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Ecosystem services of termites (Blattoidea: Termitoidae) in the traditional soil restoration and cropping system Zaï in northern Burkina Faso (West Africa)

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ABSTRACT

The present study provides evidence of the effectiveness of some termite species in restoring barren soil and in maintaining long-term soil productivity, thereby facilitating sustainable agriculture in sub-Saharan West Africa. Fungus-growers, in particular, move large quantities of soil to cover their food sources with 'soil sheetings', which protect the termites during foraging. We selected study sites in northern Burkina Faso from four age-stages of the traditional restoration system Zaï, thus spanning three decades of soil restoration—barren, crusted land, a millet field, and two reforested sites. In a randomized block design, termites were attracted to different organic materials. The aim was to assess the impact of their foraging structures (soil sheetings, foraging holes) on the restoration progress. We quantified soil turnover by termites, macroporosity, water infiltration rate, and physicochemical soil properties. Fungus-growing *Odontotermes* and *Macrotermes* species were the decisive soil engineers throughout the year, but only *Odontotermes* initiated the restoration process. The dry weight of soil bioturbated during the dry season ranged between 216 and 32 tons ha^{-1} mon^{-1} in the most rehabilitated Zaï forest and the barren area, respectively. By creating tunnels, the foraging activity of termites increased the water infiltration rate by a factor of 2 to 4. Sheetings built on compost and hay showed significant increase in most parameters relevant for plant growth, especially during the dry season. However, the benefits resulting from the termites' tunnelling activities (improved water availability and soil aeration via macropores, soil turnover) are in the early stages of Zaï restoration likely to be more essential than the increased nutrient contents in sheeting soil, since water deficit leads to sapling mortality much faster than nutrient shortage. Our study revealed that the impact of termites is dependent on the particular species and their ecological requirements. Further studies in other areas are urgently required to clarify how generally valid our results are.

1. Introduction

Unsustainable agricultural practices are among the leading causes of soil degradation (Bai et al., 2008) and biodiversity loss (Foley et al., 2005). In sub-Saharan Africa where millions of inhabitants depend on small scale rain-fed agriculture for their livelihoods and where vast areas are barren and degraded due to climate variability and unsustainable use, the consequences are particularly devastating (Batjes, 2001; Mertz et al., 2012). However, cultivation does not necessarily damage the soil but might even help restore former fertility. Restoration and sustainable agricultural practices can be achieved through utilization of the ecosystem services of soil organisms (Crain and Bertness, 2006; Brussaard et al., 2007). Termites (Blattoidea: Termitoidae) provide self-renewing ecosystem services, which might be a relevant option for sustaining soil productivity and rehabilitating degraded soils in tropical agroecosystems (Jouquet et al., 2011). This may be especially true in northern Burkina Faso (West Africa), where termites are the only active decomposers and main soil turbators all year round (Rouland et al., 2003).

The Zaï technique: soil restoration with the help of termites. The improved Zaï practice is an impressive example of a traditional soil water conservation and cropping method (Roose et al., 1993). It

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triggers termite activity and takes advantage of their ecosystem services for restoring degraded, crusted soil in semi-arid West Africa (Laguemvare, 2003; Reij et al., 2009b; see below). After the devastating droughts of the 1970s, some farmers in the sub-Sahel zone of Burkina Faso improved traditional planting pits (or *Zaï*) by increasing their dimensions and adding organic matter to them, thereby attracting termites that modify the crusted soil (Roose et al., 1999; Kaboré and Reij, 2004). Most termites construct networks of interconnected foraging tunnels leading from their nests to the accumulated organic matter on the soil surface, where they end in foraging holes (macropores). They cover the food source with protective soil sheetings, thus protecting themselves against direct sunlight, desiccation, and predation during foraging. As an additional measure in the improved Zaï practice, stone lines capture the soil and reduce water runoff (Reij et al., 2009b). Zaï functions best in areas with a minimum of 300 mm and a maximum of 800 mm rainfall; the soil surface should be barren, flat, and hard in order to generate sufficient runoff (see Roose et al., 1993). Kaboré and Reij (2004) provide a good overview of the advantages and disadvantages of the improved Zaï practice. The technique was considered crucial in triggering the process of agricultural intensification and environmental rehabilitation in the Sahel (Reij et al., 2005). Surprisingly, no study has attempted to clarify the various roles played by different termite species in the restoration process or how the system can be optimised by

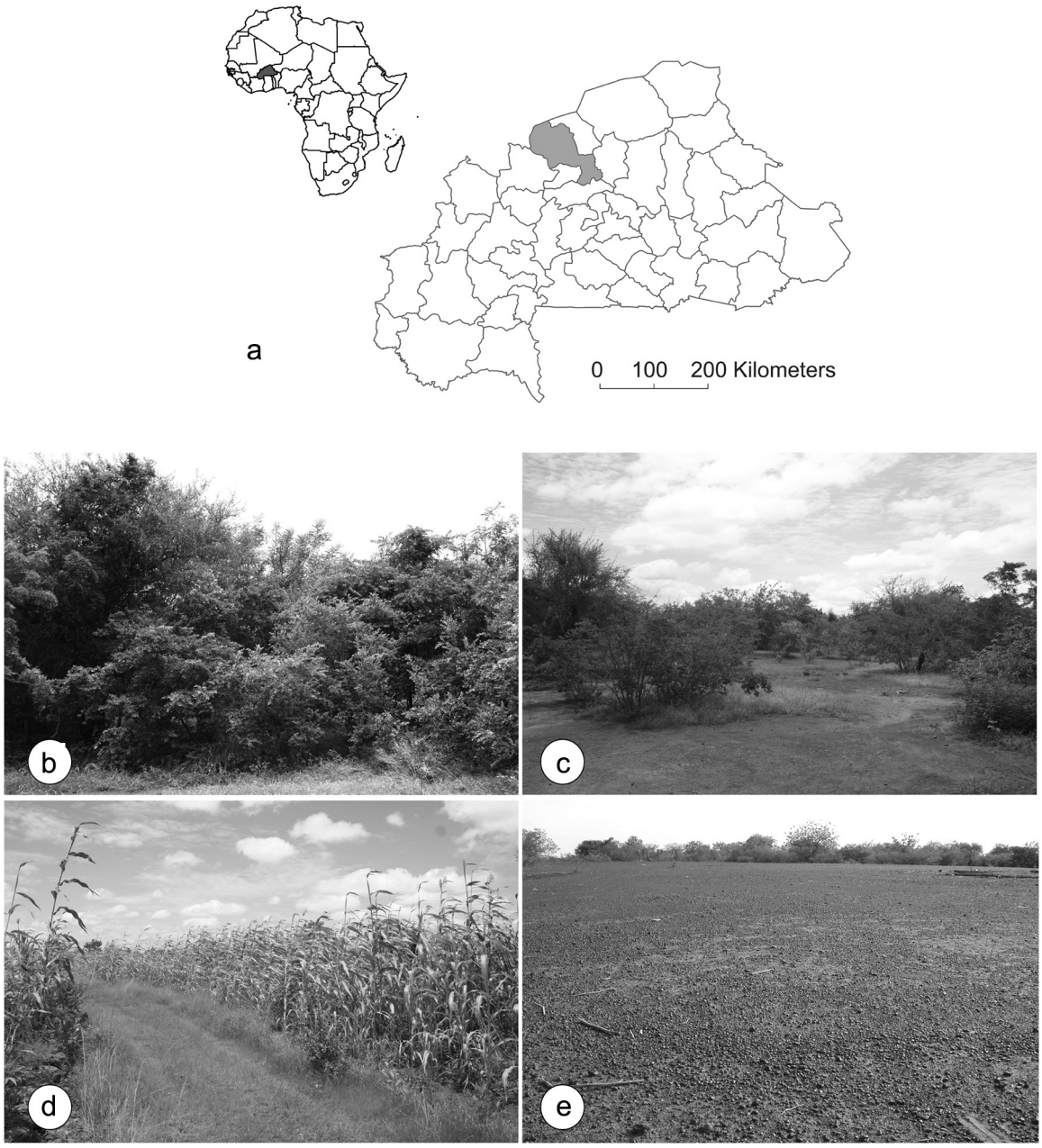

Fig. 1. The geographic location of Burkina Faso in West Africa and of the Yatenga province in the sub-Sahel region of Burkina Faso (a). The study sites are: old Zaï forest (b), young Zaï forest (c), millet field (d), and degraded, barren land (e).