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Original article

Abundance of biogenic structures of earthworms and termites in a mango orchard

P. Mora[a,*], C. Seuge[a], J.P. Rossi[b], C. Rouland[a]

[a] Laboratoire d'écophysiologie des invertébrés-UMR 137 Biosol, université Paris-XII, 61, avenue du Général-de-Gaulle, 94010 Créteil cedex, France

[b] Inra-UMR BIOGECO, domaine de l'Hermitage-Pierroton, 69, route d'Arcachon, 33612 Cestas, France

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Abstract

A comparative study of the spatial distributions and the quantity of biogenic structures produced by earthworms and termites (*Odontotermes nilensis* and *Ancistrotermes guineensis*) has been conducted in a mango orchard at Thiès (Senegal).This study showed that surface biogenic structures may represent a large amount of modified soil (up to 536.5 g m^{-2}) which vary depending upon the seasons and the species. Whilst the quantity of casts was independent on the season (178.6 g m^{-2}), *O. nilensis* sheetings fluctuated with the seasons. In addition, we show that the spatial organisation of surface biogenic structures fluctuates with seasons. It displays patches ranging from 5 to 15 m. There is a link between the distribution of earthworm casts and the vegetation. In addition, spatial distribution was also linked to the biology of constructing species. We observed that the *A. guineensis*' filling structures were mainly located under the mango trees during the dry season where the stems and the brushwoods were abundant. It appears that the spatio-temporal distribution of the biogenic structures under study depended upon two main factors: season and vegetation. However, depending upon the biology of the engineer, these two factors influenced the spatial distribution of structures in different ways.

Keywords: Earthworms; Termites; Casts; Sheetings; Biogenic structures; Spatial distribution

1. Introduction

Termites and earthworms are physical ecosystem engineers and play a central role in important ecosystem function such as soil structure dynamics and organic matter cycling [1]. Their activity results into the formation of the so-called biogenic structures. However, at the ecosystem level, the population impact of a given Ecosystem Engineer is partly modulated by its pattern of distribution. Because their populations often display non-random spatial distribution, accounting for that spatial pattern greatly improve our capacity to understand the functional impact of Ecosystem engineers. Although some data are available on the population spatial distribution, little is known on the pattern of the biogenic structure themselves [2]. This work aimed to test for spatial non randomness in the distribution of termite and earthworm deposits at the soil surface and assess the scales at which patterns (if any) occur. We also investigated the seasonal activity of deposit production and examined if the spatial patterns of activity were constant through time

* Corresponding author. Fax: +33 1 45 17 15 05.
E-mail address: mora@univ-paris12.fr (P. Mora).

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2. Materiel and methods

2.1. Site

The study was undertaken in a mango (*Mangifera indica*) orchard at Thiès, Senegal (70 km East of Dakar). The annual rainfall is 600 mm. The wet season normally occurs from June to September The site hosts two types of termites (*Ancistrotermes guineensis, Odontotermes nilensis*) and one type of earthworm (Eudrilidae), all producing surface biogenic structures.

2.2. Biogenic structures

Three types of biogenic structures were present at Thiès:

- earthworm casts which passed through the earthworm's intestine;
- and two types of termite structures. First, sheetings built by workers of *O. nilensis* using soil-impregnated saliva. They were present as thin sheets of earth covering the food supply. Second filling structures built by *A. guineensis*. These were made of saliva-impregnated clay and are located inside the food supply (e.g. stems, brushwood).

2.3. Quantification of biogenic structures

In order to measure the abundance of casts, sheetings and filling structures in different seasons, three surveys were conducted: at the beginning of the dry season (October 1999), at the end of the dry season (May 2000) and during the rain season (September 2000). During each season, three collections were done. For each season, the result corresponds to the average of these three collections.

Two 100 m transects separated from 15 m were studied one under a line of the mango trees, the other between lines of mango trees. Biogenic structures were collected every 5 m along the transect in 1 m^2 squares (block). Thus, 40 blocks were sampled. All collected structures were dried at 105 °C then weighed.

2.4. Study of the spatial distribution

The presence of spatial autocorrelation in the data was assessed using Geary's index on the basis of an Euclidian distance matrix [3]. Pairs of points were taken as neighbours when their separating distance was equal to or lower than a given threshold. In order to explore different spatial scales, three threshold values were examined: 5, 10 and 15 m. We used these distance thresholds because they are multiple of the minimum inter-sample distance (i.e. 5 m.) and we restricted the analyses at scales < 15 m because larger distance lags would have yielded too few data pairs.

3. Results and discussion

3.1. Quantification of biogenic structures

The mass of biological structures was greatest at the end of the dry season (536.5 g m^{-2}) as compared to 206.3 g m^{-2} at the beginning of the dry season and 178.6 g m^{-2} during the wet season (Fig. 1). During

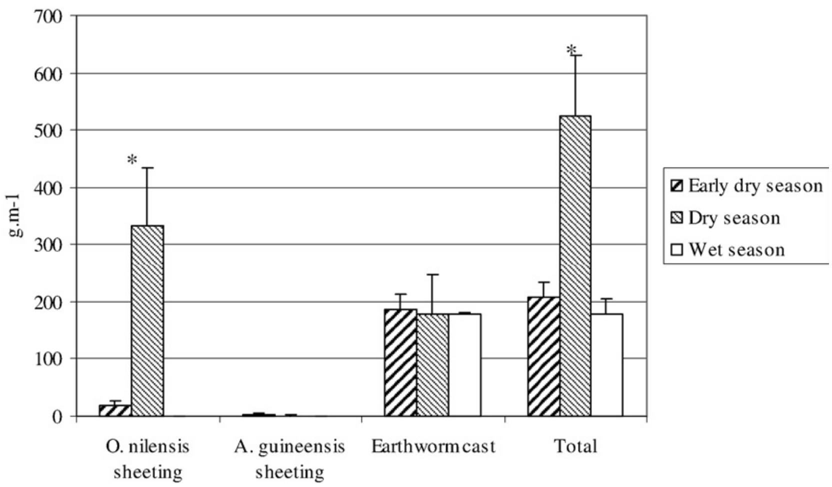

Fig. 1. Mass of biogenic structures collected on the two transects (*: $P > 0.05$).

the early dry season and the wet season biogenic structures were mainly represented by earthworm casts with 90% and 100%, respectively, *O. nilensis* sheetings represented the highest proportion of biogenic structures with 62% during the dry season. The quantities of casts collected in the orchard were similar at each sampling time. In contrast Termite structures varied according to the seasons (Fig. 1) particularly those of *O. nilensis* which were more abundant in the dry season. During the wet season, the drastic reduction in the number of sheetings may have been caused by heavy rain or reduced termite activity as has been shown by Wood [4] and Collins [5].

3.2. Spatial distribution of biogenic structures

The presence of spatial autocorrelation in the distribution of the different biogenic structures was analysed using Geary's autocorrelation test applied at various spatial scales (Table 1). At the beginning of the dry season, there was a significantly autocorrelated spatial structure of earthworm casts at the 5 m scale. At the end of the dry season, earthworm casts and *O. nilensis* sheetings were autocorrelated at 5, 10 and 15 m whereas *A. guineensis* ones were only so at 10 and 15 m. During the rain season, earthworm casts (the only ones to be cropped) showed a significant spatial structure at the 5 m scale.

In the rain season and at the beginning of the dry season, quantities of earthworm casts did not differ between the two transects ($P > 0.05$) whereas, in the dry season, they were more abundant under mango trees ($P < 0.001$) (Table 2). This seasonal variability in the spatial distribution of casts might be linked to differences in the vertical distribution of earthworms as a result of a drying of the surface soil [3,4]. During the dry season, casts were more common under mango trees, where temperature is lower and soil moisture higher. If the quantity and quality of the litter might influence the density and biomass of the earthworms [6], it appears, in our study, that the abundance of earthworms is rather linked to the shading than to the type of the litter since the repartition of casts is homogeneous during the rain season, when sun exposure decreases, the herbaceous cover appears and the soil is less dry. On the contrary, *O. nilensis* sheetings were more abundant between the lines of mango trees at the beginning ($P < 0.05$) as well as during the dry season ($P < 0.05$). *A. guineensis* sheetings, were more common under lines of mango trees during the dry season. For termites, it is the nutrition mode and the distribution of the vegetation which influences the distribution of sheetings. *O. nilensis*, which feed preferably on grass, are located in mango tree-free zones whereas *A. guineensis*, which consume the inside of dead stems, are more common under mango trees.

To conclude, it appears that the spatio-temporal distribution of the biogenic structures under study depends upon two main factors: season and vegetation. However, depending upon the biology of the engineer,

Table 1
Geary's autocorrelation index (C) and associated probabilities

		Wet season		Early dry season		Dry season	
Distances (m)		*C* observed	*P*	*C* observed	*P*	*C* observed	*P*
5	Earthworm	0.7200	0.0384*	0.6760	0.0202*	0.5320	0.0015*
5	*O. nilensis*	ND	ND	0.8790	0.2221	0.7071	0.0320*
5	*A. guineensis*	ND	ND	0.8620	0.1913	1.0530	0.6304
10	Earthworm	0.8197	0.0573	0.8970	0.1845	0.6302	0.0006*
10	*O. nilensis*	ND	ND	0.9850	0.4477	0.7848	0.0298*
10	*A. guineensis*	ND	ND	0.9260	0.2581	0.8108	0.0489*
15	Earthworm	0.8695	0.0649	0.9710	0.3664	0.7623	0.0029*
15	*O. nilensis*	ND	ND	1.0200	0.5736	0.8398	0.0315*
15	*A. guineensis*	ND	ND	0.9920	0.4623	0.7812	0.0055*

*: significant, ND: not tested.

Table 2
Amount of the biogenic structures on the transect 1 (between the lines of mango trees) and transect 2 (under mango trees) according to the seasons

	Early dry season		Dry season		Wet season	
	Transect 1	Transect 2	Transect 1	Transect 2	Transect 1	Transect 2
Earthworm casts	163.7 (± 26.4)	207.8 (± 27.9)	4.4 (± 2.6)*	370.7 (± 81.7)*	149.01.2 (± 21.9)	207.9 (± 29.0)
O. nilensis sheetings	23.2 (± 6.3)*	12.9 (± 8.3)*	511.9 (± 118.3)*	162.0 (± 58.5)*	0	0
A. guineensis sheetings	4.2 (± 2.6)	0.8 (± 0.6)	0*	12.3 (± 5.4)*	0	0

*: significant $P < 0.05$; ±: standard deviation.

these two factors influence the spatial distribution of structures in different ways.

Considering the role of these engineers with respect to the functioning of the soil, Decaens and Rossi [7] indicated that the patchy distribution of biogenic structures concurs to the spatial heterogeneity of resources in the ecosystem. Spatial heterogeneity leads to a diversity of micro habitats which facilitate the coexistence of numerous species, and thus allows a better sharing of resources [8,9]. Consequently, this spatial heterogeneity of resources results in a decrease in the competitive pressure and an increase in biodiversity [10].

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