Short Research Article

Origin and dynamics of termite mound soils in southern India

ABSTRACT

Aims: In Southern India, termite above-ground nests can have the shape of cathedral (CAT) or lenticular (LENT) mounds. Although CATare built by the fungus-growing species *Odontotermes obesus*, the origin and evolution of LENT remain unknown. Therefore, the aim of to study was to estimate the origin and dynamics of LENT from their specific physical and chemical properties.

Study site: This study was carried out in the Bandipur Tiger reserve (dry deciduous forest), Karnataka, Southern India.

Methodology: All the soil samples were collected in a Fluvisol in the Mule Hole experimental watershed.Only large size mounds between 1.5 - 1.8m high were considered in this study. Soil samples were collected from the outer wall of CATnest and from the soil surface layer (0-5 cm deep) and surrounding soil. Particle-size distribution and dispersion were obtained by process of sedimentation. All the statistical analysis such as principal component analysis (PCA) were calculated using R studio and R version 3.2.1.

Results: Using elemental physical and chemical properties, this study showed a gradient of soil properties from the soilsampled between 50-100 cm depth to CAT, LENT and the surrounding topsoil (Fluvisol), suggesting that: (i) CAT can be considered patches in the landscapes with specific physical and chemical properties in comparison with CTRL and LENT; (ii) LENT mounds can result from the progressive modification of CTRL (autogenic origin of LENT) and their degradation leads to a progressive recovery of CTRL properties or (iii) they originate from the colonization of abandoned CAT by other termite species (exogenic origin of LENT).

Conclusion: This study confirms the complexity of CAT and LENT fates and the need for long-term datasets to determine the origin and evolution of LENT mounds.

Keywords: Fluvisol, *Odontotermes obesus*, Southern India, Termite mound soils.

1. INTRODUCTION

Termites (*Isoptera*) are considered the most dominant invertebrate decomposers and ecosystem engineers in tropical ecosystems due to their influence on soil dynamics [1,2]. In deed, they construct different types of soil biogenic structures (e.g., termite mounds and sheetings) which have significant effects on nutrient cycling and water dynamic [3,4]. Amongst them, termite mounds are conspicuous features of tropical savannas and forests. They are made of soil coming from different soil depths and they are characterized by different soil physical and chemical properties in comparison with the surrounding soil environment [5,6].

In Southern India, few termite species build above-ground mounds and most of them are built by *Odontotermes obesus* [7] .These mounds are mainly made of soil sampled between 50 to 100 cm depth [8] .They usually have a cathedral (CATnest) shape and they can reach up to 2m high in some circumstances while their erosion leads to an accumulation of soil in their periphery (CATperiph). Termites are also found in lenticular mounds (LENT), which are usually covered with vegetation. The origin and dynamic of these mounds remains, however, speculative. It has been suggested that they result either from the activity of other species, such as *Odontotermes redamanni*, or to the colonization of abandoned *O. obesus* mounds by *Odontotermes* spp.To tackle this question, the objective of this study was to use the physical and chemical properties of these two types of termite mounds and those from the soil eroded from the mounds to discuss their dynamic and relationships.

2. MATERIALS AND METHODS

2.1 Study site

The present study was carried out in the Mule Hole basin (4.1 km²), which is part of the the Bandipur Tiger reserve (dry deciduous forest) in Southern India at 11°44′ N and 76°26′ E (Chamarajanagar, Karnataka, India). The Mule Hole basin is part of the ORE-BVET project (Observatoire de Recherche en Environnement - Bassin Versant Expérimentaux Tropicaux, http://bvet.omp.obs-mip.fr/) and Multiscale Tropical Catchments (M-Tropics) (https://mtropics.obs-mip.fr/). Soils are mostly Fluvisol and more information concerning the study site can be found in Jouquet et al. [8]

2.2 Study models and soil sampling

The size of CATnest is highly variable [7] and only large size mounds between 1.5 to 1.8m high were considered in this study. LENT mounds were differentiated according to their sizes: LENTsmall (< 1 m^3), LENTmedium (between 1 to 3 m^3) and LENT large (> 3 m^3). Soil samples were collected from the outer wall of CATnest and from the soil surface layer (0-5 cm deep) for the other treatments (n = 3). The surrounding environment ('CTRL', distance from any termite mound ~ 5-10 m) was sampled at 0-5 cm depth (n = 3 per type mound category, i.e. total number of samples = 12). Soils were also sampled in the 50-100 cm soil layer ('PROF') where termites are known to sample the soil used for the edification of CATnest [6] (n = 4).

2.3 Soil properties

Soil properties measured included the particle-size distribution, after destruction of organic matter and dispersion with sodium hexametaphosphate (AFNOR, NFX 31 107): clay (< 2 µm) and silts (2-50 µm) were obtained by sedimentation and sand (50-2000 µm) by wet sieving. The C and N concentrations and δ13C and δ15N were measured using an elemental analyzer Flash 2000 HT coupled to an isotope ratio mass spectrometer Delta V Advantage from Thermo Fischer Scientific. C and N isotope ratios were defined using the delta notation:

$$\delta \text{ sample } (‰) = [(\text{Rsample} - \text{Rstandard})/\text{Rstandard}] \times 1000$$

where R is the isotopic ratio 13C/12 C and 15N/14 N for the sample and reference gas, Rsample and Rstandard, respectively. The stable isotope ratios were calculated relative to the Pee Dee Belemnite standard (PDB) for C and relative to atmospheric N2 for N. The cationic exchange capacity was determined at soil pH by exchange with cobalti hexamine (AFNOR, NF ISO 23470).

2.4 Statistical analyses

The physical and chemical signatures of soil (Fluvisol) samples were analysed by a principal component analysis (PCA) with a matrix of 31 samples. All statistical were calculated using R studio and R version 3.2.1 with ade4, Facto Mine R and factoextra packages.

3. RESULTS AND DISCUSSION

The dynamics of termite mounds has been little explored especially because for this long term studies following how mounds change over time are required [9]. Using elemental pysical and chemical properties, the PCA displayed a differentiation of soil samples mainly along the first axis, which explained approximately 42% of the total variability (Fig.1) along a gradient from PROF to CAT and then LENTsmall and CTRL.

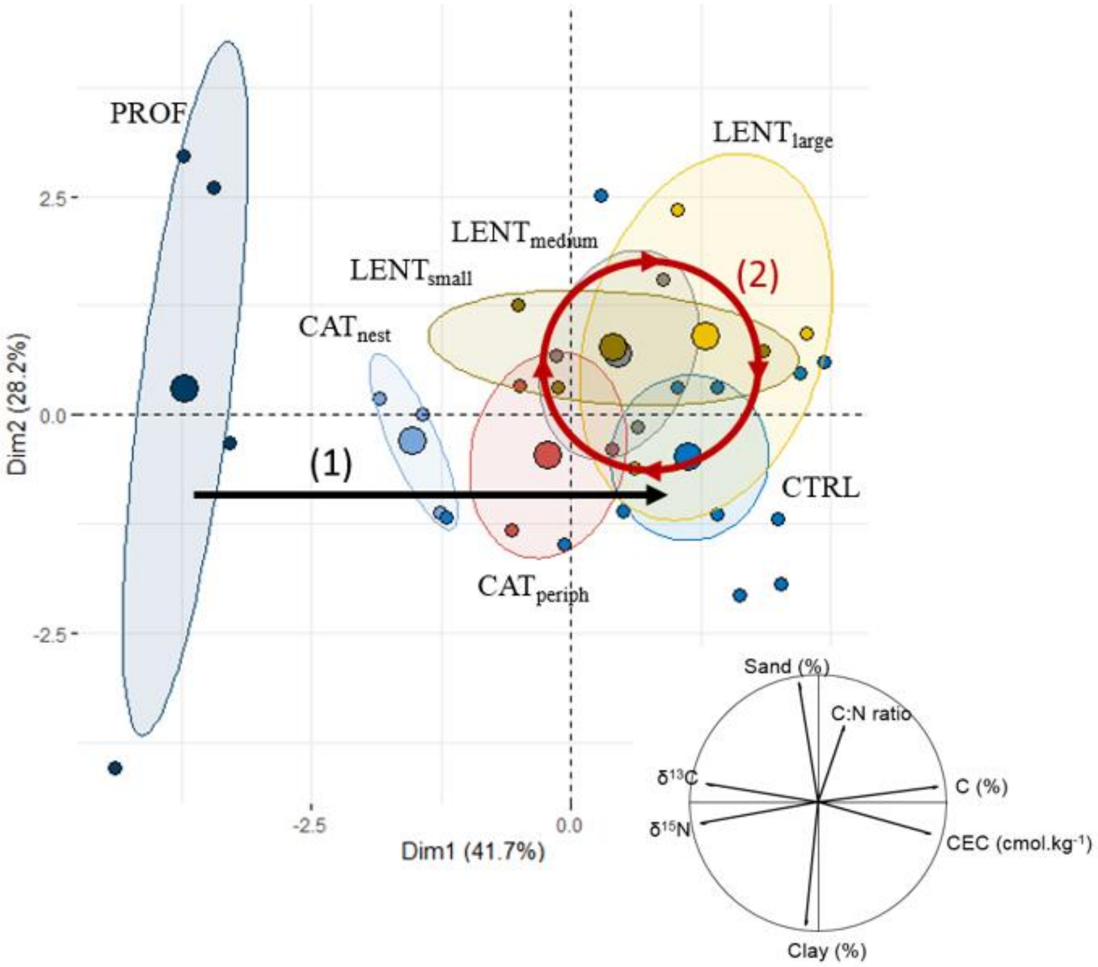

Fig. 1 Principal component analysis (PCA) and correlation cirle of the soil physical and chemical properties of termite mound soils, CAT_{nest}, $\text{CAT}_{\text{periph}}$, $\text{LENT}_{\text{small}}$, $\text{LENT}_{\text{medium}}$ and $\text{LENT}_{\text{large}}$ and the control soil sampled at 0-5cm depth (CTRL) or at 50-100 cm depth (PROF). The arrow and the circle represent the different trajectories between CAT, LENT and CTRL.

Conversely, CTRL and LENT mounds had very similar fingerprints and they were mainly differentiated along the second axis, which explained 28% of the total variability. Considering these results, different scenarios can be suggested to explain the dynamics of termite mounds in south-Indian forest ecosystems. CATnest can be considered as patches in the landscapes with specific physical and chemical properties in comparison with CTRL. Obviously, their degradation by animals or their erosion by the rain is important for the redistribution of Soil Organic Matter (SOM), clay and nutrients in tropical ecosystems. The degradation of CATnest leads to the creation of a mound (CATperiph), with intermediate soil physical and chemical properties between those of CATnest and CTRL (Trajectory n°1). This result therefore suggests that a progressive erosion of CATperiph is likely to lead to the recovery of soil properties similar to those observed in CTRL, most likely after the vegetation develops and soil bioturbation by other animals or the whole erosion of the soil.

The PCA showed overlaps between CTRL and LENT, showing that these soil properties are very similar and suggesting that LENT is likely to emerge from and degrade into CTRL (Trajectory n°2). The physical and chemical properties of LENT are initially very similar to those of CTRL but their colonization by vegetation and development of termite activity is likely to create self-organized patches with their own dynamics and evolution following an autogenic succession, as observed in the Amazon [10]. Conversely, the lack of termite activity in LENT, possibly after their predation by sloth bears [11], could lead to their progressive degradation until the recovery of CTRL properties. Finally, the PCA suggests another possible dynamic. CATperiph could not be differentiated from LENTsmall and LENTmedium. This result therefore suggests a possible exogenic origin of LENT mounds, or in other words that CATperiph can also evolve into LENTsmall after its colonization by other termite species and possibly other invertebrates (ants, earthworms, millipedes, coleoptera, etc) [12], which could then benefit from the elevation and specific soil properties of CATperiph and gradually modify them into LENTmedium and later LENT large. This hypothesis is in line with the long-term study of Josens et al. [9] (2016) that showed that lenticular mounds occupied by *Odontotermes aff.* pauperans in African savannahs can originate from degraded cathedral mounds of *Macrotermes* sp. Conversely, since CAT are mainly made of soil sampled at 50-100 cm depth [8], an exogenic origin of CATnest emerging from degraded LENT is unlikely.

4. CONCLUSION

In conclusion, scenarios could be proposed from the specific soil physical and chemical properties of termite constructions. Similarity in soil properties confirmed the link between cathedral and lenticular mounds in Southern India. However, as already highlighted by Pullan [13] and Josens et al., [9], the fate of termite mounds can be very complex and our descriptive approach is likely to be insufficient to shed light on the close relationships between CAT and LENT. Therefore, we call for more data, and especially long-term datasets describing the dynamics of termite constructions in order to confirm their origin and evolution.

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