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Dominance of native earthworms in secondary tropical forests derived from slash-and-burn Mayan agricultural practices (Yucatán, Mexico)

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ABSTRACT

In order to assess earthworm communities influenced by successional changes in tropical subdeciduous forest (TSF), we studied several secondary forests developed after annual crops in southern Yucatan (Mexico). All these secondary TSF were derived from slash-and-burn (S&B) Mayan shifting agricultural practices. Accordingly, four repetitions of four stages in the S&B shifting system were selected: currently cultivated annual maize crops, three-year-old fallow, and 20- to 30-year-old and 50-year-old secondary forests. Earthworm communities were characterized according to richness, abundance, and biomass values; some soil-related variables were also determined, both environmental (litter, moisture, and temperature) and physicochemical (texture, Cation exchange capacity-CEC, P, N, C). C and N content and CEC were lower in annual crops than in fallow and forests. Except for soil temperature (slightly lower in forests stages) and clay and sand content (respectively lower and higher in late stages), the other edaphic (pH, P content) and environmental variables (litter and soil moisture content) did not vary among successional stages. Five species of earthworms were found, one exotic (*Dichogaster affinis*) and four native (*Balanteodrilus pearsei, Diplotrema oxcutzcabensis, Mayadrilus calakmulensis*, and an unidentified ocnerodrilid). A higher number of species (4) was found in annual crops, whereas late successional stages contained only two species; conversely, higher values of abundance and biomass were found in 50-year-old forests than in annual maize crops. The native *B. pearsei* dominated all successional stages, with relative values of abundance and biomass over 80% in fallow and forested stages, reaching up to 99% in 50-year-old forests. The single exotic species was limited to annual crops with relatively low abundance and biomass values. We discuss the reasons for the prevalence of the native *B. pearsei* and the absence of exotic species in successional stages, especially regarding the kind of soils characteristic of the Yucatán peninsula, and the persistence of ancient Mayan agricultural practices.

1. Introduction

In tropical ecosystems, the effect of human (anthropogenic) disturbance on earthworm communities is widely recognized (Fragoso et al., 1997, 1999b; González et al., 2006, 2008; Hendrix et al., 2006). Common effects of human disturbance involve the disappearance of some species, invasion by others (generally exotics), and changes in the abundance and biomass of the species that remain (Fragoso et al., 1999b). Commonly, epigeic species are more severely affected, whereas endogeic and anecic species are more resistant to disturbance (Fragoso et al., 1997; Jiménez et al., 1998). Hendrix et al. (2006) and González et al. (2006, 2008) summarized these changes and proposed two complementary models to explain the composition of tropical earthworm communities in terms of the relationship between natives and exotics and the function of the degree of disturbance; in both models, assuming that exotics invade and establish, a severe disturbance generally produces an exotic-dominated community.

Following natural succession, recovery of earthworm communities in severely disturbed tropical forests (e.g., complete elimination of trees) has been studied in abandoned tree plantations (González et al., 1996; Römbke et al., 1999), pastures (Geissen and Guzmán, 2006; Sánchez-de León et al., 2003; Zou and González, 1997), and savanna- derived fallows invaded by exotic plants (Koné et al., 2012). Up to now, any research on earthworms has been conducted during the succession of abandoned annual

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crops (González et al., 2008). In some of these studies, earthworm community changes were described following the use of chronosequences, where it is assumed that all stages were developed from a similar original condition and share similar edaphic, topographic, and environmental conditions (Bautista-Cruz and Del Castillo, 2005; Marín-Spiotta et al., 2008). In all these examples, earthworms were studied in fallows and secondary forests. The latter are recognized as an important tool for the conservation of biodiversity and for C sequestration (Brown and Lugo, 1990), both above and below ground (reviewed in Marín-Spiotta et al., 2008). The slash-and-burn agricultural system (S&B) is a kind of shifting agriculture (Manshard, 1974) practiced by several indigenous societies from tropical Africa, Asia, and South America. Mayan people, currently recognized as a group with a high knowledge of their natural resources and with elaborate agroforestry practices (Gómez-Pompa, 2003), are one of the several indigenous Mexican groups that used this system. In the Yucatán peninsula, the Mayas practiced S&B shifting agriculture for thousands of years and during most of the last century (Eastmond, 1998). This system consisted of annual maize crops grown for 2–3 years on the same land, followed by a resting stage of 20 years; during the resting stage, tropical forest fallows developed through natural succession. After this period of time, fallows were burned and farmers grew maize again, taking advantage of the ash-fertilized soil (Eastmond, 1998). This practice began to change during the last 40 years, after fertilizers became available and enabled Mayan farmers to use their cultivated fields for more than two years (Moya et al., 2003). The change in agricultural practices, coupled with the migration of farmers to cities, permitted the development of older secondary forests.

Although extensive research has been conducted to characterize Yucatán's secondary forests, including ecosystem processes like decomposition, nutrient cycling, C sequestration (Read and Lawrence, 2003a,b), and plant and faunal inventories (Callaghan and Pasos-Enríquez, 2010), few studies exist on belowground processes and biota. In addition, and despite its importance in soil functioning, no earthworm studies have been conducted in the Mayan S&B agricultural system.

The objective of this study was the characterization of earthworm communities in cultivated fields and secondary forests that belong to the Yucatán S&B system. Considering results obtained in other secondary forests of Southern Mexico (Fragoso, 2001), we expected to find more exotic worms and a lower diversity of species in cultivated fields compared to secondary forests. Likewise, we predicted that the number of species in forests should increase with the age of abandonment.

2. Material and methods

2.1. Study site

The study site is located on the mid-Yucatán peninsula, along the southern border of the state of Yucatán, and in the area surrounding the Kaxil Kiuic Biocultural Reserve (20°33′13″N, 89°33′10″W) (Fig. 1). The landscape is characterized by small hills of less than 200 m alternating with low relief zones, developed over karst and molded since the Miocene (24 mya) (Bautista et al., 2005a). The climate is tropical wet (Aw), characterized by an average annual rainfall of 900–1300 mm, with rains falling during May–January and an intense dry season during February–May; average annual temperature varies between 23–28 °C, with a mean of 26 °C. Although the Yucatán peninsula is characterized by little- or undifferentiated soils (Regosols and Cambisols), low-activity clay Lixisols predominate at the study site (Bautista et al., 2005b; INEGI, 2014) and are characterized by subsoil enriched with clays and with a high base status (IUSS, 2014).

2.2. Land use and vegetation

In this region, as on most of the Yucatán Peninsula, the Mayans have managed their lands for thousands of years following slash-and-burn agriculture. In the study area, this practice was

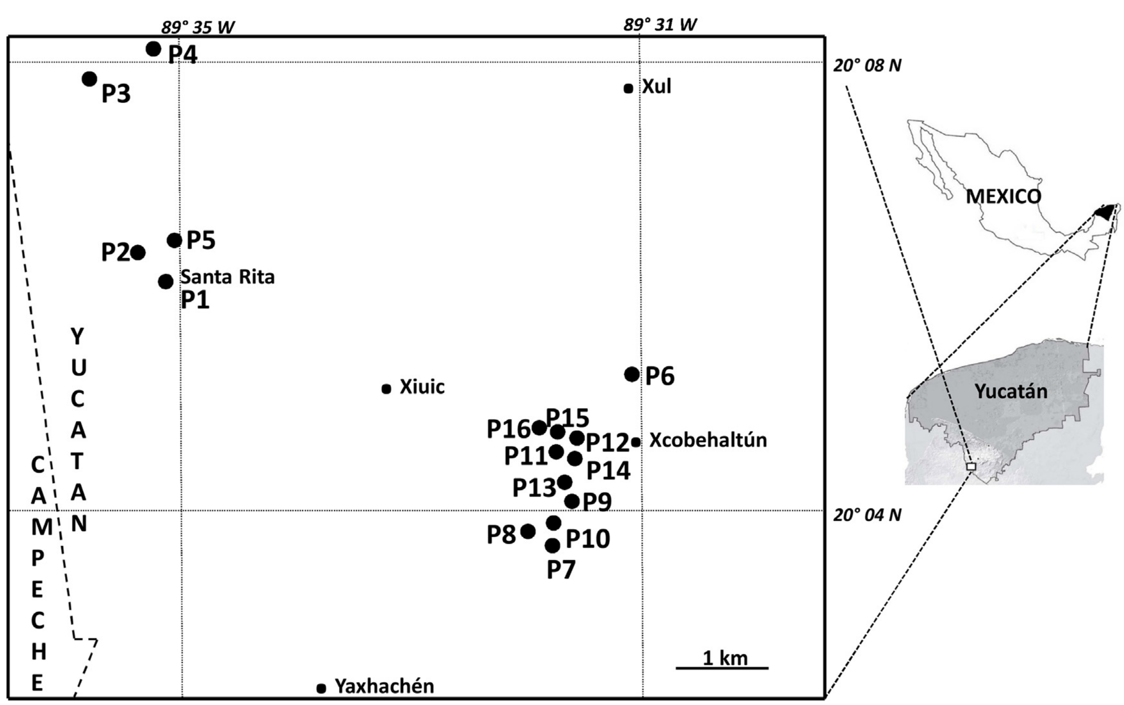

Fig. 1. Geographical localization of crop and successional plots sampled for earthworms in Central Yucatán, Mexico. P13–P16 = plots under maize cultivation; P9–P12 = plots under natural succession after three years; P5–P8 = plots under natural succession after 20–30 years; P1–P4 = plots under natural succession after more than 50 years. See Table 1 for more information on each plot.