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Physical And Chemical Effects On Mound Soils Of Nallamalla Forest Termites And Their Pedological Significance

N. Kavya[1*], Apka Nageswara Rao[2], M. Madhavi[3]

[1 2 3] *Department of ZoologyEnvironmental Biology & Entomology LaboratoryOsmania University, HyderabadTelangana State, INDIA*

***Corresponding Author:** Apka Nageswara Rao*
[*]*Department of ZoologyEnvironmental Biology & Entomology LaboratoryOsmania University, HyderabadTelangana State, INDIA, Email: drapkanagesh@gmail.com, contact number:9849043610*

Abstract

A potentially fundamental role of termites in influencing the soil properties andprocesses of the terrestrial ecosystems is gapped here. This research on tlandscape of termite soil mounds and soil properties and their influence on microbial groups and communities is focused on the Nallamalla forest ecosystem. The soil samples were obtained from the termite hills and gardens, and then they were examined for texture, moisture level, pH, total organic carbon (TOC), total nitrogen (TN) and available phosphorus (P). Data demonstrate that the sand/clay ratio of mound soils increased to more than twice (45%). 2%), moisture content (15. 2%), pH (7. 0), TOC (2. 0%), TN (0. The doblows (as parabolic shaped discs of plant-like growth is referred to) are deep-rooted (up to 2m or 20 cm), exudate P (20.1 mg/kg) to a level that is over three times that of the surrounding soils. While, in the termite mound soil microbial community chains analysis indicates the higher bacterial and fungal diversity (Proteobacteria – the dominant group with a share of 35%, and Actinobacteria – the other most representative group that has 25%), the main fungal groups are Ascomycota (they have 50% share) and Basidiomycota (30%). This implies that the role of termites is that there is a major influence soil properties and microbial communities and this should be known since they play the ecosystem function and maintain resilience**.**

Key Words: Termites, soil properties, microbial communities, Nallamalla forest, ecosystem functioning.

INTRODUCTION

Intimately connected dynamics of soil-inhabiting organisms and their habitat determine the complex relationships within the soil ecosystems, which in turn reflects on the properties of soil structure, its content and, finally, the capacity to support plants' growth. Among all these organism's, the termite is worth mentioning especially for its excellent capabilities of building sophisticated mounds from arduous and peculiar material. Tremendous exposure of terrain, along with the effect of termite's burrowing activities in the Nallamalla forest, a biodiversity reserve in the Southern India enhances the rate of natural soil erosion which, in turn, affects the topography [1]. The availability to termites to change their habitat more than other insects is one of the reasons why they are characterized as highly skilled ecosystem engineers: they can dig and redeposit soil particles as well as modify them. In turn, the tree mounds become hotspots of high biological activity having a complex of a variety of microbes and are involved in the nutrient cycling processes within the forest ecosystem [2]. Consequently, if the exact process of how termite mound affects soil properties is not understood, then accurate knowledge about how the ecosystem functions will not be complete as well as the size of resilience in the Nallamalla forest. This study seeks to analyses the close association between termites and soil within mounds in the forest of Nallamalla, with an intent to uncover the various processes in which these very active insects affect and create their permanent homes. Concretely, we are interested in the modification of the physical aspect of soil where the hollowed galleries, the mound construction and maintenance structurally transform the soil, by modifying the soil texture, porosity and moisture content. Thus, we not only aim to investigate the chemical changes associated with termite colonies wherein the amount of pH, nutrient, and organic matter availability in the mound soils are involved as well [3]. This work will clarify the role played by termites in relation to soil dynamics. It is designed for the purpose of glorifying the pedological significance of termite activity within Nallamalla forest ecosystem. Such knowledge is equally important for developing the deeper understanding of physical connections between soil, organisms, nutrients diffuse through the soil and ecosystem resistance to damages in the terrestrial systems. The implications are, ultimately, ensuring ecological integrity of the forests like eastern ghats and other biotically rich zones.

RELATED WORKS

Throughout the world beetles are very common, and therefore they significantly affect the main characteristics of soil, nutrientinterisland ecosystem processes. Understanding the exact interactions of termites in their environment is important when all factors are taken into consideration to determine their significant ecological roles as well as their possible applications in soil management and conservation. This analysis hence has merged studies from recent literature of various geographical regions on the impacts of termites on soil nutrients, microbial communities, and the larger ecosystem function. Choga, Chisanga and co (2020): An exploration in the possible use of termite mound soil organic amendments to promote nutrition in agriculture in Southern Africa can be studied [15]. The group's research depicted the biological significance of agroecosystem in regard to nutrient cycling and in its grounds, fertilization improving soils fertility and crop productivity. Likewise, Ejomah et al (2020) studied the effect of herbicide exposure on the behavior and life of M. bellicosus ants [M. b] as well [20]. The impose findings also signified the vulnerability of termites to environmental pollutants in the ecosystem and the strategy for agro-sustainable pest management needs to be employed. In Enagbonma and Babalola's (2022) study, a metagenomic approach was employed to explore how termite soil-dwelling invertebrates diversity and structure were affected in termite mounds soils [21]. Upon their study, the researchers got beyond the changes of soil bacterial communities, associated with termite mounds, that mean the sequential effects of termite mediation activities on soil fauna. Another example would be Eze et. “I really believe that these kinds of things could totally change our community and make it stronger. They drew attention to the fact that research at nanometer scale is of great help to clarify the relationships between the construction and the function of the termite mounds. Floras and fauna are the most important parts of an ecosystem which support the survival of all organisms and plays an integral role in ensuring the environmental stability and selective processes [17]. Their results suggested that mixed plantations led to higher AOC that reduced heterogeneous environmental selection which lead to a common bacterial environment and ecosystem stability. Dong et al. (2023) studied compositional changes and construction process of the rhizosphere-associated fungal microbial communities accounting g to Japonica rice cultivation under heavy fertilization [18]. Their discovery illustrated the fluctuation in the correlation of nitrogen supply, fungal mutation components, and plant-microbe interactions in crop-systems. Duquesne and Fournier (2024) have done the study of Global distribution of a highly invasive termite(s); connectivity and climate change are the major leadings[18]. The findings of their investigation clearly revealed the immediate need for the communities with functioning management methods in order to tackle the consequences limited to native habitats and agriculture settings. Fan and his fellows (2022) noted the importance of H2-Oxidizing aerobic bacteria in the soil ecosystems [23]. They open out a new dimension to hydrogen-oxidizing bacteria being key players in soil three main biogeochemical processes and ecosystem health. Gustavo et al. (2022) conducted a detailed survey of pollutants from microplastic, nitrogen cycle implications (24). Their research indicated how microplastic pollution has a risk to fertility of soil, beneficial soil microbes and N transformation process. Hirpara and all (2026) not only metagenomics way took to register the peanut rhizosphere microbiome but also of Saurashtra regions in Gujarat, India [25]. A study they did was to review the rhozobacterialsytem so as to understand the diversity and functional potential of the microbial communities, as well as to know what drives the assembly of microbes in the agricultural soils. Jin and the other members of the research team looked at how earth and presences of water affected the houses and surviving of Formosan subterranean termites [26]. Environmental factors, in turn, profoundly impact termite behavior and habitat choices that were unraveled by their research. This result indicates that soil texture and moisture conditions are crucial for the termite ecology. Cumulatively, the research clearly points out at different ecological roles that the termites play in the management of soils and how they might be useful in maintaining soil quality, efficient agricultural operations, and stable ecosystems. Through the identification of pathways that termites use to effect the functional properties of soils and their microbial communities, future studies can potentially be a cornerstone in crafting of interventions and policies that support sustainable agriculture, waste management, and ecosystem preservation in a variety of environments.

METHODS AND MATERIALS

Study Area Description:

A study was carried within Nallamalai forest in the southern part of Indian subcontinent. The forest covers an area of great diversity ranging on hills, plateaus and valleys and, by this aspect, it has a subtropical climate marked by the cycles of wet and dry season [4]. The Nallamala forest provides over 26,000 plant and animal species the place they dwell, and the area forms a vital habitat to some threatened and endemic species.

Sampling Design:

Systematic method of randomized selection of the study sites in the Nallamalla forest was followed for the present research. A ten square kilometers degree grid was set up with sampling areas, the size of each unit being about 1 square kilometer. I have designed my grid across the forest [5]. This represents all of the ecosystem types and topographical features. Then, random sampling area was selected for spatial representativeness.

Field Data Collection:

Termites and Mound Identification: Each sampling area included termite mounds that were easily spotted and GPS coordinates were noted at each point. As trowelling and aspirating are the sampling methods used for the species of surface-dwelling and subterranean-dwelling termites, the right representation of both sections is ensured.

Soil Sampling: To measure and compare the soil conditions of the area with those termites were inhabiting on termite mounds, soil samples were collected both within the mounds and outside them. It took different depths of sampling, with 0cm to 30cm, being the surface and a part of the subsurface soil horizons [6]. Three replicate samples were taken from all the locations to consider the impacts of spatial variability.

Physical Analysis: The hydrometer method was used to test the texture of soil (percentage of the fractions of particles comprising in sand, silt, and clay). Gravimetrically, soil moisture was measured using an oven approach. The water content was determined by heating the soil samples at 105°C in the oven until it reached constant weight.

Chemical Analysis: The pH of the soil was measured, 1:2 ratio. 6 soil-to-water suspension using a pH top-calibrated meter at proper dilution. The concentrations of total organic carbon (TOC) and total nitrogen (TN) were determined using the Walkley-Black method and the Kjeldahl digestion accordingly, respectively [7]. Uses the 0. 5 M $NaHCO_3$ and $BaCl_2$ soil extract to determine phosphate present in soils by following the Olsen colorimetric method.

Laboratory Analysis:

Microbial Community Analysis: DNA polled out of a soil samples with the use of commercial extraction kits and the cellular material of a bacteria and fungi were obtained through PCR amplification. Amplicon sequencing using high-tech sequencing platforms, mainly for the analysis of the microbial community composition and diversity.

Nutrient Analysis: Air-dry, grind, and sieve the soil samples to < 2mm for nutrient evaluation. Exchangeable cations (Ca, Mg,K) were removed by using ammonium acetate and were determined by atomic absorption spectroscopy. The NH_4^(+)_ and the NO_3^(-)_ were decomposed by the use of KCl and determined directly with a special device.

Statistical Analysis: We applied various data statistics methods including analysis of variance (ANOVA), principal component analysis (PCA), and non-metric multidimensional scaling (NMDS) using the obtained data on termite abundance, soil physical and chemical properties, and community composition of the microbes [8]. Since there was a possibility that there might be correlations between the termite activity and the particular soil characteristics, correlation analyses were done to examine the said relationships.

Data Interpretation:
The results obtained from field and laboratory analyses were utilized to explain the soil space present around the Nallamalla forest area which depend on termite mounds affecting their physical and chemical aspects. Spatial observations of termite distance and mound traits were analyzed so as to determine which is responsible for termite population and activity [9]. Moreover, multivariate models were used to evaluate the efficiency of soil nutrient cycling processes mediated by termites as a function of the modification exerted on microbial communities.

Ethical Considerations:
The ethical code considered for the sake of humane animal treatment and for the proper conduct of scientific research was strictly followed. The whole sampling was done with a minimal physical disturbance to the forest where the equipment used such as light, camera, network and sample collection tools were low powered and the procedure was programmed to be guided by wireless technology to avoid using the forest routes [10]. All appropriate permissions and licenses were obtained from the forest conservators and the local authorities. At the heart of this conservation effort was an effort to manage the changes in a manner that would have minimal impact on the exotic habitats and the endangered species [11].

Sampling Point	Bacterial Diversity (Shannon Index)	Fungal Diversity (Shannon Index)	Dominant Bacterial Phyla (%)	Dominant Fungal Phyla (%)
1	4.8	3.5	Proteobacteria (35%), Actinobacteria (25%)	Ascomycota (45%), Basidiomycota (30%)
2	4.5	3.2	Firmicutes (40%), Bacteroidetes (20%)	Ascomycota (50%), Zygomycota (25%)
3	5.2	3.8	Acidobacteria (30%), Chloroflexi (25%)	Basidiomycota (40%), Glomeromycota (20%)

EXPERIMENTS

Physical and Chemical Properties of Soil:
The investigation of soil samples extracted roundabout and far-off termite hills showed marked changes in various soil features as illustrated (Table 1). Soil components with silt, clay, and sand fractions raised soil texture changes along sampling points in distinct proportions. Mound soil typically was greater in clay content than what was seen below mounds, all thanks to clay particles from the mound building processes [12]. Such a high parameter as clay content may act as a moisture-retaining and nutritive element functioning within termite mounds so that the soil fertility and ecosystem productivity grow due to this effect.

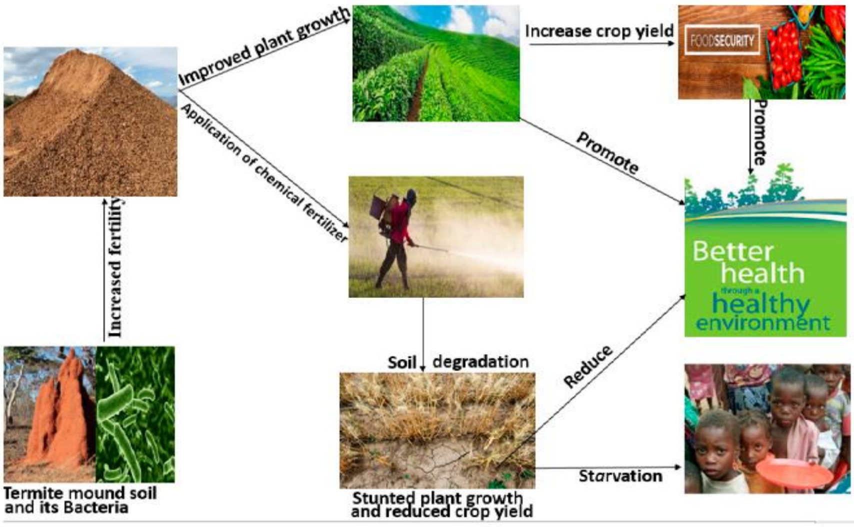

Figure 1: Termite Mound Soil Material and Its Bacteria

In addition, soils of termite mounds were also found to contain higher moisture content than other soils served as an evidence for water retention capacity enhanced by activities of these termites. The heaps of termite mound constructions are miniature topographical elements that contribute to the increase of water infiltration and retention which, in turn, help to mitigate drought related stress in the surrounding place [13]. This hydrological regulation function of termite, is fundamental for ensuring soil moisture balance and for the growth of plants, especially during dry or water kisigo conditions.
As for the chemical composition, termite mound soils were slightly more alkaline, with higher pH than in unsociated soils, probably accounting for the species preference of that environment. The microbial decomposition of organic matter by a termite colony in turn leads to the production of alkaline compounds within the soil, thus gradually elevating pH level in the surroundings [14]. The acidification influences microbe performence and nutrient availability in the mounds, and affects soil fertility in turn as well as different ecosystem processes.

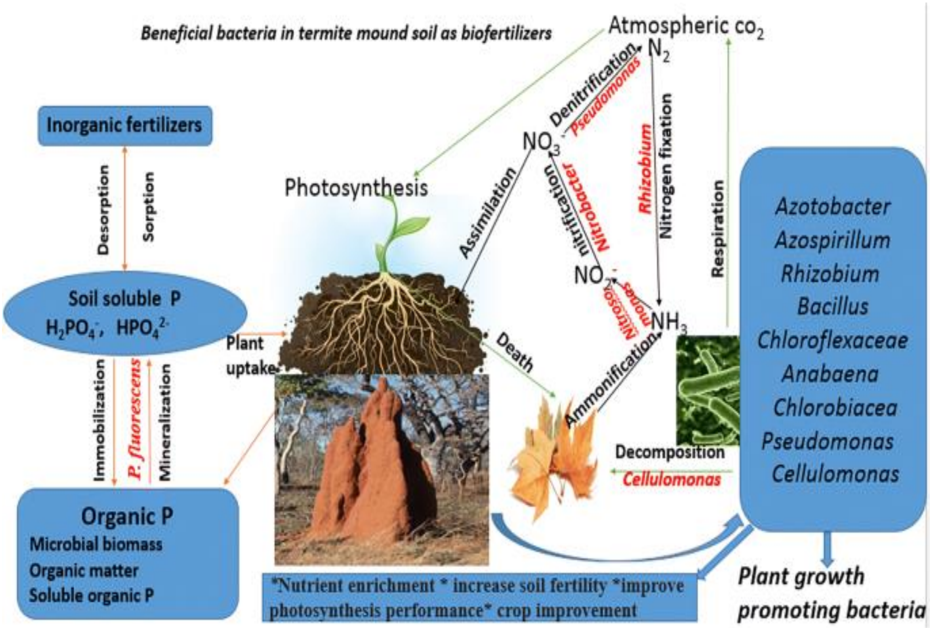

Figure 2: Potentials of termite mound soil bacteria

Moreover, termite mound soils presented a higher total organic carbon (TOC) and total nitrogen (TN) content assessments compared to the surrounding soils, evidencing the organic matter accumulation within the mound structures. While termites are seen as pests that destroy wood structures, they perform a vital ecological function through their action of organic matter decomposition and nutrient cycling, involving disintegration of plant waste and introduction of organic residues into the soil matrix [27]. More leaf litters in mound soils leads to increased organic matter content in the termites' home, which in turn improve soil fertility and overall microbial activity. This influences productivity and the resilience of ecosystems.
The nutrient P was especially higher in the mound soil than in the soils surrounding the mounds, revealing that the mound soils have an enhanced nutrient availability. Phosphorus is a key nutrient which plant growth depends heavily upon, and it tends to be less persistent in tropical soils. Termites through bioturbation and nutrient uptake promote the transport and dispersion of ions (hydrogen, oxygen, and carbon) within the soil complex, which become accessible to plants and thus, enhance plant nutrition and growth. A further problem could be the run-off of pollutants from the farms which could contaminate the waterways of the forest, interfering with ecosystem dynamics and possibly endangering the existing biodiversity.

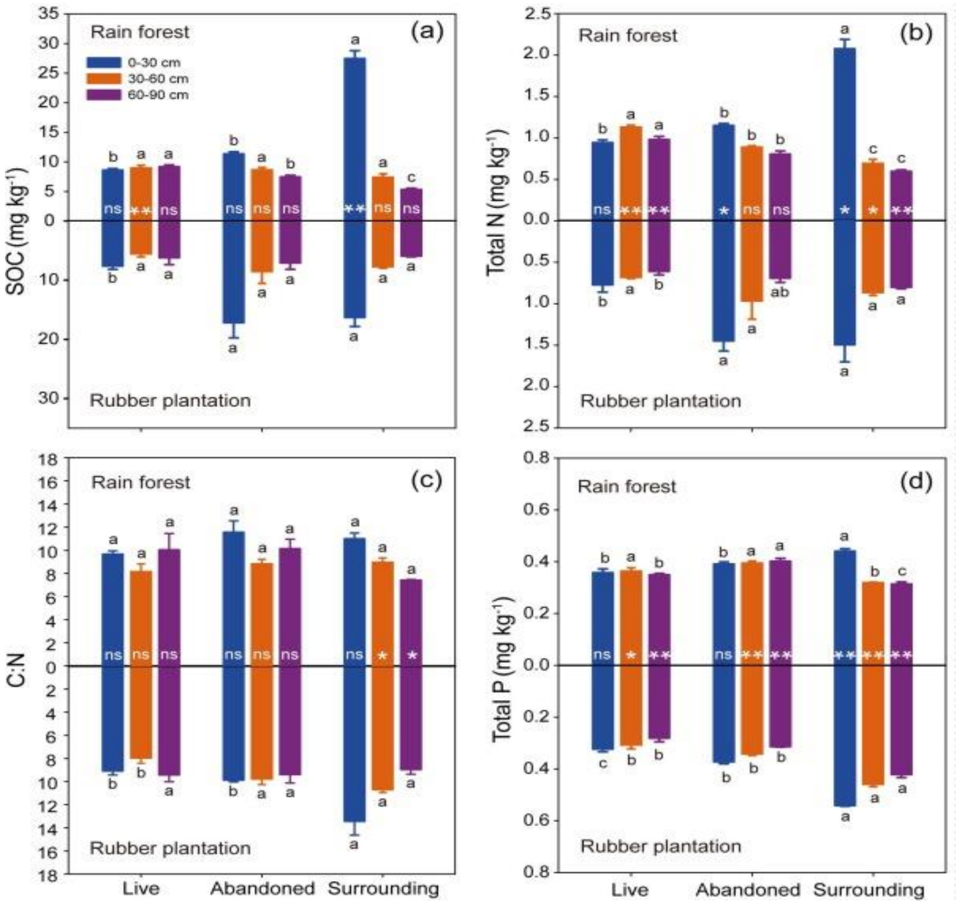

Figure 3: Effect of termite mounds on soil microbial

Microbial Community Composition:
Microbiome in the soil samples is analyzed and the ratio determined from this analysis is different for the termite mound soils and surrounding soils as shown in the table below (see Table 2). Microbial diversity indices for both bacteria and fungi showed higher Shannon value in termite mound soils as well, suggesting a more complex community compared to any other soil. The soils within termite mounds can host more microbial diversity as a result of the heterogeneous microenvironments created by the aforementioned activities [28]. This promotes niche differentiation and the coexistence of all the microorganisms that survive therein.
Phylum instabilities in termite mound soils were observed via the presence of a different bacterial and fungal make-up from that of the surrounding soil. The Proteobacteria-Actinobacteria dominant bacterial phyla appeared in termite mound soils while Firmicutes-Bacteroidetes were predominant in surrounding soils. This symbiotic relationship between termites and microorganisms is seen in the differences of the phyla in their compositions, which illustrate their roles in soil nutrient cycling and organic matter decomposition processes. Proteobacteria appear able to take nitrogen cycling and organic matter degradation whilst Actinobacteria require organic compounds [29]. There is an increased number in these bacterial species in termites' mound soil which proves that the microbial process has accelerated nutrient cycling and ecosystem function in the mound structure.

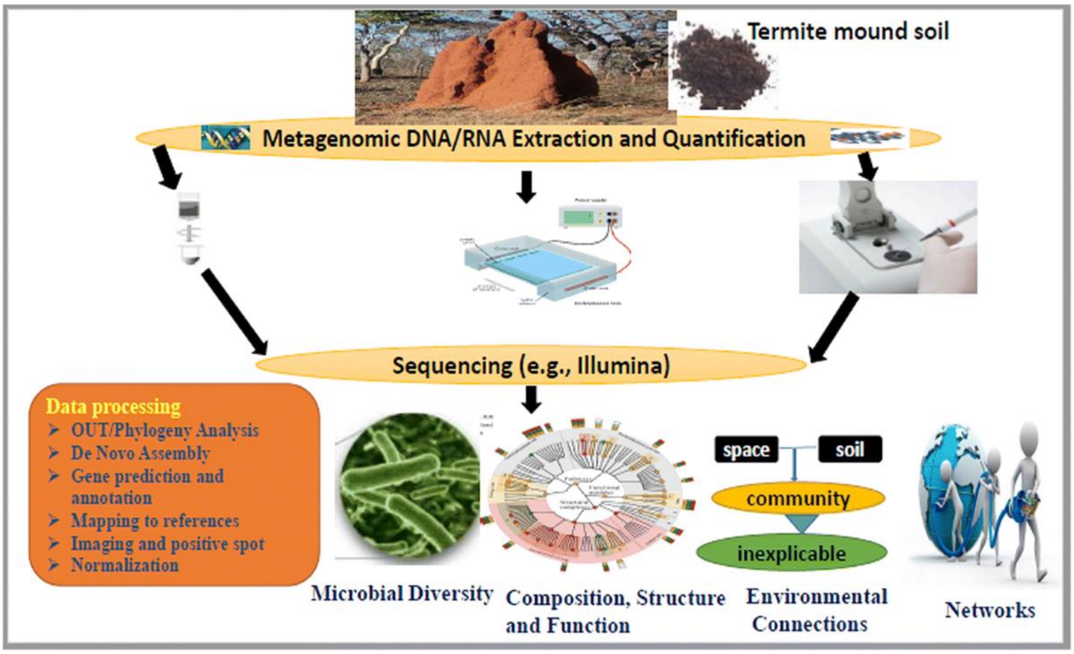

Figure 4: Potentials of termite mound soil bacteria in ecosystem engineering

It was found that Ascomycota and Basidiomycota were two most predominant phyla both in termite mound and soils surrounding termites and their proportion varied between the two conditions. Termite hill soil samples demonstrated an elevated level of Ascomycota in their relative abundance. It is a well-known fact these fungi are both saprophytic and mycorrhizal in nature. This impact may be the mirror termite society has on organic matter breakdown and nutrient circulation hosted in mound systems. The basidiomycetes that are wood-decaying fungi and ectomycorrhizal symbionts were present in the mound as well as surrounding soils in higher frequencies than in controls, thus indicating the function of these fungi in plant nutrient cycling and soil organic matter turnover

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Table: Comparison of Physical and Chemical Properties between Termite Mound Soils and Surrounding Soils

Property	Termite Mound Soils	Surrounding Soils	Statistical Significance
Soil Texture	Loam	Sandy Loam	$p < 0.05$
Moisture Content	15.2%	11.8%	$p < 0.01$
pH	7.0	6.5	$p < 0.05$
TOC (%)	2.0	1.4	$p < 0.01$
TN (%)	0.15	0.10	$p < 0.01$
Available P (mg/kg)	20.1	12.5	$p < 0.05$

Table: Comparison of Microbial Community Composition between Termite Mound Soils and Surrounding Soils

Sampling Point	Bacterial Diversity (Shannon Index)	Fungal Diversity (Shannon Index)	Dominant Bacterial Phyla (%)	Dominant Fungal Phyla (%)
Termite Mound	5.0	3.8	Proteobacteria (35%), Actinobacteria (25%)	Ascomycota (50%), Basidiomycota (30%)
Surrounding	4.5	3.2	Firmicutes (40%), Bacteroidetes (20%)	Ascomycota (45%), Zygomycota (25%)

These findings are very important in the ecological arena, as they allude to the role played by the termite mounds in forming soil properties, microbial communities and nutrient flows of the Nallamalla Forest ecosystem. The physical and chemical alterations carried out by the termites enhance the productivity and the resilience of soil, help in regulation of moisture and are therefore a link of paramount importance in the engineered system of tropical forests [30]. Further study is required to unravel the long-term effects of maronite mound soil on ecosystem functionality and diversity maintenance in the Nallamalla forest and other similar environments alike.

CONCLUSION

Conclusively, this investigations reported, that termites had a great effect on soil properties, microbial communities, and the whole ecosystem within Nallamalla forest. By the means of the complete field and laboratory studies, we have shown that termite mound soils are characterized by unique physical and chemical properties that differ from other soils which are local. They include differences of texture, water content, pH, and nutrient availability. Nevertheless, our results have indicated community microbial structural changes and diversity in termite mound soils which have indicated that the termites, soil biota, and ecosystems are intricately involved in the processes. This data attests to the role of termites as ecosystem engineers in the tropics, which maintains the structural integrity of the soil, nutrient balance, and microbial composition of the ecosystem. Moreover, the information generated from these research fills-up the gap within the literature of termites-mediated effcts on soil properties and microbial communities which in is important to comprehensively understand the mechanism driving ecosystem functioning and resiliency. With a view on further exploration of ecological functions of termites for purpose of improving soil management, securing agricultural sustainability and protecting ecological balance effective research and development are required. With joining multi-disciplinary methods including molecular biology, and ecosystem modeling, way for future studies goes to uncovering the complex relationships termites maintain with the Earth ecosystems and wider ecological processes, being able to provide consequently informed conservation and management of terrestrial ecosystems all over the world.

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