Ann. For. Res. 66(1): 2846-2860, 2023
ISSN: 18448135, 20652445
ANNALS OF FOREST RESEARCH
www.e-afr.org

# TERMITE DIVERSITY ALONG DIFFERENT LAND USE PRACTICES IN WESTERN ODISHA, INDIA

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## ABSTRACT
Termites, commonly known as ecosystem engineers, play a significant role in ecosystems especially in the tropics mainly for recycling dead wood from trees. Human induced land use can alter termite species diversity and abundance. Still, information regarding taxonomy, diversity and ecological effects of termites for different land uses is not widely known. This paper is intended to study the effect of land use systems like the forest, pasture land and crop fields on termite diversity in semi-arid western parts of Odisha, India. We observed only two families namely Termitidae (95.5%) and Rhinotermitidae (0.5%), including six genera in different land use sites. The relative abundance of the genus in different study sites showed that 87.09% of the total termites belonged to *Odontotermes.* Significantly high value of termite diversity, Species richness, and abundance was encountered in dense reserve forest and lowest value of termite diversity, Species richness, and abundance was observed in croplands. Highest Dominance in Cropland was evident from the practice of monoculture. Pasture fields showed borderline values between forest and cropland. We believe that the study of termite diversity across the land use systems will help in planning appropriate conservation and management strategies.
Key words: diversity, ecosystem, termites, land use, management

## *Introduction*

Land use refers to human-induced changes for agricultural, industrial, residential, or recreational purposes by Ramachandra and Bharath (2012). Soil is the most live-supportive element for below-ground organisms commonly called soil biota. Soil biota continuously interacts with and modulates the physical structure, chemical properties, and biological aspects of the soil (Siqueira et al. 2014; Frouz et al. 2015). In tropical arid and sub-arid ecosystems, soils are usually fragile, highly susceptible to erosion and compaction, and characterized by low clay and nutrient contents, low water infiltration rates, and low water holding capacities. In these environments, litter decomposition and soil bioturbation are mainly carried out by termites, and because of that they are considered the "soil engineers" or "ecosystem services providers" (Lavelle 1997; Bignell and Eggleton 2000; Holt and Lepage 2000; Jouquet et al. 2011, 2016; Bottinelli et al. 2015). It has been observed that land use can exert a strong influence on the abundance, biomass, diversity, and community composition of soil macro-fauna (Decaëns et al. 1994; Barros et al. 2002). The termite population is affected by any induced modifications in the land use system and disturbed areas show to harbor a low termite population as reported by (Zeidler et al. 2002; Sileshi and Mafongoya 2005; Poovoli and Rajmohana 2016). However, the majority of studies focusing on the effect of anthropogenic disturbance on termite diversity are mainly from tropical rain forests (Eggleton et al. 1996; Dosso et al. 2013), and the influence of land use on termite species diversity remains poorly understood in semi-arid subtropical areas like India.

***Material and Methods***

**Study sites & Climate**

The present research was carried out in nine different land use management sites in the Western part of Odisha during the year 2020. This region comes under the agro-climatic zone and lies between 20°43'N to22°11'N latitude and 82°39'E to 85°13'E longitude respectively and is covered with a geographical area of 665,700 hectors. The elevation range from the sea level is about 140 to 280 meters. The present study covers four climatic sessions i.e., summer from March to May, rainy from June to September, post-monsoon from October to November, and winter from December to February. The average annual rainfall in the study sites is172.4 mm in 2020. The humidity remains in this area feel highest (83.0%) between July to September followed by 48.7% in April to May and the lowest humidity recorded in the rest of the month.

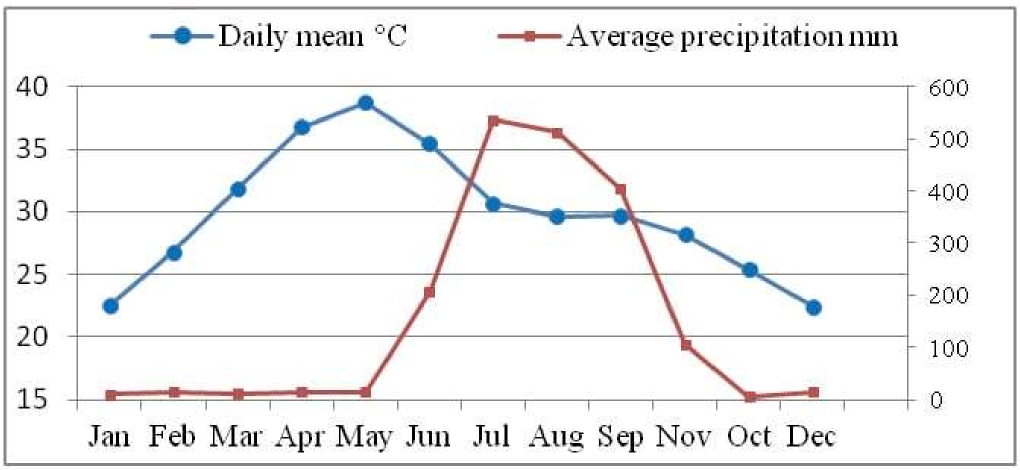


**Figure 1:** Climatological data of Sambalpur district during the study period. Source: http://tcktcktck.org.

***Soil types***

The study sites were dominated by mixed red and yellow soils Sahu and Mishra (2005). These soils are moderately shallow in depth and coarse-textured. The upland soils are shallower and lighter in texture than the low land soils. Major land use practice includes agricultural practice (32%), deciduous dense forest (54.5%) and permanent pasture lands (2%) of the total area (https:// agricoop. nic.in /sites /default /files /28. Sambalpur.pdf)

The termites were collected during 2020 and the field surveys were conducted in early morning between 8 AM to 10 AM. Nine land use habitats were selected in three localities of Sambalpur district i.e., Rairakhol, Maneswar and Kuchinda blocks with three distinct soil types , namely red soil, brown forest soil, and sandy soil respectively. Different land use systems were (1) Reserve forest (FO1) where the grazing activities were allowed for domestic animals throughout the season; (2) Naturally developed primary reserve forest without any grazing activity (FO2); (3) Naturally vegetated dense reserve forest (FO3) with elephant movement activity (4)

Kaju plantain pasture that was intensively grazed by domestic animals (PA 1); (5) Forest derived pasture land (PA2) ; (6) Dry pasture land (PA3); (7) Mono rice cropping land with conventional/intensive tillage (CR1); (8) Traditional/manual tillage with mono-cropping land (subsistence agricultural land) (CR2); (9) Double rice cropping land (Slash and burn agriculture) (CR3).

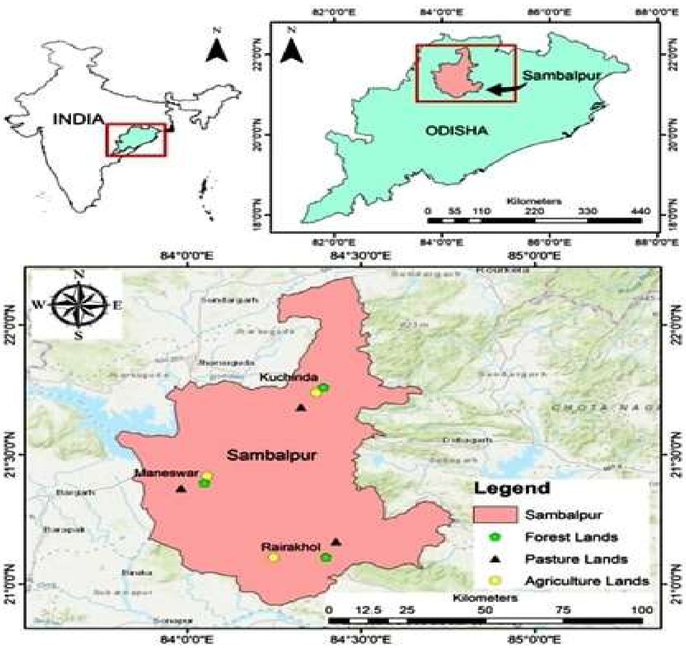


**Figure 2:** Sambalpur map showing the study sites.

*Termite sampling*

Termite sampling in the forest was done following( Eggleton et al. 1995 ) with a transect of 50×2 meters. To avoid unusual disturbances, the transects were placed by observing homogeneous surrounding habitats. Moreover, canals, large streams used by local people, cliff edges, and canopy gaps were avoided by moving the transect line between 45° from the starting point. It was suitable for both qualitative and quantitative analysis and has also been used by many researchers (Muvengwi et al. 2017; Arif et al. 2019; Dangerfield 1998). A 50m×2m Transect was laid out and the area was divided into five subsections about 10 meters apart. Each section was observed by two people for 30 minutes. The observation was carried out by choosing major microhabitats such as soil litter department about 5cm from the surface area, surface dead wood, cow stool that accumulated on soil, the bottom of the root, and dead and decaying wood. The termites from arboreal nests and epigeal parts and subterranean parts within the transects were collected. Only soldier groups were collected and transferred into a labeled plastic vial containing 70% alcohol. The number of soldier termites was calculated in the field after sampling and brought back to the laboratory of the School of Life Sciences at Sambalpur University for further study. Other factors such as soil temperature, air temperature, moisture, GPS coordinate point, and sampling date was also recorded.

***Termites Identification***

Termites collected were identified at Zoological survey of India, Kolkata. The termites were identified morphometrically following common characteristics of termites like mesonotum, metanotum, legs, rostrum cerci, the shape of the head, presence, and absence of eyes, the segment of antennae, and structure of pronotum etc. Specimens were identified to species level, using soldier castes.

***Statistical data analysis***

The diversity indexes such as the Shannon diversity index of (Shannon 1948), Simpson index of (Simpson 1949), and evenness index of ( Magurran 1969; Pielou 1969 )were calculated using PAST (paleontological statistics) version 4.70 2021. Ordinal data were plotted with (nonmetric multidimensional scaling) nMDS parameter and visualized data plotted using origin pro-2023 software (Origin pro, version 2023.OriginLab Corporation, Northampton, MA, USA). Bray Curtis distance calculation was used to interpret the community structure by using the sites matrix. The purpose was to understand the similarity between the sites and seasonal changes in species accumulation in nine land use habitats. The assessment of similarity (nMDS) allowed the description of the similarity between the nine land use sites. The subfamily and genera abundance of termites among the three different sites were also calculated to understand the dominance. Shannon diversity was performed to determine the diversity within the habitat. Further, the effect of land use on the abundance of each species, termite richness, abundance, Shannon Wiener index of diversity and evenness was assessed using one-way analysis of variance (ANOVA) followed by post hoc Fisher's LSD using Minitab. Finally CCA were conducted using PAST software to elucidate the relationships between termite assemblages and soil characteristics.

***Result*s**

The present study indicates a considerable change in termite community structure in response to altering land use practices. A total of 16 termite species were recorded during the study. They belong to two families i.e., Termitidae (95.5%) and Rhinotermitidae (0.5%), including six genera i.e., *Odontotermes* (Holmgren 1912), *Microtermes* (Wasmann 1902), *Macrotermes* (Holmgren 1910), *Coptotermes* (Wasmann 1896), *Microcerotermes* and *Dicuspiditermes* (Krishna 1965).

The termite species under the above genera include *O. guptai, O. globicola* (Wasmann), *O. feae* (Wasmann), *O. brunneus, O. obesus* (Rambur), *D. obtusus* (Silvestri), *O. paravidens. O. redemani* (Wasmann) *O. giriensis* (Roonwal and chhotani), *C. ceylonicus* (Holmgren), *O. horni* (Wasmann), *O. bellahunisensis* (Holmgren and Holmgren), *M. pakistanicus* (Akhtar), *M. obesi* (Holmgren), *M. beesoni* (Snyder) and *M. annandalei*. During the study, family Termitidae was found to include the most dominating termites followed by Macrotermes and Coptotermitinae. The relative abundance of the genus in different study sites showed that 87.09% of the total termites belonged to *Odontotermes followed by Microtermes* (4.7%), Microcerotermes (3.9%), *Dicusppiditermes* (2.4%), *Macrotermes* (0.6%), and *Coptotermes* (0.5%). The most abundant occurrences species was *O. obesus* (29.6%), followed by *O. feae* (20.7%), *O. brunneus* (16.7%) and *O horni* (7.5%) *O redemani* (6.6%), *M obesi* (4.5). C *ceylonicus* (0.5%) was the least encountered species (Figure 3 and Table 1)

**Table 1:** Distribution of termites in three land use systems during premonsoon, monsoon, and postmonsoon period.

| Reserve Forest | | | | Pasture land | | | | Crop field | |
|---|---|---|---|---|---|---|---|---|---|
| Termite Sps. asons | remon soon | Mons oon | tmonso on | remon soon | Ionso on | Postmo nsoon | Prem onsoo n | Mons oon | ostmon soon |
| *O. guptai* | + | + | + | + | + | - | - | - | - |
| *O. globicola* (Wasmann) | - | + | + | - | + | + | - | - | - |
| *O. feae* (Wasmann) | + | + | + | + | + | + | + | + | + |
| *O. brunneus* | + | + | + | + | + | + | + | + | + |
| *O. obesus (Rambur)* | + | + | + | + | + | + | + | + | + |
| *D. obtusus* (Silvestri) | + | + | + | + | + | + | - | - | - |
| *O. paravidens* | + | + | + | + | + | + | - | - | - |
| *O. redemani* (Wasmann) | - | + | + | + | - | - | - | - | - |
| *O. giriensis* (Roonwal and chhotani) | - | + | + | - | - | - | - | - | - |
| *C. ceylonicus* (Holmgren), | - | + | + | - | - | - | - | - | - |
| *O. horni* (Wasmann) | + | + | + | + | - | - | - | + | - |
| *O. bellahunisensis* (Holmgren and Holmgren) | - | + | + | - | - | - | - | - | - |
| *M. pakistanicus* (Akhtar) | - | + | + | - | - | - | - | - | - |
| *M. obesi* (Holmgren) | + | + | - | + | + | + | + | + | + |
| *M. beesoni(Snyder)* | + | + | + | - | - | + | - | - | - |
| *M. annandalei* | - | - | - | - | - | - | - | + | + |

It was observed that wood feeders were more common in both forest land and pasture land except agricultural land, where most of the termites are soil-wood feeders and humivores in nature. Out of 16 nos. collected species seven species belong to mound building species and nine are subterranean species living in underground nests (family Rhinotermitidae). Only Termitidae was known for its wide verity of nesting habitat ( epigeal, wood, and subterranean) (Loko 2019),

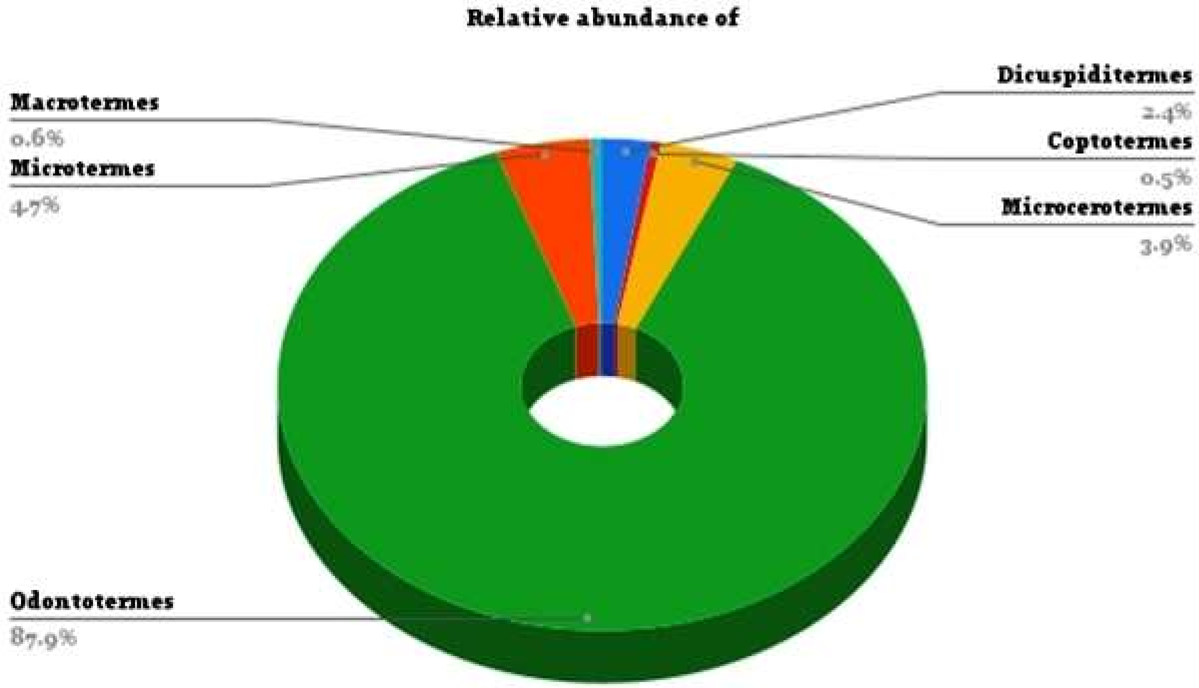


**Figure 3:** Relative abundance of six genera of termites.

**Taxonomy and functional diversity of termites across different land use site**

We calculated the relative abundance of six termite genera under nine land use (Figure 3) and genera *Odontotermes* was found to represent highest abundance among all the land use systems (87.9%). Two way ANOVA revealed a significant difference in termite abundance between land use types where $F_{8,\ 108} = 11.63$, $P<0.001$. However difference in termite abundance between seasons was not significant. The assemblage of termites in different land-used areas shows that the forest has the highest diversity followed by pasture land and cropland (Table: 2) *O. guptai, O. globicola, O. feae, O. brunneus, O. obesus, Dicuspiditermes. sps., M. beesoni, and O paravidens* were most commonly found in forest and pasture land used sites. Species like *M pakistanius, O giriensis, O. redemani, O. ceylonicus* were only found in forest land. Agricultural land recorded 5 species. i.e *O. feae, O. brunneus, O. obesus, O. horni* and *M. annandalei.* Cropland mounds were found to harbor *M. obesi* only from the family Macrotermes. Interestingly *M. annandalei* was the only species first time recorded from rice fields in Sambalpur district. *O. obesus* and *O. giriensis* showed the highest abundance in naturally developed primary reserve forests (FO2). Fisher post hoc LSD showed that the abundance of termites in the different land use systems was significantly different across all paired comparisons at 95% Confidence limit (Table 2).

**Table 2:** Termite community diversity indices in three land use sites.

| Land use Practice | Diversity Indices (Average ± SEM)) | | | | |
|---|---|---|---|---|---|
| | Species richness | Abundance | Dominant Index | Shannon-Weiner Diversity Index | Evenness Index |
| Forest | 7.89±0.45[a] | 154.3±10.2[a] | 0.18±0.008[a] | 1.855±0.05[a] | 0.8231±0.021[a] |
| Pasture field | 5.11±0.45[b] | 100.6±10.6[b] | 0.24±0.2[b] | 1.506±0.09[b] | 0.9184±0.023[a] |
| Crop land | 3.78±0.22[c] | 45.11±4.26[c] | 0.32±0.2[c] | 1.234±0.07[c] | 0.9242±0.021[b] |
| $F_{2,24}$ | 28.5*** | 32.22*** | 12.96*** | 19.62*** | 6.91** |

Species richness showed significant difference among land use practices ($F_{2, 24}$=43.53, P< 0.001) with maximum in forest area having an average number of 8 followed by 5 numbers in pasture land and 4 numbers in crop land (Table 2). Most commonly used index of diversity (H') in ecological studies range from 0 to 5, usually ranging from 1.5 to 3.5 (https://www.webpages.uidaho.edu/veg_measure/modules/lessons/ module%209 (composition &diversity)/9_ 3_ Estimating%20Biodiversity.htm). We observed significantly high value of termite diversity (2.032) in dense reserve forest and lowest value of 1.02 in cropland ($F_{2, 24}$ =19.62, p<0.002). The abundance was also significantly high in forest land uses ($F_{2, 24}$= 38.22, P < 0.001). The evenness of termite's assemblage in different species in three different land used practices was calculated using Pielou's measure of species evenness, i.e. $J = H'/\ln(S)$ where H' is Shannon Weiner diversity and S is the total number of species in a sample, across all samples in dataset and its changes in between the range 0 to 1. The higher value of evenness (0.9242) in crop land indicates less variation among the species distributed as compared to forest land use with the value of 0.823. Significantly higher Simpson Dominance index were recorded in crop lands (0.32) and least (0.18) in forest land use system ($F_{2, 24}$= 12.96, P<0.001), (Figure 4).

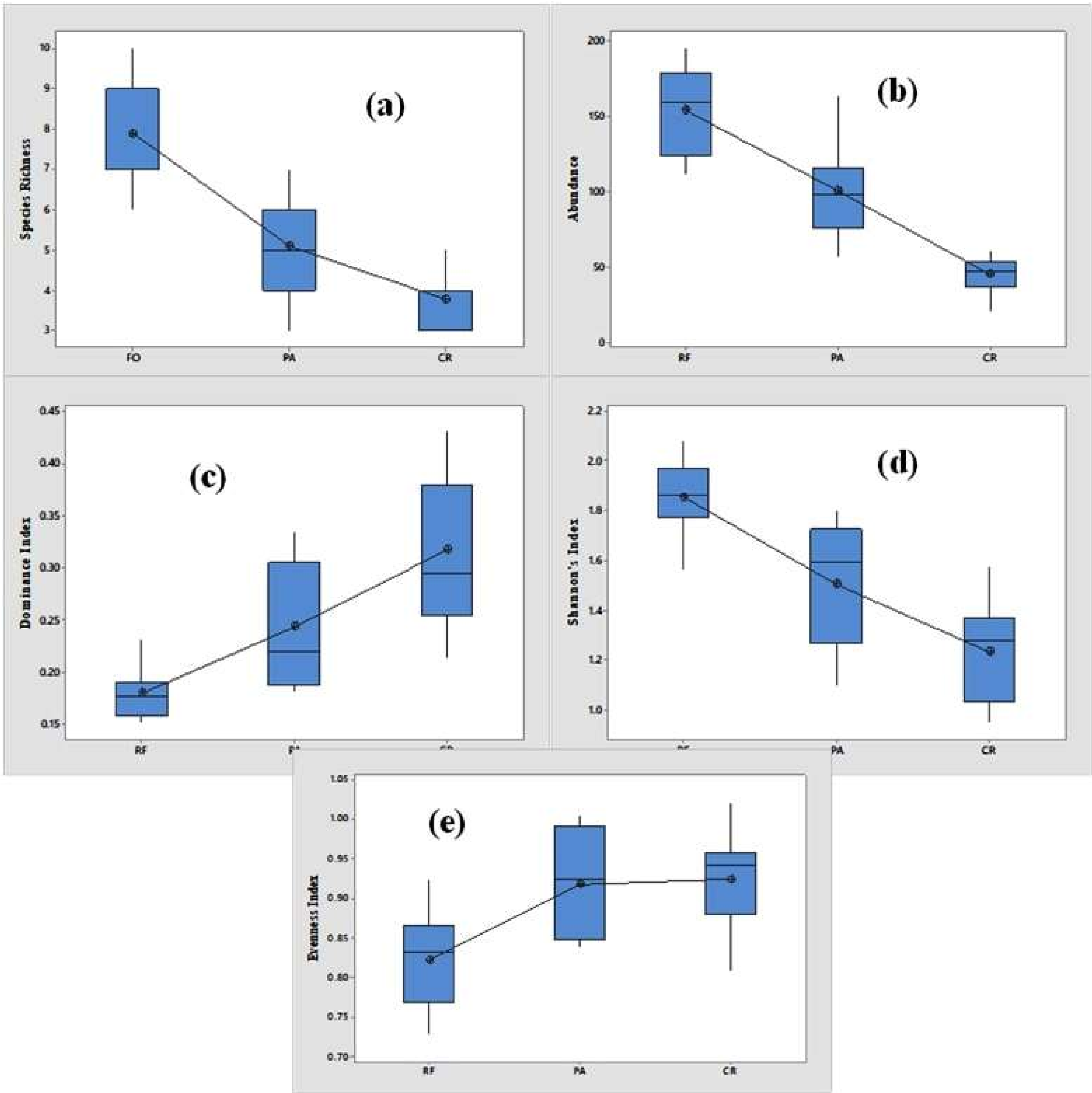


**Figure 4:** Mean ± SE of termite species richness (a), abundance (b), Dominance index (c) and Shannon Wiener index of diversity (d), Evenness index (e) across the three land use types followed by post hoc LSD test, *N* = nine replicates per site.

**Soil variables**

Sand particles in soil texture (with three replica) varied significantly ($F_{8, 18} = 5.77$, $P < 0.05$) across the three land-use types, with the highest values recorded in grazing area and the least in the agricultural field (Table 3). Total nitrogen, ($F_{2,33}=3.44$, $P< 0.05$ ) and Available phosphorus ($F_{2,33}=5.04$, $P< 0.01$ ) significantly differed between land use types with peak value of 118.15 (mg/kg) in reserve forests during rainy season . Though one way ANOVA did not show any significant difference of OC between different land uses but "t" test ($t_{22}=2.29$, $p< 0.01$) reveled significant difference between forest and pasture. Available potassium was not significant among three land use types as observed by both one way ANOVA and "t" test.

**Table 3:** Soil Physicochemical properties in three land use types (RF: Reserve forest; PA: Pasture land; CR: Crop field) All the values represent annual average ± SEM

| | RF | PA | CR |
|---|---|---|---|
| **Sand** | 79.22 ±3.02 | 78.84 ±1.43 | 80.84 ±0.97 |
| **Silt** | 12.25 ±3.16 | 12.85 ±3.58 | 10.67 ±3.48 |
| **Clay** | 9.91 ±2.85 | 8.42 ±0.7 | 7.08 ±1.58 |
| **OC (%)** | 1.148±0.271 | 0.497±0.08 | 0.96±0.24 |
| **TN%** | 0.258±0.038 | 0.148±0.026 | 0.27 ±0.044 |
| **AK (mg/kg)** | 24.93±2.97 | 16.87±1.82 | 16.37±1.75 |
| **AP(mg/kg)** | 62.96 ±8.83 | 28.38 ±5.2 | 56.20 ±9.72 |

The impact of termites on ecosystem is governed by the species richness and their relative abundance Eggleton and Bignell (1995). *Odontotermes* species construct their colonies underground, where they cultivate fungi that aid in cellulose digestion. *Odontotermes* appeared to play a major role in clay dynamics and soil fertility in the tropical ecosystem, The biological attributes of each species (nest pattern, life-span and distribution of fungus-comb chambers) appear to be the main determinants to account for the relative importance of termite species in soil functioning. *Odontotermes* constitute most dominant termites representing 87.4% of all the termites and it's highly abundant in forest areas in our study. This indicates its ecological importance in different land use systems especially in forests.

Forest sites showed the highest Shannon diversity index (H') ranging from 2.081-1.866 with mean value of 1.855±0.05 and with lowest dominance index of 0.18±0.008 in comparison to pasture land and crop field. This leads to structural complexity of forest area and helps termites for better feeding and habitat building with high species richness, abundance. The presence of termites in an environment means the habitat is suitable for the termites to inhabit, with temperature having a key role in defining the type of species found in the habitat (Woon et al. 2022; Arango et al. 2021; Hyseni and Garrick 2019; Woon et al. 2019). Previous researchers have shown that environmental variables such as temperature, rainfall, and local vegetation structure have an impact on termite communities (Gathorne-Hardy et al. 2001; Jones and Eggleton 2010; Junqueira et al. 2015). Our findings are in accordance with these findings.

The pasture fields in our study are mainly derived from forest clearance and also few of them having Kaju plantation or barren lands used for grazing purpose. These lands are characterized by little herbaceous vegetation. This might be the reason for less species richness, abundance and diversity in comparison to reserve forests. Many studies have reported declined in termite species richness or changes in assemblage structure following partial or complete clearance of woodlands in tropical, subtropical and warm temperate biomes (Wood et al. 1982; Gathorne-Hardy (2001); Bandeira et al. 2003; Jones et al. 2003; Dawes 2010; Vasconcellos et al. 2010). Our finding is in conformity with the above cited observations.

It has been observed that termite diversity (H') in agricultural land use sites varied between 1.173-1.026. We found lowest species richness and abundance in croplands. Monoculture practices in plantations might be one of the reasons for the lower species richness as also reported by (Prasetyo 2002). Biotic determinants such as vegetation structure and food availability have been considered as important influences on termite foraging intensity and decomposition rates at the local scale (Leitner et al. 2018; Mugerwa et al. 2011). In addition to biotic and abiotic drivers, multiple studies have indicated that anthropogenic disturbance and land-use intensification have resulted in decreased termite richness and altered community assemblages (Hausberger and Korb 2016; Jones et al. 2003; Muvengwi et al. 2017; Olugbemi 2013). We performed Non-metric multi-dimensional scaling (nMDS) for visual illustration of assemblage variation across sites and distance intervals.

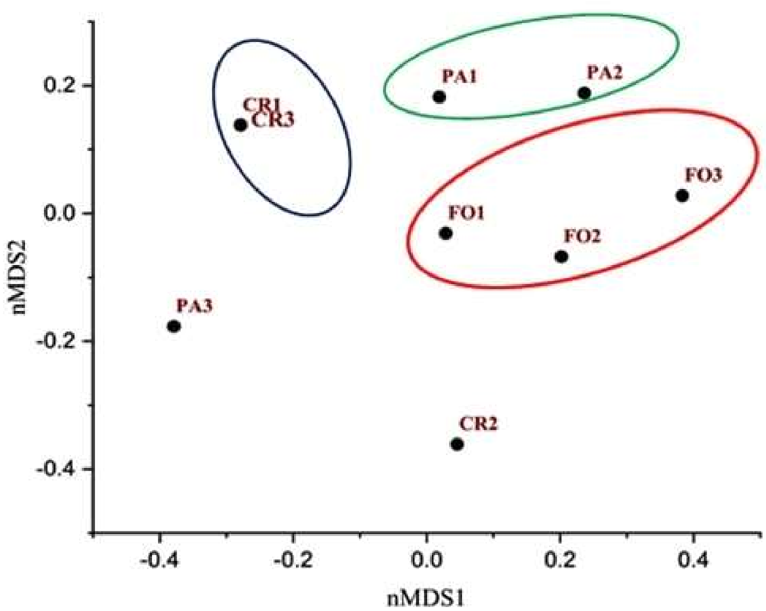


**Figure 5:** Non-metric multi-dimensional scaling (nMDS) ordination of abundance of termite species for Forest, Pasture and cropfields.

In our study, Non-metric multidimensional scaling (NMDS) ordination showed that forest sites are more similar in terms of termite abundance and species richness to one another and therefore are ordinated closer together. Similarly PA1, PA2 and CR1, CR3 are ordinated closer together for pasture land and crop fields respectively.

Canonical correspondence analysis of sixteen termite species in three land use systems was carried out using soil physico-chemical properties (N, C, P, K) (Figure 6) to elucidate the relationships between biological assemblages of species and their environment.The first and second axes explain 57%, 35 % of the variance, respectively illustrating the relationship of termite abundance and the measured environmental ariables. The termite species are *D. obtusus, M. annandalaei, M. bessoni, M. obesi, M. pakistanicus, O . bellahunisensis, O. 0besus, O. brunneus,* *C. ceylonicus, O. feae, O. glabicola, O. guptai, O. giriensis, O.horni, O.redemanni, O.parvidens.* Thus CCA in our study indicated OC, AP, and TN as the main predictors of termite assemblages.

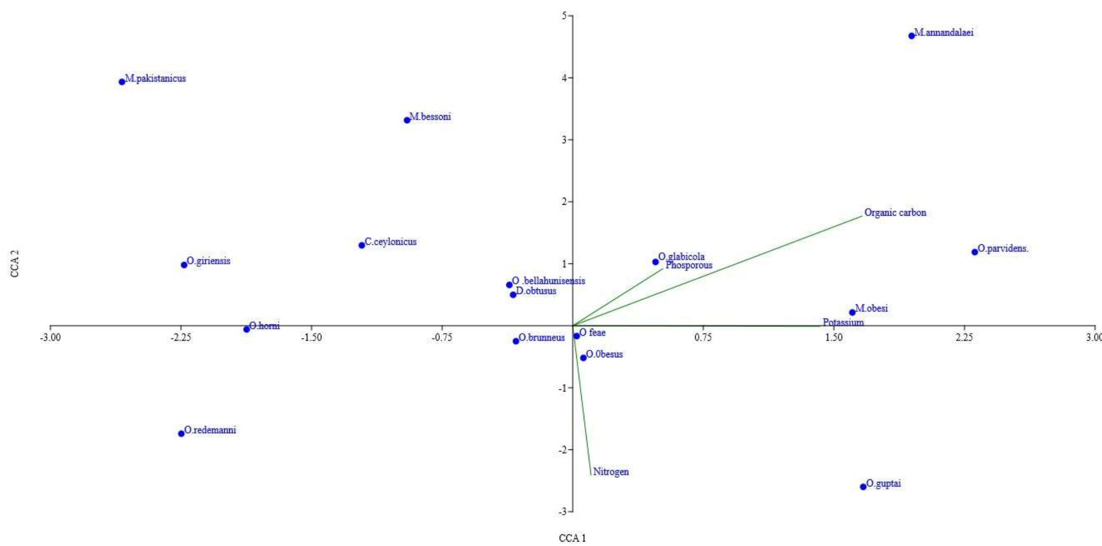


**Figure 6:** Canonical correspondence analysis of sixteen termite species in three land use systems using the soil chemical parameters shown by arrows.

***Discussion***

In our study, we recorded a total of 16 termite species that belong to two families; Termitidae (95.5%) and Rhinotermitidae (0.5%) and six genera i.e., *Odontotermes* (Holmgren 1912), *Microtermes (*Wasmann 1902), *Macrotermes* (Holmgren 1910), Coptotermes (Wasmann 1896), Microcerotermes and Dicuspiditermes (Krishna, 1965). Termitidae represented the most dominant family in our study in comparison to Rhinotermitidae found in both tropical and sub tropical regions. Ranjith and Kalleshwaraswamy (2021) reported 132 species from five families, of which Termitidae (Latreille 1802) is the dominant family comprising 101 species from 27 genera and four subfamilies. This corroborates our finding where termitidae family dominated in western part of Odisha.

***Conclusions***

In conclusion we observed significant difference in species richness, abundance, Shannon's diversity among different land use types. This study indicated that the land use intensification was associated with reduction in community characteristics. It can be concluded that changes in physicochemical soil quality of different land uses affect termite communities and induced changes in its composition with inconsistent loss of some species. However, there is possibility that some termites can adapt well to the decline in soil quality. The large variability notices in our study suggests the need of continuous monitoring to appraise the long-term impact of land use change on termites.

***Acknowledgments***

The authors gratefully acknowledge the Head, School of Life Sciences, Sambalpur University, Odisha for providing the necessary research facilities. The authors highly acknowledge ZSI, Calcutta for identifying the termites up to species level. One of the authors acknowledges UGC New Delhi for providing RGNF fellowship to carry out the present work.

***Conflict of Interest***

The authors have no conflict of interest.

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