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Effect of Land Use Intensity On Diversity And Abundance of Soil Insects And Earthworms In Sumberjaya, Lampung

Efek Intensitas Penggunaan Lahan Terhadap Keanekaragaman dan Kemelimpahan Serangga Tanah dan Cacing Tanah di Sumberjaya, Lampung

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ABSTRAK. Serangga, termasuk rayap, semut dan kumbang secara taksonomi beragam, melimpah dan secara ekologi berperan penting dalam lingkungan tanah. Walaupun tidak terlalu beragam, cacing tanah juga melimpah di dalam tanah. Tujuan penelitian ini adalah melihat pengaruh pola penggunaan lahan terhadap keanekaragaman dan kemelimpahan serangga dan cacing tanah di Sumberjaya, Lampung. Metode yang digunakan adalah monolit (cacing tanah), transek (rayap) dan winkler (semut dan kumbang). Rayap dan semut diidentifikasi sampai tingkat spesies, semut sampai genus dan kumbang sampai tingkat famili/sub famili. Hasil penelitian menunjukkan tujuh tipe penggunaan lahan (hutan dengan tingkat gangguan rendah, hutan dengan tingkat gangguan lebih besar, tumpangsari kopi, kopi monokultur, tanaman pangan, tanaman sayuran, dan semak) ditemukan 53 genus semut, 59 famili/subfamili kumbang, 37 jenis rayap,dan 10 jenis cacing tanah. Keanekaragaman dan kemelimpahan semut, kumbang dan rayap menurun seiring peningkatan intensitas penggunaan lahan. Perbuhan pola penggunaan lahan tidak berpengaruh terhadap keanekaragaman dan kemelimpahan cacing tanah tetapi cacing tanah yang ditemukan pada tipe penggunaan lahan yang semakin intensif cenderung lebih kecil. Deforestasi menyebabkan hilangya spesies cacing tanah lokal.

Kata kunci: tanah, serangga, cacing tanah, keanekaragaman, kemelimpahan, penggunaan lahan

ABSTRACT. Insects, including termites, ants, and beetles are taxonomically diverse, abundant, and ecologically important in the soil environment. Although not too diverse, earthworms are also abundant in the soil. The objective of this study was to determine the effect of land use (LU) change on diversity and abundance of soil insects and earthworms in Sumberjaya, Lampung. Methods used were monolith (for earthworms), transect (for termites), and Winkler (for ants and beetles). Termites and earthworms were identified up to species, ants up to generic level, and beetles to family/sub-family level. Results show that from seven land use types (less disturbed forest, more disturbed forest, polyculture coffee, monoculture coffee, food crop, vegetable crop, and shrub) we found 53 ant genera, 59 beetle families / subfamilies, 37 termite species, and 10 earthworm species. Diversity and abundance of ants, beetles, and termites decrease as LU intensity increases. LU change did not affect earthworm diversity or abundance, but smaller-sized earthworms tended to be found in more intensive LU types. Deforestation caused the loss of native earthworm species.

Key words: soil, insect, earthworm, diversity, abundance, land use

INTRODUCTION

Insects are taxonomically diverse, abundant, and ecologically important in the soil environment. Some groups of soil insects (ant, beetle, termite) provide important ecosystem functions, including predation, herbivory, and soil organic matter (SOM) decomposition. Earthworms, although not as diverse as insects, also provide important ecosystem function, including SOM decomposition, soil nutrient cycling, and soil structure engineering (Lavelle and Spain, 2001). Soil biota may be very sensitive to land use changes (Senapati *et al.,* 2005) including deforestation. Decrease in their diversity or abundance could lead to loss of ecosystem functions they may otherwise perform.

During the last several decades, most of the forested area in Sumatra has been converted into various land use (LU) types (van Noordwijk *et al.,* 1995), including coffee-based systems, crops (food-crops and vegetable crops), and shrubs in Sumberjaya area, West Lampung (Syam *et al.,* 1997; Evizal *et al.,* 2005). Forests were slashed-and-burned for coffee plantation while rice, maize, or vegetable were intercropped with the young coffee plants. The coffee plantation was then established as monoculture or polyculture systems. The polyculture coffee system were as simple as shaded system (with *Gliricidia, Erythrina,* or *Paraserianthes* as the shade trees) or as complex as the multistorey coffee (with various fruit or medicinal trees and other plants standing within the plantation) (Verbist *et al.,* 2004). When coffee productivity or price dropped, farmers cut the coffee and grew food crops or vegetable crops instead; otherwise they abandoned the plantation. In other situation, the field was fallowed in case they did not have adequate inputs to maintain the crops (Evizal *et al.,* 2005).

Land use changes have been claimed to cause the depletion of soil biological diversity, but the claim needs adequate evidence (Giller *et al.,* 1997). Fragoso *et al.* (1997) reported that the land use change from forest to agroecosystems lead to the loss of various species and functional groups of earthworms and subsequent reduction of land productivity in Mexico. Jones *et al.* (2003) has also reported the reduction of termite diversity and abundance as a result of deforestation and land use intensification in Jambi, Sumatra. Did deforestation and land use change reduce the diversity and abundance of soil insects and earthworms in Sumberjaya area, West Lampung? The objective of this study was to provide evidence whether land use changes reduce the diversity and abundance of selected soil insects (ants, beetles, termites) and earthworms.

METHODS

Ants and beetles were sampled using Winkler method, while termites and earthworms using transect and monolith, respectively (Susilo and Karyanto, 2005), from seven land use types in Sumberjaya area, West Lampung during the rainy season (January-February) of 2004. The observed land use types included less-disturbed forest, more-disturbed forest, polyculture coffee, monoculture coffee, food crop, vegetable crop, and shrub (fallow). Sample points were gridded from an Ikonos map (200 m map grids), ground checked, and selected (Afandi *et al.,* 2005). Monoliths were taken from 88 selected points while transects and Winkler were taken from 35 out of the 88 points as such that there were 5 points (transect and Winkler samples) and 6-14 points (monolith samples) per land use type. The position of each sample point was determined using a global positioning system (GPS). The positions of monolith, transect, and Winkler in each sample point were illustrated in Figure 1, i.e. one monolith at the centre (grid, GPS) point, one transect at 8 m from the monolith, and three Winkler quadrates at 2 m from the transect.

Litter was collected and incubated using Winkler apparatus (Chung and Jones, 2003). Collection included the litter scraping from three 1 m x 1m Winkler quadrates using the gloved hands, sieving it using 1 cm x 1 cm sieve, and transferring the resulting litter (< 1 cm diameter) using debris bags (i.e. pillow cases) into an incubation room. After weighed using ELTRA® balance (maximum weight of 5 kg, minimum scale 20 g), the litter was then incubated within the Winkler bags for 72 hours (room temperature and humidity). Ants and beetles escaping from the air-dried litter plunged into 70% etahnol solution in a collecting jar at the bottom of the bag. Ant and beetle specimens were transferred into vial containing 70% ethanol solution for labeling and identification. Ants were identified up to generic level using Hashimoto (2003), Bolton (1994), and Alpert and Susilo (2005) while beetles were identified up to family or subfamily level using Chung (2003) and Borror *et al.* (1981).

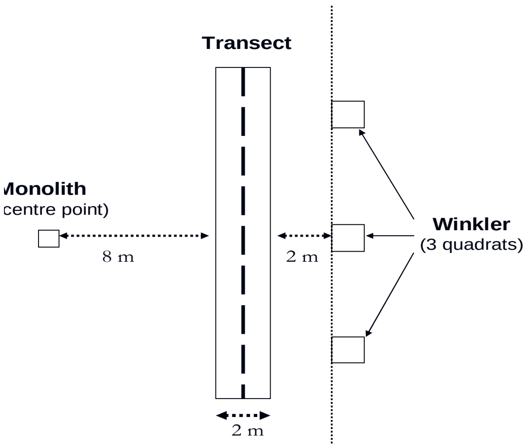

Figure 1. The positions of monolith, transect and Winkler samples in a sample point

Termites were collected from soil within a 20 m x 2 m transect in 4 x 1.5 person-hours. Four person-hour (2 persons each for 2 hours search) was spent to search for termites from soil (scraping using a trawl) and an additional two-person hour from various micro niches within the transect. Termite specimens (soldier caste) found during the search were collected into glass vials containing 70% ethanol solution for preservation and identification. Termite specimens were identified up to species (or morphospecies) level using Ahmad and Akhtar (1981), Thapa (1981), Tho (1992), Homathevi (2003a; 2003b), and Jones *et al.* (2003).

A monolith, i.e. a block of soil sample of dimensions 25x25x30 (depth) cm (Anderson and Ingram, 1993; Swift and Bignell, 2001) including the litter on the soil surface, was taken from the sample point for the search of earthworms. The litter, and subsequently the soil in the monolith, was placed into a plastic tray and sorted bit by bit. Any spotted earthworm was collected into vial with 15-20 ml of 4% formalin. Upon arrival in the base-camp or laboratory, earthworms were washed thoroughly with clean water, and stored in vial with 15-20 ml of 70% ethanol. The specimens were identified up to species (or morphospecies) level using Sims and Easton (1972), Reynold and Righi (1994), and Jones (2003). The specimens were also weighed to document their biomass (based on blotted preserved specimens, Swift and Bignell, 2001).The earthworm species were also traced for their origins, i.e. native versus exotic (Fragoso *et al.,* 1999).

The ant, beetle, termite, and earthworm data were tabulated separately but each table contained the list of taxa and their abundance per sample point (replication) per land use type. The diversity (per sample point) was thus presented at various taxonomic levels depending on the macrofauna group, i.e. the number of species (per 20 m x 2 m transect for termites or per 25 cm x 25 cm x 30 cm monolith for earthworms), the number of genera (per 3 x 1 m^2 litter for ants), and the number of families (per 3 x 1 m^2 litter for beetles). Meanwhile, the abundance was presented as the number of individuals per sample point (per 3 x 1 m^2 litter for ants or beetles, per transect for termites, and per monolith for earthworms).

Land use intensity was used in this study as the indicator of the land use change. The land use intensity value (%) for each land use type was determined using Evizal *et al.* (2005) approach, as follow.

Land use intensity = f (input, output)

where the input included tillage and weeding (ranging from no tillage to manual to fully mechanized), fertilizer (frequency, dosage), pesticide (frequency, dosage), and irrigation (ranging from rain-fed to full irrigation) and the output included crop diversity, standing cover, harvested portion, and productivity. The input-output data were gathered through interviewing the landowners. The average of land use intensity was compared across land use types using the protected least significance difference (LSD) at 0.05 level (SAS Institute Inc, 1989).

Diversity and abundance values were correlated with the land use intensity values. The coefficient of correlations (r) were calculated automatically from Microsoft Excel while the test of significance for r was determined manually (Snedecor & Cochran, 1980) using t-test at 0.01 or 0.05 level.

RESULTS AND DISCUSSION

Results show that based on the (land use) intensity, the seven land use types in the Sumberjaya area, West Lampung, can be arranged as follow: less disturbed forest, more disturbed forest, shrub, (polyculture or monoculture) coffee, food crop, and vegetable crop. The arrangement illustrates land use changes (including deforestation) in increasing levels of intensity (Table 1).

Table 1. Land use intensities of land use types in Sumberjaya area, West Lampung, January 2004

No.	Land use type	Average intensity (%)
1	Less-disturbed forest	3.4a
2	More-disturbed forest	16.4b
3	Shrub	26.6c
4	Monoculture coffee	50.1d
5	Polyculture coffee	52.1d
6	Food crop	59.5f
7	Vegetable crop	74.5g

The same letters following the means indicates significant difference using a protected LSD test at 0.05 level

Since monoculture coffee and polyculture coffee were of the same land use intensity, both were designated as the same land use type category, i.e. as the coffee plantation, and thus we have now six land use types in the area. From six land use types we found 53 ant genera (Susilo, 2005), 59 beetle families / subfamilies (Susilo *et al.,* 2005), 37 termite species (Susilo and Aini, 2005), and 10 earthworm species (Murwani *et al.,* 2005).

Diversity and abundance of ants, beetles, and termites decreased as land use intensity increased (**Figure 2, 3, 4, 5, 6, and 7**). For ants or beetles the decrease could be related to the thickness (weight) of litter in which they lived (found). Similar to the trend of diversity and abundance of ants or beetles, the litter weight tended to decrease along the increasing gradient of land use intensity (Figure 8). In addition, the thicker the litter, the higher the diversity and abundance of ants or beetles (**Figure 9, 10, 11, and 12**). The beetle-litter correlation, however, was slightly tighter (0.438 and 0.688) than ant-litter correlation (0.404 and 0.421, also note the less confidence level). That might be related to their feeding behavior; some beetles could directly use litter as food (litter decomposers) while most ants cannot use litter directly as food source. Most ants are carnivorous, some feed on specific prey (predators) while others opportunistically forage for various food items, including alive or dead organisms (Brown Jr., 2000; Kaspari, 2000; Schultz and McGlynn, 2000), but not litter. Abundance of some ants was dependent on the availability of their prey, especially termites and hypogastrurid springtails (Susilo and Hazairin, 2005). In the case of termites, deforestation and subsequent increasing land use intensity caused changes in canopy structure and loss of termite microhabitats which in turn affected detrimentally on termites existence (Jones *et al*., 2003). In the deforested land use types, the canopy was more open so to expose an increasing number of forest-dependent termites to new ground level microclimates beyond their tolerable range which in turn contributed to less survival and more reproductive failure to their colonies. In addition, increasing land use intensity could reduce the probability of termite alates to find suitable nesting sites to establish new colonies. Still, if that could occur, the colony members (progeny) would be less likely to find suitable feeding sites because of the depauperation of the sites through human activities (tillage and weeding).

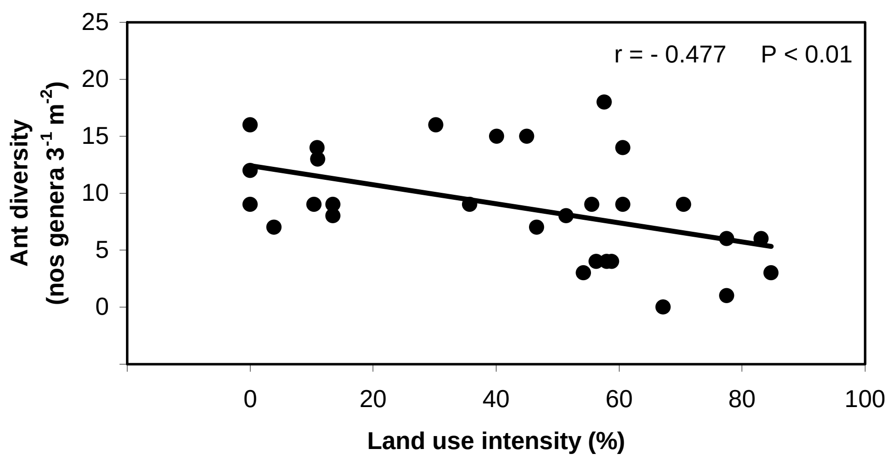

Figure 2. Relationship between ant diversity and land use intensity

The earthworm case, however, was somewhat different from that of the other three macrofauna groups. Land use change did not affect either earthworm abundance ($r = 0.283$, $p > 0.05$) or diversity ($r = 0.243$, $P > 0.05$), but smaller body-sized earthworms tended to be found in the more intensive land use types (**Figure 13**). In addition, deforestation seemed to cause the loss of native earthworm species (**Figure 14**). This might be attributable to availability of litter and soil macroporosity. As in Figure 8 above, litter was less available in land use types of higher intensity. Food (litter) scarcity did not decrease earthworm abundance or diversity. Instead, the shortage seemed to favor earthworms with smaller body size. Smaller sized earthworms could still survive in the environment (land use types) with poor organic matter (litter). In other words, smaller sized earthworms seemed to be more adaptive to land use intensification than the bigger sized earthworms.

Soil macroporosity was known to decrease in more intensive land use types. The number of soil macropores decreased as a result of deforestation, i.e. from 12% in the less disturbed forest to an average of 3% in coffee plantations (Hairiah *et al.,* 2004). It is predictable that the soil macropores be even fewer in the cropped land (food crop or vegetable crop). Thus, beside economical in terms of food consumption, smaller sized earthworms could have other advantage, i.e. grant for their movement and manuverability in the soil in these latter land use types (non forest systems). In contrast, bigger sized earthworms, for instance the native earthworms (megascolecids) (Figure 14), were inefficient in terms of food consumption, of limited movability in the soil, therefore not fit and could not survive in the more intensive land use types, as was the case in this study.

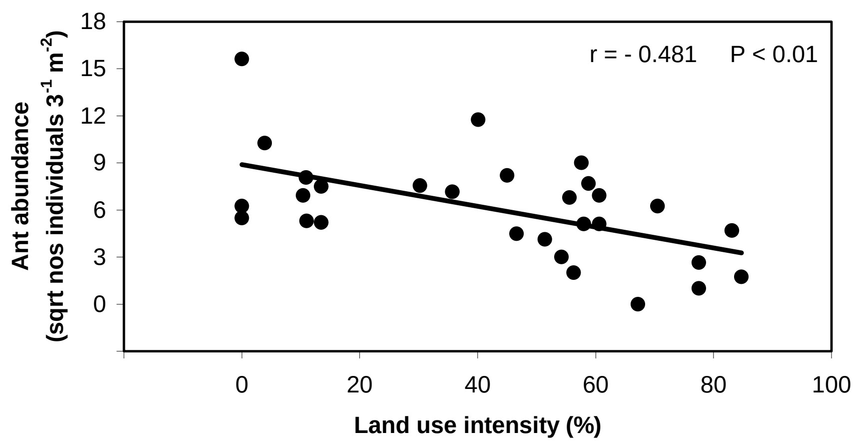

Figure 3. Relationship between ant abundance and land use intensity

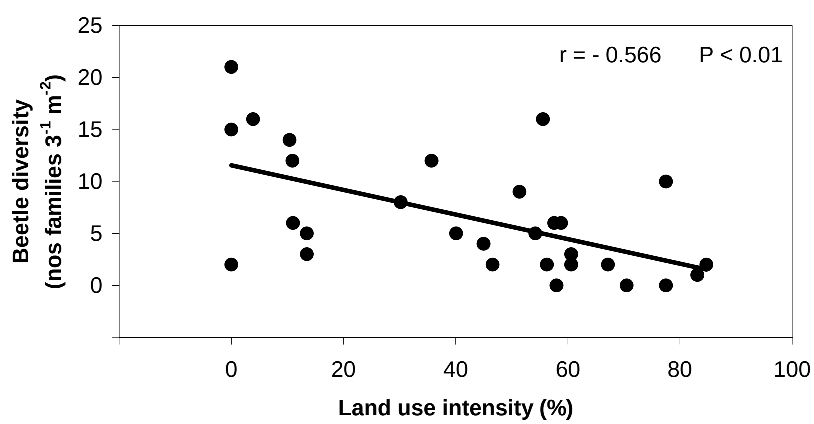

Figure 4. Relationship between beetle diversity and land use intensity

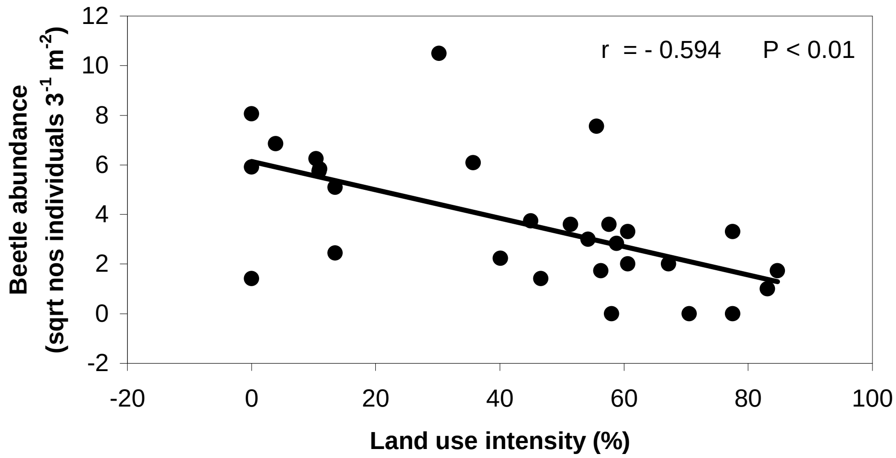

Figure 5. Relationship between beetle abundance and land use intensity

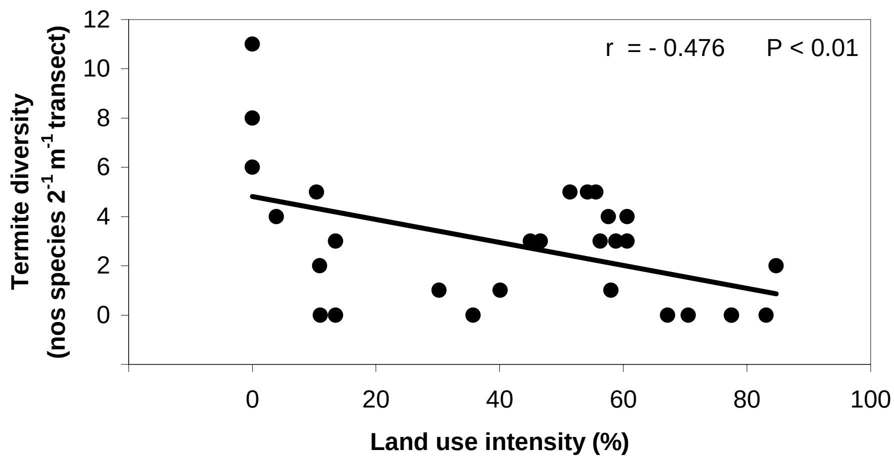

Figure 6. Relationship between termite diversity and land use intensity

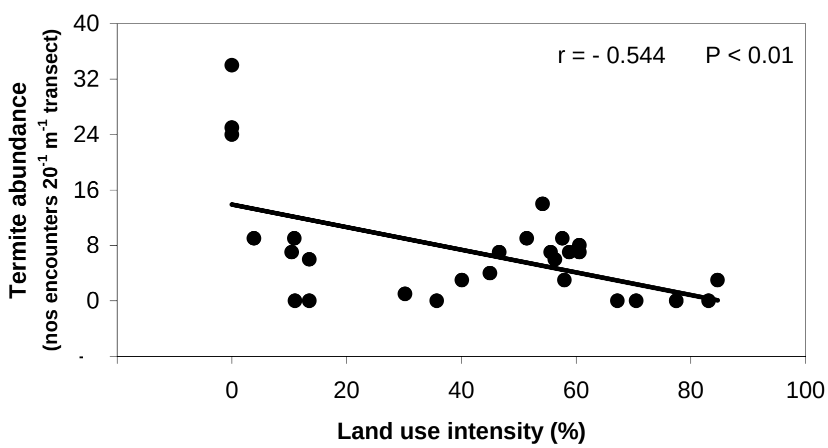

Figure 7. Relationship between termite abundance and land use intensity

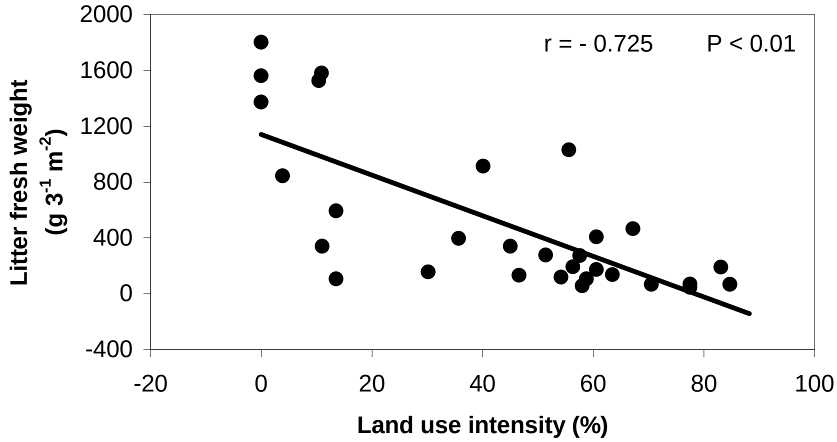

Figure 8. Relationship between litter weight and land use intensity

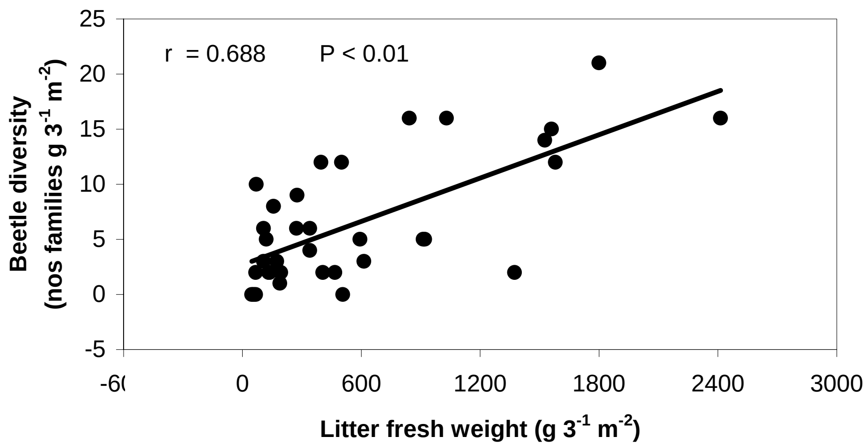

Figure 9. Relationship between litter weight and beetle diversity

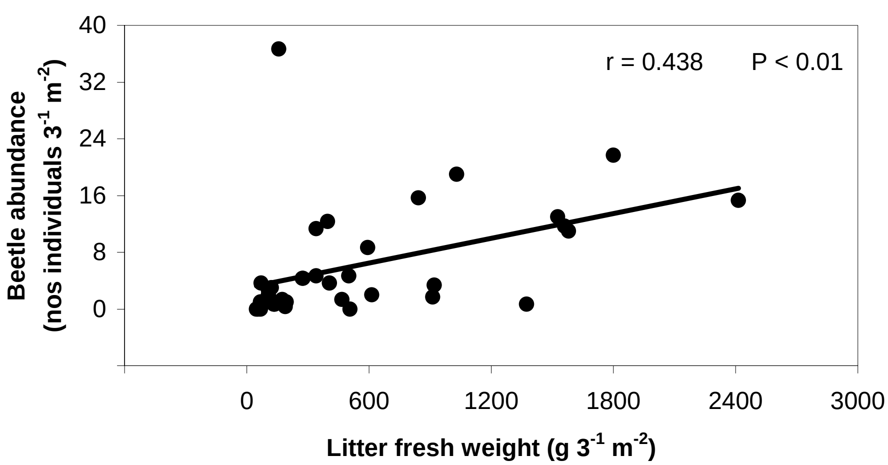

Figure 10. Relationship between litter weight and beetle abundance

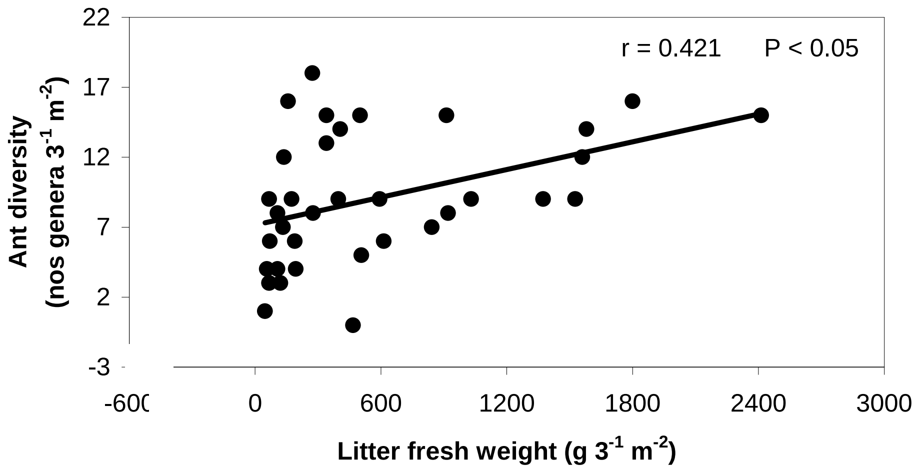

Figure 11. Relationship between litter weight and ant diversity

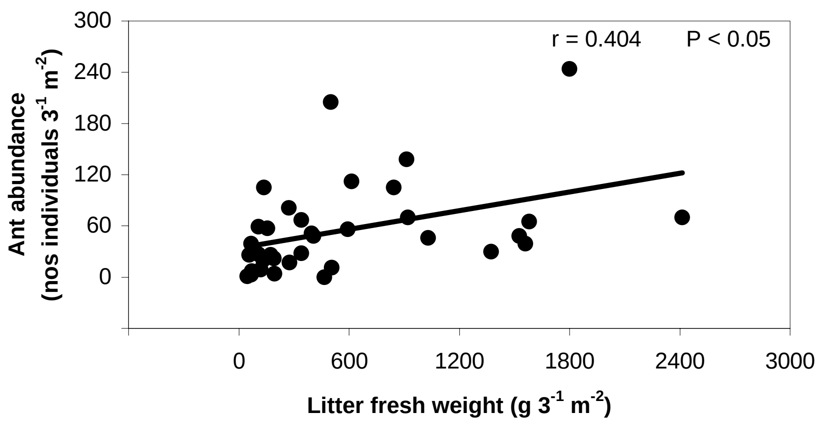

Figure 12. Relationship between litter weight and ant abundance

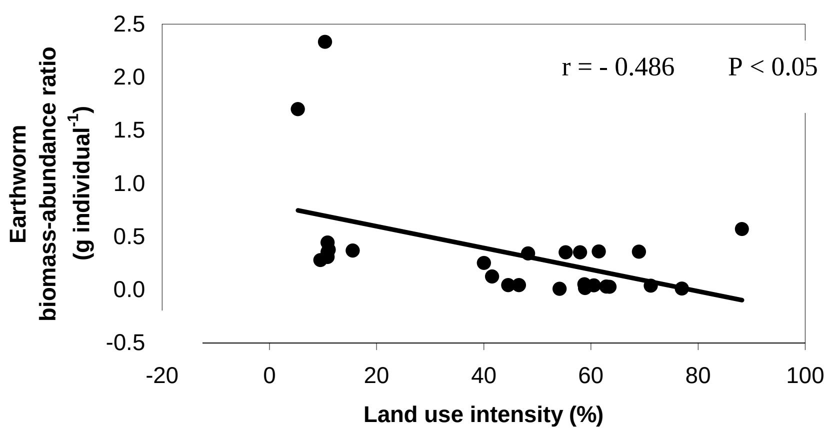

Figure 13. Relationship between earthworm biomass-abundance ratio and land use intensity

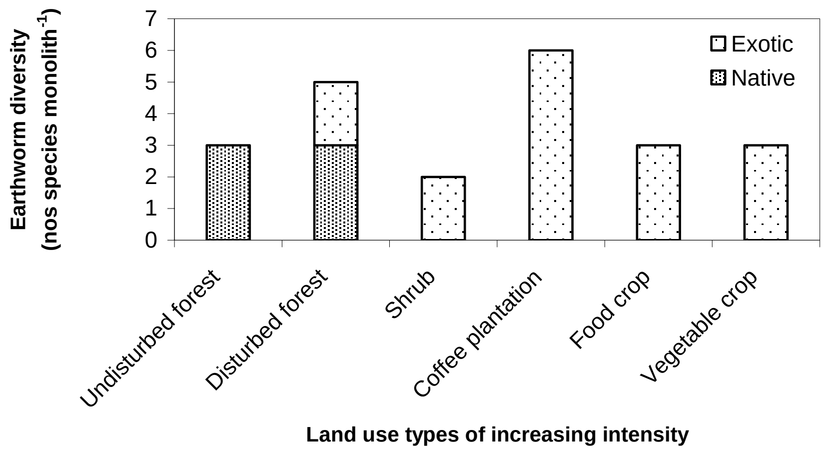

Figure 14. Distribution of native and exotic earthworms across land use types of increasing intensity

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