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Influence of soil type on the properties of termite mound nests in Southern India

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ABSTRACT

Termite mounds are conspicuous features in many tropical ecosystems. Their shape and soil physicochemical properties have been suggested to result from the termites ecological need to control the temperature and humidity within their nests and protect themselves from predators. This study aimed to determine the influence of the parent soil properties on the shape and soil physical and chemical properties of termite mounds. Termite mounds built by the fungus-growing termite species *Odontotermes obesus* were compared in two forests with different soil properties (Ferralsol or Luvisol) in Southern India. Our findings confirm that soil properties influence the physicochemical characteristics of mound material and may affect the shape, but these impacts are mostly independent of the size of the mounds (i.e., the age of the colonies). Mound walls were more enriched in clay and impoverished in C and N in the Luvisol than the Ferralsol. However, their shape was more complex in the Ferralsol than the Luvisol, suggesting a possible link between the clay content in soil and the shape of termite mounds. The results also suggest that clay becomes enriched in *O. obesus* mound walls through a more passive process rather than solely by particle selection, and that termite mound shape results from the soil properties rather than the ecological needs of termites. In conclusion, although ecologists have mainly focused upon the influence of termite ecological needs on their nest properties, this study highlights the need for a better understanding about the role of the soil pedological properties and, as a consequence, how these properties drive the establishment and survival of termites in tropical ecosystems.

1. Introduction

Fungus-growing termites (Termitidae, Macrotermitinae) construct belowground chambers or aboveground mounds to protect their colonies and their exo-symbiotic fungi. Depending on the challenge of their immediate environment, termites are assumed to modify the properties of their nests in two ways: first, by selecting and modifying the soil material they use and/or by modifying the shape of their mounds.

For construction, fungus-growers transport clay-enriched soil from deep soil horizons to the soil surface (e.g., Jouquet et al., 2004; Abe et al., 2009, 2012; Edosomwan et al., 2012; Mujinya et al., 2013). This enrichment in clay particles improves the resistance of termite mounds to predators and rain and it is usually more significant in long-lasting structures than in short-lived soil constructions (Jouquet et al., 2002, 2005, 2007, 2015a). Termites also influence soil chemical properties, such as soil C and N contents within their nest materials. However, the influence of termites on the C and N content is highly variable. For example, the soil organic matter (SOM) content in Macroterminae-built structures was reported to be similar (Eschenbrenner, 1986), higher (Black and Okwakol, 1997; Jouquet et al., 2003), or lower (Arshad et al., 1988; Garnier-Sillam and Harry, 1995; Contour-Ansel et al., 2000; Sall et al., 2002; Jouquet et al., 2005; Jouquet et al., 2015b) than the surrounding putative control soil. This large variability could be due to impacts specific to each termite species (the “behavior” force, *sensu* Harris, 1956) and the interaction between termite behavior and their environment (the “material” and “climate” forces). Although unstudied, it is also likely that the influence of termites on soil properties and their needs to control their environment vary according to the age of the termite colonies. Soil collection from deep layers requires more investment

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for young termite colonies, which are, therefore, likely to preferentially use the soil from the surface layer that is more easily available. In contrast, in the large network of galleries built over time by old colonies, termites may go deeper in the soil profile and use soil particles with a higher clay but lower C and N contents than soil in the surface layer. Nevertheless, to date the respective influences of the soil properties and colony age remain unknown.

Termites are also held able to modify the shape of their mounds to control the humidity and temperature within their nests (Noirot and Darlington, 2000; Korb and Linsenmair, 1998a,b; 2001; Turner, 2004). However, this conclusion was only made from studies carried out in Africa or with African species, despite the fact that termite mounds are also conspicuous features of Asian landscapes (Jouquet et al., 2015c). In addition, the influence of the environment (usually the vegetation cover) on termite mound shapes has only been highlighted with cathedral and dome shaped *Macrotermes* sp. mound nests (i.e., Korb and Linsenmair, 1998a,b; 2001), while other genera also produce complex above-ground nest structures (i.e., species of the genus *Odontotermes*). More research is therefore needed to determine whether the ability of fungus-growing termites to adapt the properties and shape of their mounds is a generality rather than an exception.

The species *Odontotermes obesus* (Macrotermitinae subfamily) produces some of the most impressive larger mounds that can be encountered in Southern India. These constructions are usually up to 2 m high with many circumvolutions (Roonwal, 1970, 1978) and resemble those produced by the African species *Macrotermes bellicosus*, whose archetypal mounds are commonly illustrated in books and reviews. Thus, the mounds of *O. obesus* can be used to test the concepts modeled from *Macrotermes* sp. concerning the factors determining termite mound composition and shape in general. The main aim of this study was therefore to determine whether the shape and properties of *O. obesus* mound constructions are constant or vary depending on the surrounding environment. A second objective was also to investigate whether the impact of termites on soil properties and termite mound shapes are constant for a given environment or if they vary according to the age of termite colonies.

2. Materials and methods

2.1. Study sites

Termite mound properties and shapes were analysed in the Bandipur Tiger reserve forest (Mule Hole experimental watershed, Karnataka state, 11°44′N and 76°26′E) and in the forest of the Jubilee Garden in the Indian Institute of Science (IISc, Bangalore city, Karnataka state, 13°01′N and 77°33′E). Soils are Ferralsols and Luvisols (World Reference Base for Soil Resources, 2014) or Oxisols and Alfisols (Soil Survey Staff, 1999), in Bandipur and IISc forests respectively (Barbiéro et al., 2007; Braun et al., 2009; Jouquet et al., 2015a,b). As a result of the short-term variability of the South–West Monsoon, the annual rainfall ranges from 900 to 1100 mm yr^{-1} in both forests. In Bandipur forest, the vegetation is a dry deciduous woodland, dominated by the "ATT" facies (i.e., *Anogeissus latifolia*,*Tectona grandis* and *Terminalia crenulata*, Barbiero et al., 2007). In IISc, the vegetation is also a dry deciduous forest but it is dominated by Acacia trees, mainly *Acacia auriculiformis*, and to a lesser extent by *Leucena leucocephala*, *Parkia biglandulosa*, *Gliricidia sepium* and *Delonix regia* (Jouquet et al., 2015a).

In these environments, *Odontotermes obesus* builds mounds that are very similar in shape to those produced by *Macrotermes bellicosus* in Africa with numerous ridges and complex structures (Roonwal, 1970,1978) (Fig. 1). Seventeen active termite mounds

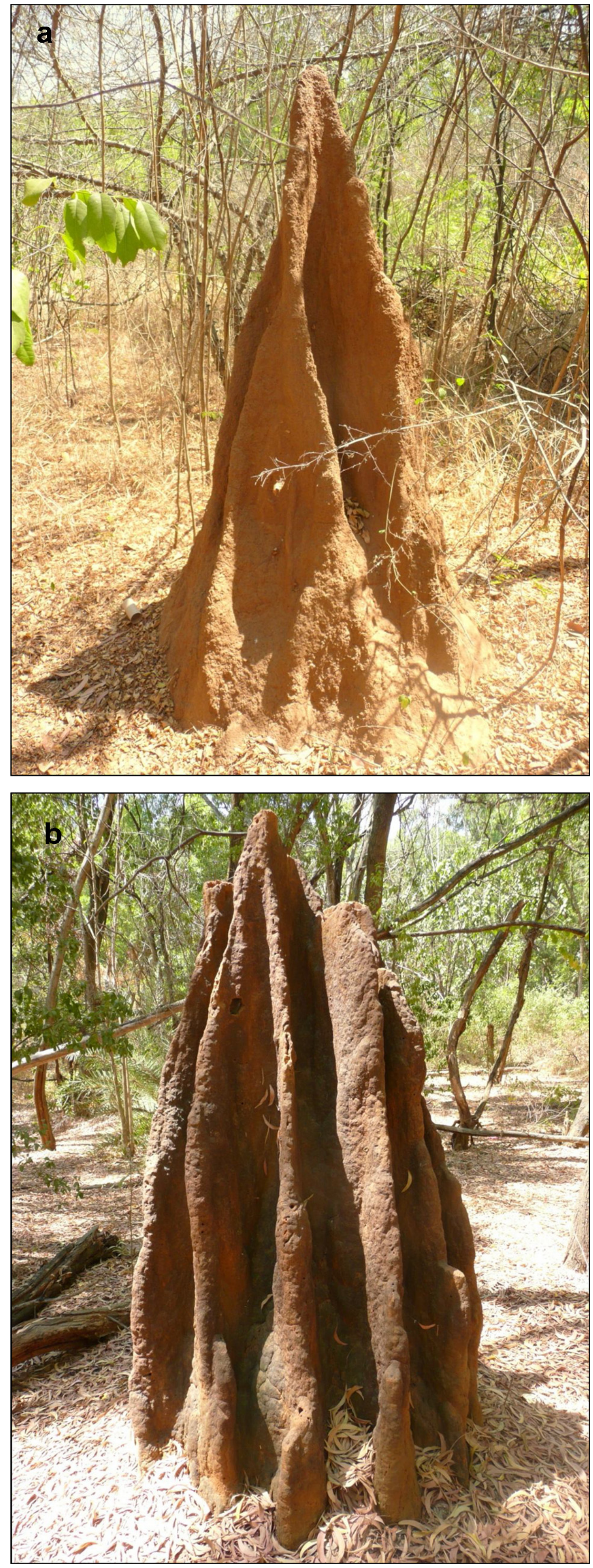

Fig. 1. Examples of *Odontotermes obesus* termite mounds produced at IISc in the Luvisol (a) and at Bandipur in the Ferralsol (b) environments in Southern India (Karnataka). Photos P. Jouquet, April 2014.