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Short communication

Decreasing fallow duration in tropical slash-and-burn agriculture alters soil macroinvertebrate diversity: A case study in southern French Guiana

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ABSTRACT

In the humid tropics, slash-and-burn cultivation causes changes in the composition of soil biota communities. We investigated the soil macroinvertebrates (body length ≥ 2 mm) in five sites, two at Maripasoula, an Aluku village along the Maroni river (French Guiana), with short fallow (≈ 8 years), and the other three at Elahe, a Wayana village along the same river, with long fallow (≈ 25 years). We report observed species richness, the corresponding estimates by bootstrap and its associated standard deviation. At both sites the cultivation led to impoverished communities. The overall observed species richness i.e. γ diversity was ca. twice as larger in Elahe than in Maripasoula. The landscape at Maripasoula was dominated by highly disturbed areas with the direct consequence that local species richness relied on colonization from an impoverished regional species pool. On the contrary, in Elahe, crops formed small patches scattered across a landscape essentially constituted of rich undisturbed or slightly disturbed forests hence higher γ diversity. The proportion of rare species ranged from 44% to 54%. We found 6 indicator species amongst which 5 were associated to the old secondary forest in Elahe and one, the earthworm *Pontoscolex corethrurus* was associated to crop fields in Maripasoula (short fallow system). Results are discussed in a landscape context in terms of conservation and management of soil macrofaunal diversity in agro-ecosystems.

1. Introduction

Soil invertebrates are key mediators of soil functions in agro-ecosystems. They substantially affect many important processes that take place below-ground like comminution and incorporation of litter into the soil, building and maintenance of structural porosity and aggregation in soils through burrowing, casting and nesting activities and control of microbial activities (Lavelle et al., 2006 and references therein). Invertebrates therefore contribute to the ecosystem services provided by soils and for this reason, they are increasingly considered as a resource to be managed and protected. Amongst soil biota, macrofauna (animals with body length ≥ 2 mm (Anderson and Ingram, 1993)) are dramatically affected by cultural practices and various authors have discussed the utility of managing their populations to improve the sustainability of soil fertility especially in countries or regions where farmers have limited access to mineral fertilizers (Matson et al., 1997; Brussaard et al., 2007; Rossi and Blanchart, 2005).

In the tropics, the traditional slash-and-burn system (shifting cultivation) consists of cutting the forest, burning the trees and settling familial agriculture for several years. Long fallow periods follow the cropping period and the regeneration of the vegetation combined with the recovery of soil fauna contribute to restore soil organic content and structure which in turn affect soil water and nutrient dynamics. These processes require a long fallow period (Grandisson, 1997). Unfortunately, the changes from a traditional to a permanent agriculture that accompany a population demographic growth generally lead to a decrease in the fallow duration (Fleury, 1998). Ultimately, the cropping period is followed by the establishment of permanent pastures used for cattle ranching instead of fallows. This is the case for huge surfaces of land in Brazil where these practices have a strong detrimental impact upon soil physical and chemical properties of the soil as well as diversity and activity of soil biota with dramatic impacts on the sustainability of agriculture (Mathieu et al., 2005).

In French Guiana, the demographic pressure threatens the long-lasting equilibrium between slash-and-burn agriculture and

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nature conservation, due to the progressive disappearance of shifting cultivation. In southern Guiana near the Suriname border, the duration of fallow in the slash-and-burn system has decreased from 15 to 7–8 years in the last 30 years (Topoliantz et al., 2006). The traditional shifting cultivation is still practised in that region by Amerindian communities and the duration of the fallow ranges from 15 to more than 100 years (Fleury, 1998). The aim of this study was to assess the impact of slash-and-burn cultivation upon the diversity of soil macrofauna in two agricultural systems that differed by the duration of the fallow period. We investigated a traditional shifting cultivation system in a small Wayana Amerindian village and an accelerated rotation cycle in a larger Aluku village where the demographic pressure is strong. Crops are mostly manioc (*Manihot esculenta* Cranz) i.e. cassava in both villages and the studied systems are good examples of traditional shifting cultivation (Wayana Amerindians) and change to permanent agriculture due to demographic pressure (Aluku village) (Grandisson, 1997).

2. Materials and methods

2.1. Sites

The present survey was carried out in southern French Guiana near the border between France and Suriname along the Maroni river. We investigated soil macrofauna diversity in agricultural fields of two communities, Wayanas (indians) and Alukus (maroons, of ancient African lineage). Wayana Amerindians are still using the traditional slash-and-burn system where short cropping periods (ca. 2–3 years) alternate with long fallow periods ($\approx$25 years). The fields (thereafter referred to as "abattis") are settled by cutting and burning forest plots and are planted with manioc which constitutes the basic food. Soils are not tilled and manioc cuttings (from previous crops) are planted after resprouting. Neither Wayanas nor Alukus use pesticides, herbicides or fertilizers. Alukus are using a similar system with the difference that cultivation does not exceed 1 year and fallows are shorter ($\approx$8 years on average). The length of the cultivation period depends on the soil fertility and the spontaneous regrowth of vegetation (Topoliantz et al., 2006).

2.1.1. Amerindian village of Elahe (long fallow)

We sampled soil macrofauna in the Wayana (Amerindian) village of Elahe. This small village is situated on the Tampoc river which is a subsidiary of Maroni (3°26′N, 53°59′W). Three contrasted situations were investigated. A field that had been cut, burnt and cultivated by an Indian family 3 years before this study (EA). This field was located next to a secondary forest and was itself a secondary forest before its cultivation. It was sampled in July 1999. We sampled an old secondary forest (EF) located nearby EA (ca. 100 m). The old secondary forest showed woody species typical of mature forests (e.g. *Astrocaryum sciophilum* (Miq.) Pulle, and *Dicorynia guianensis* Amsh. (Poncy et al., 2001) which indicated that it had been left untouched for at least 100 years. The plot located in the secondary forest was resampled in May 2000 after it had been cut and burnt in December 1999 for cultivation (EB).

2.1.2. Aluku village of Maripasoula (short fallow)

The second site is located along the Maroni river (3°39′N, 54°2′W) near the village of Maripasoula, ca. 25 km downstream of the first study site. Maripasoula is a large village (pop 1200 in 1999) mostly inhabited by Aluku people. The increase in population density during the last 3 decades led to a decrease in the surface of cultivable land and the subsequent decrease of fallow duration (Fleury, 1998). We sampled a 1-year-old abattis (MA) at the end of the crop period. It had been opened by an Aluku family by cutting and burning an 8-year-old woody fallow referred to as MF. MF was characterized by pioneer woody species such as *Cecropia latiloba* Miq. and *Inga capitata* Desv. Both MA and MF plots were sampled in July 1999. The MF plot was intended to be burnt in December 1999 and we planned to resample it in May 2000 but unfortunately the Aluku family did not burn it as expected.

The mean annual temperature is 26 ° C and the mean annual rainfall is 2000 mm. There is a main dry season from September to December and a shorter one between March and April. Sampled soils are sandy Oxisols with pH of 5 and 4.7 on average in Maripasoula and Elahe, respectively (Topoliantz et al., 2006). The average total C content was 24.6, 22.5, 25.8, 19.1 and 18.6 g kg^{-1} while the total N content was 1.65, 1.48, 1.78, 1.39 and 1.35 g kg^{-1} the in plots MA, MF, EA, EF and EB respectively (data from Table 1 in Topoliantz et al., 2006). Other physico-chemical features of the soils at the study sites are available in Topoliantz et al. (2006).

2.2. Sampling

We used the tropical soil biology and fertility (TSBF) procedure (Anderson and Ingram, 1993). Sampling units consisted of 25 cm × 25 cm × 30 cm deep soil monoliths. As recommended in the TSBF procedure, we used 10 monoliths per transect and carried out 3 transects per plot (i.e. 30 samples per plots). The distance seperating monoliths was 5 m and transects were 20 m distant from each other. The litter was collected at each sampling point and a trench was then dug to a depth of 30 cm around the 25 cm × 25 cm area to get a soil monolith. Macroinvertebrates from soil and litter were hand-sorted and preserved in 4% formalin solution. Invertebrates were later counted and identified in the laboratory. We grouped specimens in morphospecies and identifed most of them with the help of different taxonomists. We excluded larvae from the statistical analyses because they were partially redundant with adults found in the same samples. Overall, our estimation of species richness is therefore underestimated.

Table 1
Soil macrofaunal diversity in southern French Guiana.

Sites	Acronym	*n*	Date	Mean density (ind. m^{-2})	S_{obs}	S_{corr}	Singleton	Unique
Elahe (traditional slash-and-burn)								
Secondary forest ($\geq$100 years)	EF	30	July 1999	1781.9 (289.8)	121 (8.3)	151.2	56 (46.3%)	76 (62.8%)
Abbatis (3 years)	EA	30	July 1999	541.3 (92)	45 (4.2)	56.8	20 (44.4%)	29 (64.4%)
Recently burnt forest	EB	30	May 2000	224.5 (60.8)	22 (2.1)	27	11 (50%)	12 (54.5%)
Maripasoula								
Woody fallow (8 years)	MF	30	May 2000	645.3 (76.5)	41 (3.7)	51.6	21 (51.2%)	26 (63.4%)
Abbatis (1 year)	MA	30	July 1999	1109.9 (271.2)	54 (4.6)	69.4	29 (53.7%)	39 (72.2%)

EF and EB correspond to the same plot sampled in 1999 and 2000 and was burnt in between.
S_{obs}: observed species richness; S_{corr}: bias-corrected species richness; singleton: species with at most one individual; unique: species encountered in only one sample. Percentages for singletons and uniques are computed with reference to the total species richness in the site. Standard errors for mean density and S_{obs} are indicated in parentheses.