongside an overall shift toward higher total abundance but lower taxonomic breadth near the mine.

The far sites display a classic “single-dominant” pattern, where one taxon (S. invicta) accounts for most individuals, while the remaining taxa contribute relatively few individuals each. Dominance is a key feature of ant community ecology and can shape local assemblages through behavioural interference and resource monopolisation, although the strength and outcomes of such dominance can vary among systems and contexts (Davidson, 2004; Arnan et al., 2018).

The near sites show a different structure: abundance is concentrated in two taxa (Leptogenys and Myopias), with a very small contribution from Camponotus. Ecologically, this kind of pattern is consistent with environmental filtering (only certain taxa thriving under local conditions) and/or resource-driven aggregation (high worker activity where prey or resources are concentrated). However, the figure alone cannot identify mechanism, so the safest statement is that the near sites support a numerically intense but taxonomically narrower assemblage during the sampling window.

Both Leptogenys and Myopias are predatory ponerine ants. In Leptogenys, many species specialise on oniscoid isopods, and detailed observations describe prey capture and handling behaviours during predation (Dejean & Evraerts, 1997). Myopias is likewise a predatory genus; natural-history syntheses indicate generally cryptic, small-colony taxa with feeding habits that can include apparent specialisation (e.g., millipede predation in several species) as well as strong prey preferences such as beetle predation in M. darioi (Probst et al., 2015). If predatory taxa dominate near sites, this may reflect differences in prey availability or microhabitat conditions that favour ground-hunting predators, but this remains a hypothesis because prey communities and habitat structure were not measured in the figure presented.

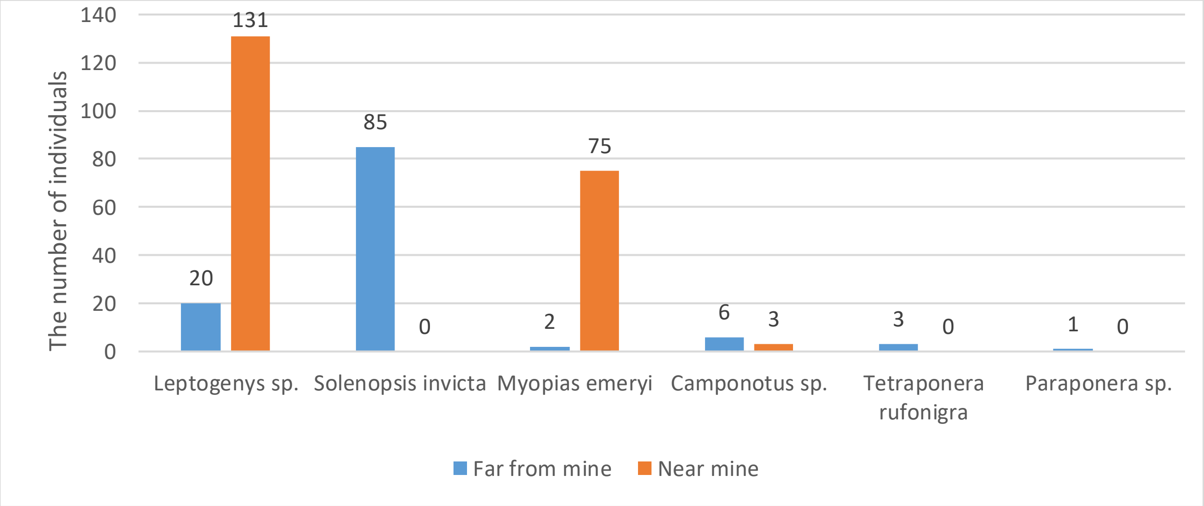

Figure 1. Ant abundance by taxon (number of individuals) at sites near the mine and far from the mine

Conversely, the far sites are dominated by S. invicta, a globally invasive species that has been linked to substantial ecological effects in some invaded systems (Wang et al., 2019). At the same time, evidence is mixed regarding how consistently S. invicta suppresses other ants across disturbed habitats; experimental colony-removal work has reported cases where co-occurring ant diversity and abundance did not increase after S. invicta removal in a disturbed system (King & Tschinkel, 2006). This supports a careful interpretation here: the figure demonstrates dominance patterns and taxonomic turnover, but does not by itself demonstrate competitive exclusion or mining-driven impacts.

A key result in the bar chart is that near sites have more individuals overall yet fewer taxa represented. Because observed richness is strongly affected by the number of individuals collected, raw richness comparisons can be misleading when sites differ in total abundance or sampling effort; valid comparisons should therefore be based on taxon sampling curves (accumulation/rarefaction) and appropriate standardisation (Gotelli & Colwell, 2001). Here, the combination of high total counts but low taxon representation is consistent with a highly uneven assemblage in which a few taxa account for most individuals (e.g., Leptogenys and Myopias near the mine), but additional covariates (e.g., habitat structure, resource distribution, and prey availability) would be required to identify the dominant ecological mechanism driving this pattern.

The most defensible wording for an article based on this figure is that ant assemblages differed between plots near versus far from mining, with clear changes in which taxa dominated and how individuals were distributed among taxa. Ants are commonly used as bioindicators because their communities respond to environmental gradients and disturbance, making them useful for monitoring change (Tiede et al., 2017). However, because the comparison is observational and the figure does not include measured confounders (vegetation structure, litter depth, pesticide use, soil chemistry), conclusions should remain at the level of association rather than causal attribution to mining.

Temperature Pattern

According to Figure 2, site-average temperatures during sampling were very similar across the two distance classes. In coffee plots far from the mine, recorded temperatures ranged from 30–31 °C across sampling points A1–A9, whereas plots near the mine ranged from 30.5–30.6 °C across B1–B9. This is consistent with the average displayed in the temperature figure (Near ≈ 30.54 °C, Far ≈ 30.56 °C), indicating only a ~0.02 °C difference in mean temperature between site categories, a practically negligible separation given the narrow within-group ranges.

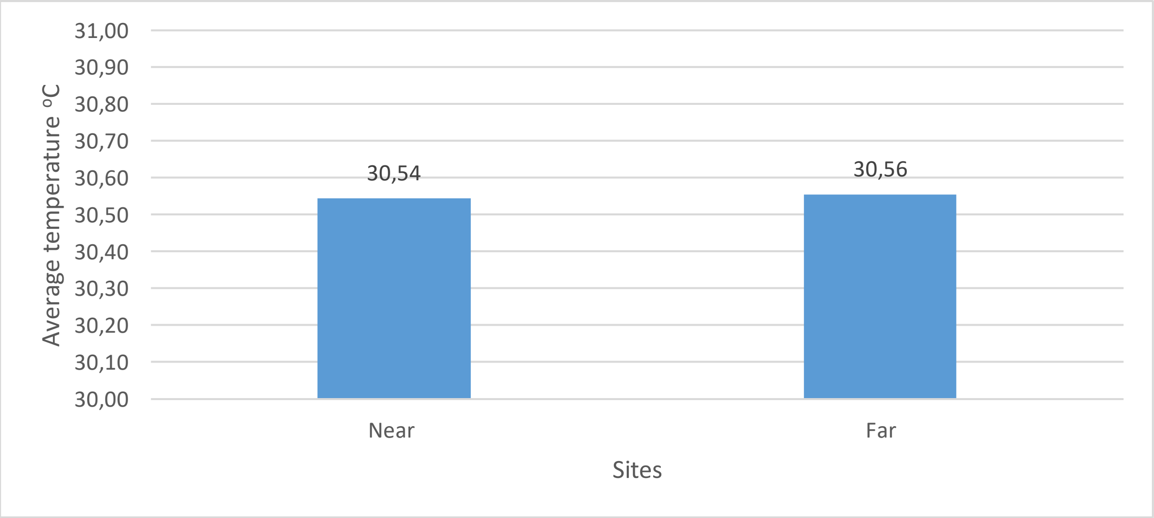

Figure 2. Mean air/ground temperature (°C) at sites near the mine and far from the mine

Temperature is ecologically relevant for ants because they are ectotherms, and substantial work shows that foraging schedules (daily activity windows) and locomotor performance can shift with temperature, especially as conditions approach species-specific thermal limits (Jayatilaka et al., 2011). Mechanistic evidence also indicates that temperature can influence feeding performance (e.g., ingestion dynamics and intake rate) in nectar-feeding ants (Falibene & Josens, 2014). Consistent with these mechanisms, warming experiments have reported that increased temperatures can alter ant recruitment at food resources and change forager abundance and richness in some contexts (Stuble et al., 2013).

However, the temperature pattern observed here is extremely compressed (only ~1 °C spread in the “far” sites and ~0.1 °C in the “near” sites), so temperature differences alone are unlikely to explain large between-group contrasts in ant community metrics. Instead, the most defensible interpretation is that temperature acted as a largely constant background condition during this sampling window, strengthening the inference that any observed differences in richness/abundance between “near” and “far” plots are more plausibly associated with other site-correlated factors (e.g., habitat structure, ground cover and litter, resource availability, soil conditions, or disturbance regime).

Integrating Indices to Interpret Community Structure

The diversity metrics showed contrasting patterns between the two distance classes. Shannon–Wiener diversity (H′) was higher at sites far from the mine (H′ = 0.8906) than at sites near the mine (H′ = 0.7215), indicating higher overall diversity when richness and relative abundances are considered together. At face value, both H′ values may appear “low”, particularly because H′ in the far sites remains < 1 even though richness is higher. In contrast, Simpson’s dominance index (D) was slightly higher far from the mine (D = 0.5607) than near the mine (D = 0.5219), consistent with stronger numerical dominance by one or a few taxa in the far sites. Evenness (E) showed the reverse pattern, being higher near the mine (E = 0.6567) than far from the mine (E = 0.4971), suggesting that individuals were more evenly distributed among the taxa recorded near the mine.

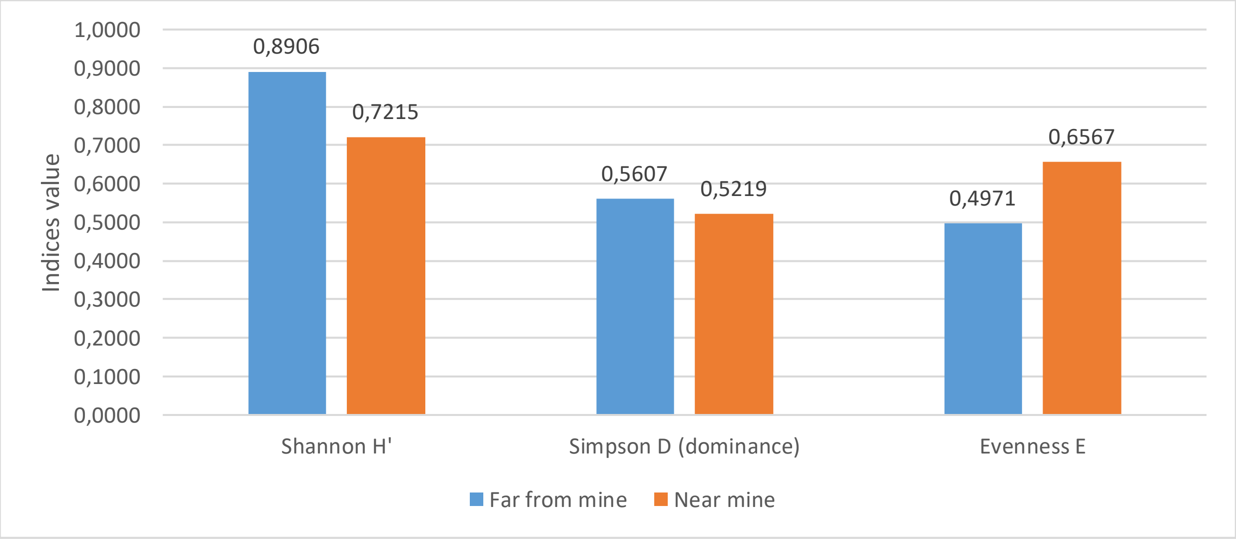

Figure 3. Comparison of ant diversity metrics between sites near the mine and far from the mine: Shannon–Wiener diversity (H′), Simpson dominance (D), and evenness (E)

Shannon’s index (H′) increases with both taxonomic richness and evenness because it reflects the structure of relative abundances in a community. In practice, diversity metrics differ in their sensitivity to rare versus common taxa, so H′ will tend to rise when additional taxa are present and not extremely rare and/or when dominance becomes less extreme (Morris et al., 2014). The higher H′ value in far sites (0.8906 vs

0.7215) is therefore consistent with a broader taxonomic set and/or a less skewed distribution of individuals among taxa. Importantly, H′ summarises richness–abundance structure but does not, on its own, identify the ecological mechanisms generating the pattern (Morris et al., 2014).

The slightly higher dominance in far sites (0.5607 vs 0.5219) indicates that far-site assemblages were more strongly weighted toward the most common taxon/taxa. This helps reconcile an important ecological point: a site can have a higher Shannon index while still showing notable dominance, because Shannon and Simpson weight community structure differently.

The higher evenness near the mine (0.6567) indicates a more balanced distribution of individuals among the taxa recorded there, despite the shorter taxon list. In practical terms, this suggests a less skewed relative-abundance structure (i.e., the most common taxon is not as overwhelmingly dominant relative to the others). Reporting both H′ and evenness is therefore helpful because evenness indices are commonly constructed to summarise the uniformity of relative abundances while adjusting for differences in richness; however, the choice of evenness index matters because many proposed indices can show biases and may not provide value-valid comparisons (Kvålseth, 2015).

Taken together, the indices indicate that far sites had higher overall diversity (H′) but also stronger dominance (higher Simpson dominance, D) and lower evenness (lower E), whereas near sites had lower H′ but higher evenness and slightly weaker dominance. This combination is internally consistent: a community can contain more taxa (raising H′) while still being numerically skewed toward one leading taxon (raising dominance and reducing evenness). Conversely, a community with fewer taxa can exhibit relatively high evenness if individuals are shared more evenly among those taxa. Because Shannon and Simpson emphasise different parts of the abundance distribution, these metrics can diverge in precisely this way (Magurran, 2021; Jost, 2006).

These patterns suggest that distance classes differ in both community membership and dominance dynamics: near sites contain fewer taxa, but none accounts for such an overwhelming share of individuals, while far sites are richer yet disproportionately dominated by a single taxon. This combination is consistent with environmental differences that simultaneously affect which taxa can persist and which taxa become numerically dominant, but the current figure cannot distinguish whether the driver is habitat structure, microclimate, resource distribution, or other unmeasured covariates. The defensible conclusion is therefore compositional and structural change, not causal attribution.

CONCLUSION

This study compared ground-dwelling ant assemblages in coffee plantations located near versus far from a coal-mining area using standardized pitfall trapping. Mean temperatures were effectively similar between distance classes, indicating that the observed community differences are unlikely to be explained by a meaningful thermal contrast during sampling. Ant assemblages differed strongly in structure: far sites supported higher taxon richness (six taxa) but fewer total individuals, whereas near sites showed higher total abundance but lower richness (three taxa), accompanied by a clear shift in dominant taxa. Diversity indices were internally consistent with these patterns, Shannon diversity was higher at far sites yet remained modest in absolute magnitude due to uneven abundances, while Simpson dominance was slightly higher and evenness lower at far sites, indicating a more concentrated community despite greater richness. Overall, the results demonstrate an association between distance class and ant community composition, dominance structure, and diversity patterns in coffee agroecosystems, while causal attribution to mining per se should be made cautiously because the study is observational and other site-level factors may covary with distanc.

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