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# Functional role of termites as soil engineers: their influence on soil organic carbon and nitrogen in pine and mahogany stands Alas Bromo

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**Abstract.** Termites are considered by the general public as pests, but their presence can be a bioindicator of environmental quality. This is because termites have a functional role as Soil Ecosystem Engginers. Alas Bromo University Forest has various stands that can influence the presence of soil macrofauna, one of which is termites. The aim of the research was to examine the functional role of termites in improving soil fertility, which was conducted in six different Alas Bromo stand areas (Pinus 1973, Pinus 2016, Pinus 1994, Pinus 2001, Mahogany 1973, and Mahogany 1949). The method used in this study is the installation of stakes as bait to determine the presence of termites in a plot measuring 20m x 20m and the distance between stakes is 4 meters. There are 5 damage classes (0, 1, 2, 3, and 4) that reflect the presence of termites. The higher the damage class, the higher the activity and presence of termites. The observation parameters taken include, Average Damage Class of stakes in each observation, Soil C-organic, and soil N-Total. The results showed that the highest termite activity was found in Pinus 1973 and Mahogany 1973 stands, while the lowest termite activity was found in Pinus 1994 and Pinus 2016 stands. This can be caused by more suitable environmental conditions and denser crowns. The results also showed that there were differences in C-organic and N-total values in each damage class. The highest C-organic and N-total values were produced in damage class 4 (1.58% and 1.53%). In contrast, C-organic values were lower in the other classes: damage class 1 (1.12%), damage class 0 (1.15%), damage class 2 (1.20%), and damage class 3 (1.25%). Similarly, N-total values were lowest in damage class 1 (0.95%), damage class 2 (1.01%), damage class 0 (1.03%), and damage class 3 (1.13%). This research

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shows that the presence and activity of termites have a positive correlation with soil fertility, this can be seen from the increase in soil C-organic and N-total at higher damage classes.

# 1 Introduction

Alas Bromo has a variety of stand types, with pine and mahogany dominating the area at various ages. Differences in stand conditions significantly impact the presence of macrofauna. [1,2]. Biotic and abiotic factors in an area are very important determinants of the presence and population density of soil fauna [3]. Among the biotic factors, stand type plays an important role in the condition of the litter produced. Termites are one of the soil fauna affected by these conditions. Research shows that the amount of litter is one of the most influential variables on subterranean termite composition [4]. Another study conducted in Malawi found that the distribution of termites in a landscape is determined by the condition of the stand [5].

Termites are widely regarded as pests. However, they can serve as bioindicators of environmental quality. Termites are important indicators that influence decomposition rates or act as decomposing agents in the tropics [6]. The presence of termites can impact the distribution of organic carbon content [7,8], and soil nutrients such as total nitrogen [9]. Research conducted in a grassland (Canga) in Carajás, Amazonia, Brazil, showed that termite activity significantly increased the concentration of organic matter. Termites are very important on the forest floor because of their role as decomposers [10]. Soil fertility can be improved by termite activity, such as increasing organic carbon. This activity is why termites are known as soil engineers [9].

Termites can recycle soil nutrients, positively affecting nutrient balance in the soil [11]. Despite their reputation as pests, termites provide essential ecosystem services. For example, farmers in Sub-Saharan Africa utilize termite mound soil for agriculture [12]. Research in savannas shows that termite mounds are nutrient centers and have potential for soil improvement [13]. Based on these findings and the limited research on termites outside mounds, this study was conducted to observe the direct impact of termite activity on soil organic carbon and total nitrogen availability in pine and mahogany stands of different ages using piles as termite bait.

# 2 Material and Methods

## 2.1 Research Location

The research was conducted from March to June 2024 under pine and mahogany stands of various ages. The study location was Alas Bromo in Karanganyar District, Karanganyar

Regency, Central Java, Indonesia (Figure 1). The analysis was carried out at the Laboratory of Soil Chemistry and Fertility, Faculty of Agriculture, Universitas Sebelas Maret.

### 2.2 Research Method

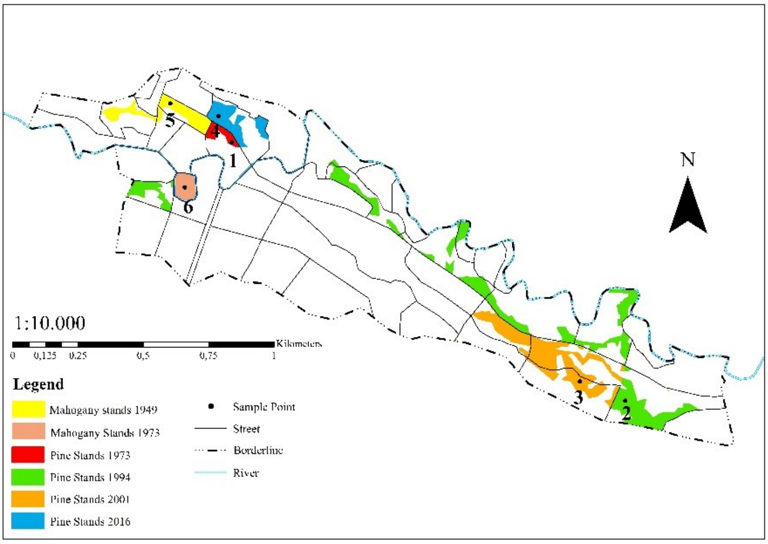


**Figure 1.** Map of Research Sample Points in Alas Bromo.

The research location map shows the sampling points in Alas Bromo. The research location was determined using a descriptive exploratory method with a purposive sampling approach. The study was conducted in stand locations suspected of having high termite activity (Table 1).

The presence of termites was identified using a method of installing stakes as bait in each stand. The area for stake installation was 20 m x 20 m, consisting of 36 stakes, with each stake placed 4 m apart. The stakes were 50 cm long, with 25 cm embedded in the soil (Figure 2).

**Table 1.** Termite bait stakes location

| Research Location | Stand Type | GPS Location |
| --- | --- | --- |
| Location 1 | Pine Stands 1973 | $-7^{0}35'5,56025''$S $110^{0}59'47.25446''$E |
| Location 2 | Pine Stands 1994 | $-7^{0}35'33.71897''$S $111^{0}0'36.38214''$E |
| Location 3 | Pine Stands 2001 | $-7^{0}35'30.17373''$S $111^{0}0'26.57018''$E |
| Location 4 | Pine Stands 2016 | $-7^{0}34'59.57779''$S $110^{0}59'45,21102''$E |
| Location 5 | Mahogany Stands 1949 | $-7^{0}35'7,33619''$S $110^{0}59'41.34744''$E |
| Location 6 | Mahogany Stands 1973 | $-7^{0}34'57.49617''$S $110^{0}59'40.98111''$E |

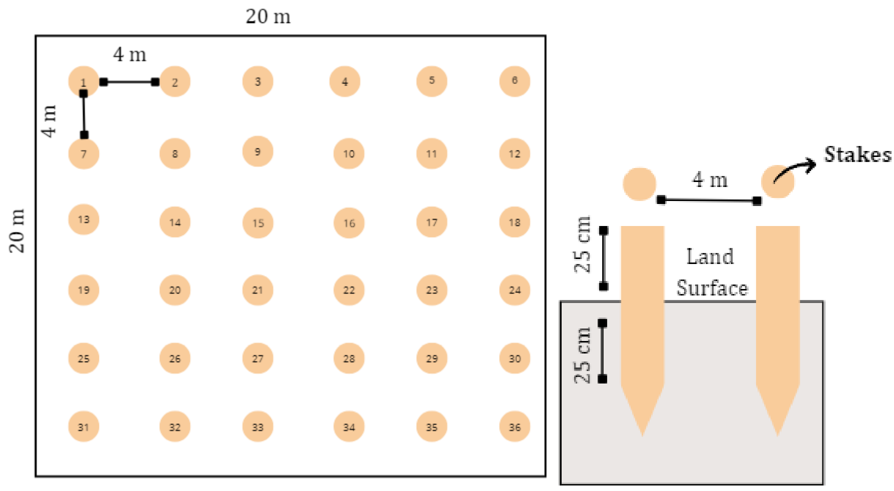


**Figure 2.** Design of Stakes as Termite Bait [14]

Observations of stake conditions were conducted every two weeks for two months, assessing stake damage levels (Table 2) and collecting termite samples for species analysis. After two months, soil samples representing each damage level were collected.

**Table 2**. Classes and Criteria of Damage to Stakes

| Demage Classs | Damage Level | Damage Criteria for Stakes |
|---|---|---|
| Class 0 | Undamaged | There were signs of termite attack on the stake, but no termites were present. |
| Class 1 | Slightly Damaged | The stake was damaged by termite attack, with deeper holes observed, but no termites were found. |
| Class 2 | Moderately Damaged | Moderate to severe damage to the wooden stake was observed. |
| Class 3 | Damaged | Severe damage to the wooden stake was observed, including visible. |
| Class 4 | Severely Damage | Framework or significant decay; the stake would break or was already brittle if pulled. |

Source: Modified [14]

# 3 Result and Discussion

## 3.1 Influences if Stand on Termite Presence

Environmental differences can affect termite life. For example, environments that maintain land cover will allow active ecosystem engineers, such as termites, to survive [15]. The biomass of vegetation in forest areas significantly impacts the presence of soil fauna [16][17].

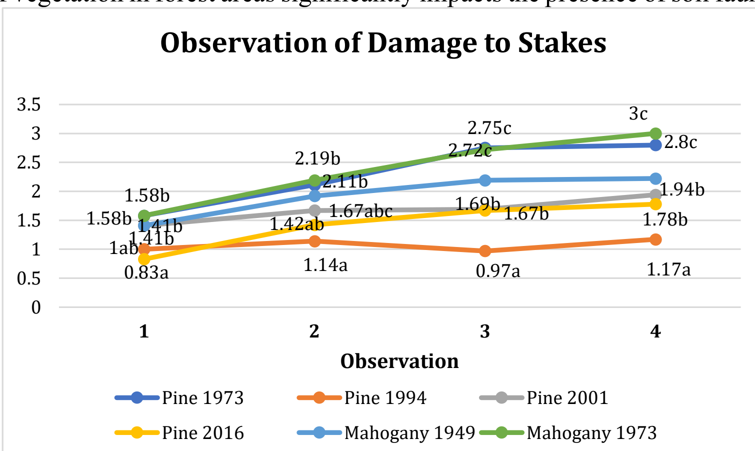


**Figure 3.** Average Value of Stake Observations for 2 Weeks at Each Stand

Based on the observations presented in Figure 3, the average damage to saplings, which are used as bait for termites, varies across forest stands. The graph illustrates the gradual increase in sapling damage during bi-weekly observations conducted over a two-month period. Higher levels of sapling damage indicate increased termite activity in each stand. In the first observation, the highest damage was recorded in Pine 1973 and Mahogany 1973 stands (1.58b), which was not significantly different from Pine 2001 and Mahogany 1949 stands (1.41b). The lowest damage was recorded in Pine 2016 stands (0.83a). In the second observation, Mahogany 1973 had the highest damage (2.19c), similar to Pine 1973 (2.11c), while the lowest damage was found in Pine 1994 (1.14a), which was not significantly different from Pine 2016 (1.42ab). The third observation showed that Pine 1973 had the highest damage (2.75c), comparable to Mahogany 1973 (2.72c), with the lowest damage in Pine 1994 (0.97c). In the fourth observation, Mahogany 1973 again showed the highest damage (3c), similar to Pine 1973, while the lowest damage was recorded in Pine 1994 (1.16a).

The significant decrease in damage value in the 1994 Pine stand in the third week was due to the replacement of stakes that had reached damage class 4. The newly installed stakes experienced lower termite activity, probably due to the presence of reduced or less active termites compared to other stands.

The highest average pole damage was recorded in 1973 Mahogany and 1973 Pine stands. The high termite activity in the 1973 Mahogany stand was due to the denser canopy compared to the Pine stand. Denser canopies increase shading, creating a cooler microclimate on the forest floor, which helps maintain lower temperatures and higher humidity levels [18] [19]. This finding is consistent with research in Cameroon, which reported a positive correlation between canopy density and termite presence, where older plantations showed greater termite abundance due to higher canopy cover [20]. The significant presence of termites in Pine 1973 stands is also related to the dense vegetation cover and abundant shrubs, creating moist conditions that support termite activity [21].

Termites are sensitive to environmental changes [20], the low presence of termites in 2016 Pine stands may be due to intensive land management practices that disrupt termite populations. This is consistent with research conducted in Limpopo Province, South Africa, which showed that termite mound density was significantly influenced by land use, with agricultural areas having lower densities compared to communal grasslands [22].

### 3.1 Soil Organic Carbon (SOC) Values Among Stake Damage Classes

Termites are soil fauna that have a functional role as engineers of soil ecosystems in tropical systems. Termites build biogenic structures, visible in the soil mounds they create, and this activity impacts soil characteristics, decomposition and nutrient cycling [6]. Termites contribute to soil organic carbon, serving as decomposition agents [8].

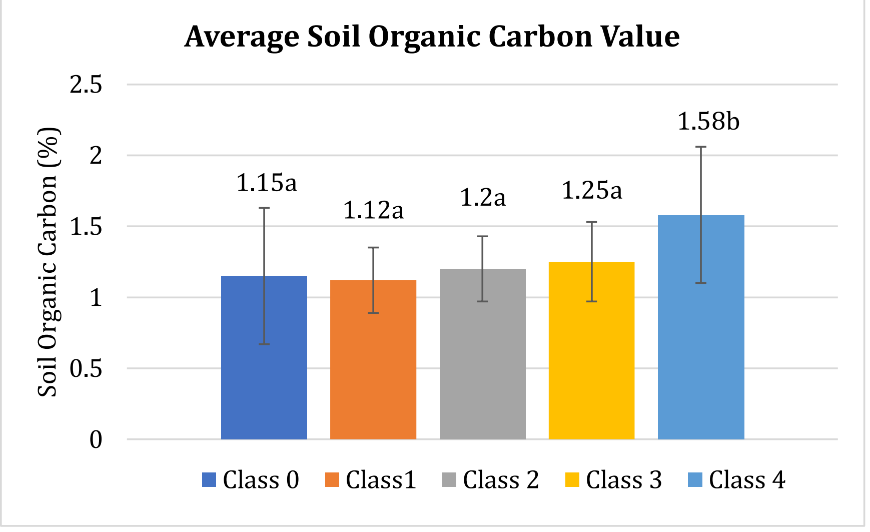


**Figure 4.** Average Soil Organic Carbon Value in Each Class of Damage Stakes

Stake damage classes indicate the level of termite activity, with higher damage classes showing greater termite activity. Figure 4 shows a significant difference in soil organic carbon (SOC) values among the stake damage classes. The highest SOC value was found in class 4 (1.58b), which was significantly different from the other classes. The lowest SOC value was found in class 1 (1.12a), followed by class 0 (1.15a), class 2 (1.20a) and class 3 (1.25). These relatively different values can be attributed to the behavior of termites in digesting soil organic matter and returning it as feces [23]

These results show that an increase in damage class, which indicates an increase in termite activity, is associated with an increase in SOC values. This is because termites accumulate organic matter and mineral particles from the surrounding environment, leading to an increase in SOC content [23], and improving the quality of the local soil [24]. Other studies have also shown that termite mounds, as centers of termite activity, and other areas affected by termite activity, have higher SOC values [25].

### 3.2 Total Soil Nitrogen Values Across Different Termite Damage Classes

Soil termites influence nutrient cycling in temperate forest ecosystems [23]. Research in Savana shows that termite mounds or nests serve as nutrient centers that have the potential to improve the soil [13]. Generally, termites are crucial decomposers capable of recycling nutrients [26][27]. They are one of the most important macrofauna, helping in nitrogen cycling and soil formation [28].

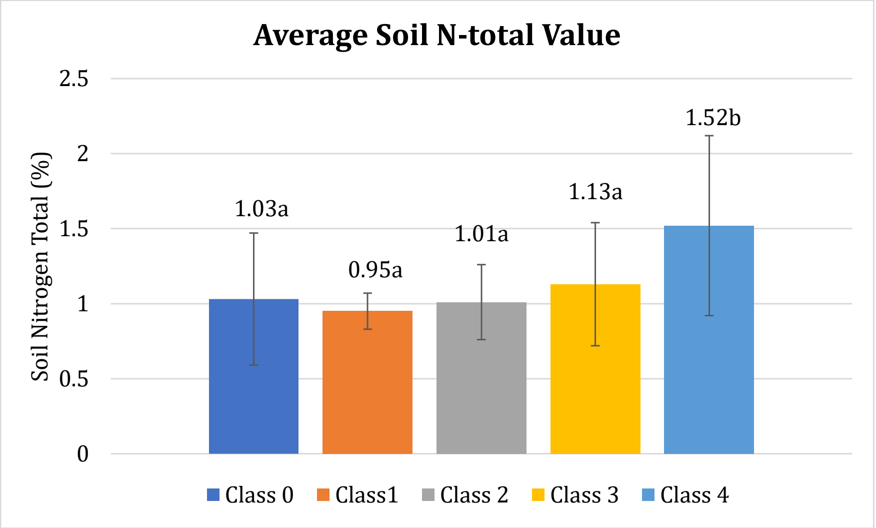


**Figure 5.** Average Value of Soil N-Total in Each Class of Damage to Stakes

Figure 5 shows significant differences in total soil nitrogen (N-total) values across termite damage classes, with Class 4 showing the highest N-total value (1.53b), significantly different from the other classes. The lowest values were found in Class 1 (0.95a), followed by Class 0 (1.03a), Class 2 (1.20a) and Class 3 (1.13a). These results indicate that higher levels of damage are associated with higher N-total values in the soil. This is due to termite activity, which increases total soil nitrogen, especially in the topsoil [29]. Termites are estimated to contribute 7-22% of N input from fixation to decomposition of plant organic matter. Nitrogen fixed by termites significantly aids the decomposition process by adding other nitrogen sources [30].

### 3.3 Correlation Analysis Results

**Table 3.** Results of Correlations Analysis

| Variable | TN | DC |
|---|---|---|
| DC | 0.374** | |
| SOC | 0.794** | 0.354** |

* DC= Damage Class; SOC = Soil organic Carbon; TN= Total-N;

Correlation analysis between damage class and soil organic carbon (SOC) and N-total values showed significant relationships of (0.374**) and (0.354**), indicating a highly significant positive correlation. This means that as the damage class increases, the SOC and N-total values also increase. This may be because higher damage classes reflect increased termite activity, which increases the SOC content of the soil. Increased levels of SOC and total nitrogen due to termite activity can improve soil fertility [31][32]. Termite bioturbation activity leads to increased nutrients, organic matter, and soil pH from the materials they collect, ingest, and excrete [33].

# 4 Conclusion

The results of this study show that there are variations in the presence of termites in several stands in Alas Bromo. Observations in Mahogany 1973 and Pinus 1973 stands consistently showed the highest termite activity, followed by Mahogany 1949, Pinus 2001, Pinus 2016, and the lowest activity was recorded in Pinus 1994. Higher termite activity was significantly positively correlated (r = 0.354**) to increased soil organic carbon values and (r = 0.374**) to total nitrogen. Damage Class 4 showed the highest SOC and N-total values, at 1.58% and 1.53% respectively. These findings emphasise the important role of termites as soil ecosystem engineers, improving soil fertility through increased SOC and nitrogen nutrients. This highlights the importance of termite activity in nutrient cycling within ecosystems. Future research could focus on the long-term impacts of termite activity on soil properties and explore sustainable management practices that capitalise on termite-induced soil improvements for agroecosystem benefits.

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