International Journal of Biology; Vol. 14, No. 2; 2022
ISSN 1916-9671 E-ISSN 1916-968X
Published by Canadian Center of Science and Education

Dynamics of the Soil Macrofauna Influenced by Improved Fallows With *Andropogon gayanus* in Hydromorphic Soil at Bondoukuy (Western Burkina Faso)

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Received: August 15, 2022 Accepted: September 19, 2022 Online Published: October 13, 2022

doi:10.5539/ijb.v14n2p46 URL: https://doi.org/10.5539/ijb.v14n2p46

Abstract

In western Burkina Faso, in the Bondoukuy cotton zone, on silty-clay soils, the rarefaction of the perennial grass *Andropogon gayanus*, characteristic of old fallows, is noticed. This grass is known to restore the structural stability of the soil rather quickly, due to a stimulation of biological activity, while the storage of organic matter in the soil remains slow. The biological aspect has been prospected through the study of invertebrate populations in 3 sites, all of which present 4 situations: 30-year-old fallows, 5-year-old natural fallows, and 5-year-old *A. gayanu***s** improved fallows and 10-year-old permanent crop fields.

The results show that invertebrate populations are very diverse. A total of 172 morphotypes were recorded, including 115 species of insects (24 species of social insects), 31 species of Chelicerata, 8 Myriapoda and 5 earthworms. In the fields, earthworms and Diplopoda populations are less important than in old fallows. On the other hand, the fields have the highest species diversity, 50 species on average. The most abundant population is found in natural fallows, with a density of 835 individuals/m²and 43 species represented. Improved fallows with *A. gayanus* have a lower stand density and species richness than natural fallows (less than 50% and 43 species). In old fallows, stands are stable with a richness limited to 30 species, while earthworms and myriapods have significantly reduced densities.

Soil invertebrate communities thus recover rapidly after crop abandonment and are fully active during the most intense phase of recovery in the first 5 years. Trees do not appear to have a significant effect on the conservation and stimulation of macrofauna except for Coleoptera.

Our results show that the cropping system adopted in the region allows for minimal conservation of soil macrofauna and that the macrofauna recovers rapidly during the fallow. Improved fallows with *A. gayanus* differ from natural fallows in limiting Termite density, while old fallows and fields are of comparable density.

Keywords: *Andropogon gayanus***,** improved fallows, hydromorphic soil, macrofauna, invertebrates

1. Introduction

The western cotton zone of Burkina Faso is subject to an increased fertilized cropping system. The economic stakes are such that the movement of migrants to the region causes strong demographic pressure (Tersiguel, 1994). Shrub and tree fallows frequently used to restore the fertility of cultivated soils and fight against weeds are scarce (Serpantié, 2003). This poses a problem with the function of restoring the fertility of the fallow soil both ecologically (erosion, decline in biological activity) and in terms of production (cultivation skills, fodder and forest production)

One of the favourable effects of the fallowing is the stimulation of the biological activity, particularly that of invertebrates "ecosystem engineers" (Mathieu, 2004; Lavelle *et al.*, 1998) with increased availability of organic residues in the fallow. However, it takes at least 10 years for these effects to be noticeable. The cultivation causes a reduction in the specific diversity and abundance of soil macrofauna which accompanies the physicochemical degradation of the soil (Rouland *et al.*, 1993; Lavelle and Rouland, 1999).

In the western region of Burkina Faso, the reintroduction of perennial grass, *A. gayanus*, has been proposed for the improvement of fallow (Serpantié *et al.*, 1997). This grass is known to restore the structural stability of the soil fairly quickly, due to a stimulation of biological activity, while the storage of organic matter in the soil remains slow.

The objective of this work is to identify the effect of the improved fallow land with *A. gayanus* on the dynamics of macro-invertebrates, through the analysis of the abundance, variety and activity of their populations.

Two hypotheses were formulated to answer our objectives.

Hypothesis 1: the presence of the perennial grass *A. gayanus*, helps the rapid proliferation of soil macrofauna.

Hypothesis 2: tree stumps are refuges conducive to the development of soil macrofauna.

This study will allow us to evaluate the effect of the improved fallow land with *A. gayanus* on the faunal composition of soils and propose possible ways to conserve the diversity and abundance of macrofauna.

The findings of this comprehensive study are likely to shed light on the role of improved *A. gayanus* fallow in the dynamics of soil macrofauna in a hydromorphic soil under a semi-arid tropical climate and provide decision-makers with a robust management plan for efficient land use and soil conservation.

2. Environmental and Geological Context

Soil macrofauna samples were collected in Bondoukuy, situated on the northern border of the South Sudanian climatic zone, known as the cotton farming zone (Figure 1). Bondoukuy lies between 11°51'N and 3°45'W with an elevation above sea level of 360 m. The average annual rainfall of the study area is 850 mm with the maximum rainfall occurring in August. The daily maximum temperature ranges between 31 and 39 °C with an average annual potential evapotranspiration of about 1900 mm. The natural vegetation cover in the area is predominantly composed of open woody savannah, whereas the dominant grass biome is *A. gayanus*, *Pennisetum pedicellatum* and *Loudetia togoensis* (Fournier *et al.*, 2001).

The geology of the study area is composed of sedimentary rocks made of sandstones and schist of the Palaeozoic and Infra Cambrian ages (Ouédraogo, 1998). The sandstone bedrock in the plateau is composed of quartz, whereas in the glacis (iron duricrust) it is of schist-dolomite (Ladmirant and Legrand, 1969). Different soil types are encountered along the local pedotoposequence unit. At the plateau, the pedological cover is predominantly composed of sandy loam (i.e., ferric lixisols), whilst at the glacis, soils are loamy (i.e., luvisols; Kissou, 1994; Ouattara *et al.*, 2006).

For centuries, human presence in Bondoukuy has markedly affected the local ecosystem. Subsistence (cereals) and cash crop (cotton) farming are the main activities practiced in the area. Although the most fertile soils are regularly ploughed, less fertile ones are increasingly subjected to a short period of fallowing (~5 years). The annual ploughing, based on cotton–maize rotations, usually leads to the collapse of soil structure, erosion and reduction of soil organic matter content. The second most common activity in the study area is extensive animal husbandry. As a result, the area is overgrazed and exposed to high demands for aerial biomass (tree bark, firewood and perennials stems) by the local rural communities.

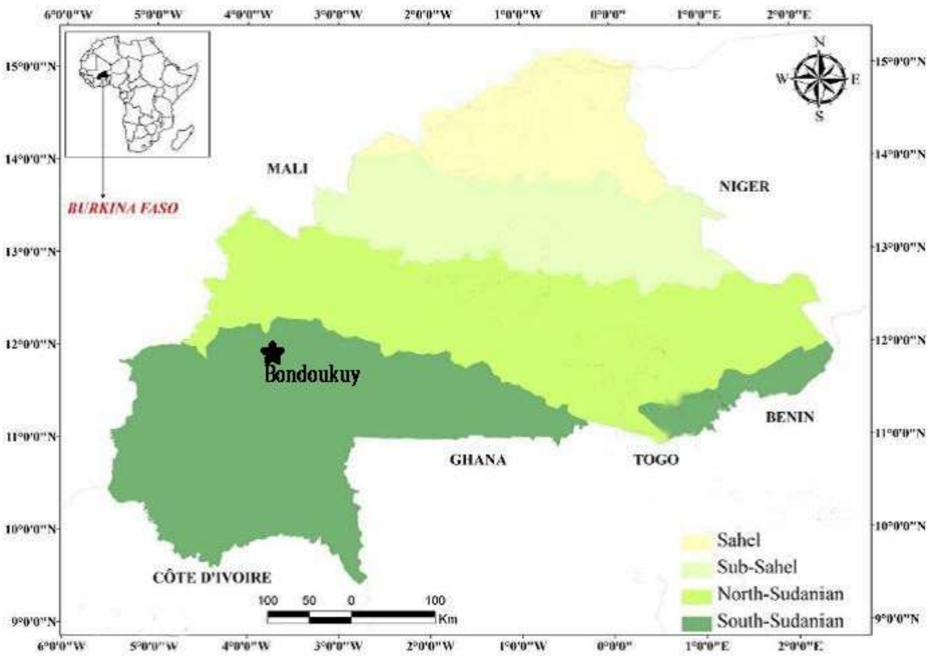

Figure 1. Phytogeographical map of Burkina Faso, showing the study area (Modified from Guinko, 1984)

3. Materials and Methods

3.1 Choice of Plots

Four situations in 3 different sites were identified in the real environment from a prospection and a survey of farmers: a 30-year old fallow (OF), a short 5 years old fallow (YF), an improved 5 years old fallow with *Andropogon gayanus* (IFA) and a permanent cultivated field of 10 years old (PC). Which makes a total of 12 selected plots.

3.2 Soil Macrofauna Sampling

The soil macrofauna sampling method used is a modified version of that recommended by the TSBF (Tropical Soil Biology and Fertility) program (Anderson & Ingram, 1993). Sampling was carried out during the rainy season from late July to mid-August. Ten soil samples were taken from each plot: 5 samples under trees and 5 samples outside vegetation. The way of taking under trees is explained by the fact that in the fields of permanent culture, there are no grasses spared, except trees. Samples are taken every 5 m along a straight line (figure 2) in each plot.

The soil macrofauna samples were realized under trees and in open areas in the 12 plots. Samples are taken with a metal square of 25 cm side at a 30 cm depth. A flat iron spade is used to separate the block of soil obtained into 3 layers of 10 cm which are then isolated to be sorted. Manual sorting is done by crumbling the soil to collect, using metal tongs, all invertebrates visible to the naked eye. They are then stored and listed in vials containing 4% formalin to fix them before storing them in 70% alcohol. In the laboratory, using a binocular magnifying glass, invertebrates are determined down to order or family and classified into taxonomic units or morphotypes.

3.3 Vegetation Description and Soil Physico-Chemical Study

The vegetation of the selected sites was characterized by phytosociological surveys according to the Braun-Blanquet method (1932) improved by Delassus (2015).

The soil physicochemical study was carried out using composite soil samples were taken at 2 depths: 0-10 cm and 10-20 cm. To take into account intra-plot variability, 3 samples were taken per plot. The following Physico-chemical analyzes were carried out: particle size analysis by sedimentation, after the destruction of the organic matter, by the pipette method on an automatic particle sizer with 5 fractions according to the Atterberg scale (Clays: 0-2 µm, fine silts: 2-20 µm, Coarse silts: 20-50 µm, Fine sands: 50-200 µm and Coarse sands: 200 µm-2 mm) (Cirad, 2017); Carbon (C) analysis using the modified Walkley-Black method (CEAE, 2003), Nitrogen (N) assay using the Kjedahl method; assays of total P by an attack with nitric acid (Bouyer, 1958) and of assimilable P by the modified Olsen method (Dabin, 1963); Ca, Mg and K are measured by ICP spectrometry (Cirad, 2017); the CEC is obtained by measuring ammonium by continuous flow colorimetry (Cirad, 2017); the measurement of exchangeable bases is carried out by percolation (Cirad, 2017) and the measurements of pH-H2O and pH-KCl are carried out using an automated titration chain with a sampler (Cirad, 2017). All these analyses were carried out in the soil science laboratory at INERA-Kamboinsé (Burkina Faso).

3.4 Data Analysis

The data collected were subjected to an analysis of variance (PROC ANOVA) with 3 factors (sites, treatments and absence or presence of trees) and to a simultaneous test of comparison of means by Scheffé (1959) considered to be the most reliable test sensitive to small differences between means (Scherrer, 1989). All tests were performed with an alpha level of 5%. These analyses were performed using the Stat View software (SAS, 2020).

4. Results

4.1 Soil Physicochemical Characteristics

ANOVA performed on the averages of the soil data of the three sites, does not show any significant differences concerning the texture and the other chemical characteristics of the soil in the 4 situations (tables 1 a, b and c). Except for available P in sites I and II and total phosphorus in site III. In general, site I is richer than sites II and III, concerning all the parameters analyzed.

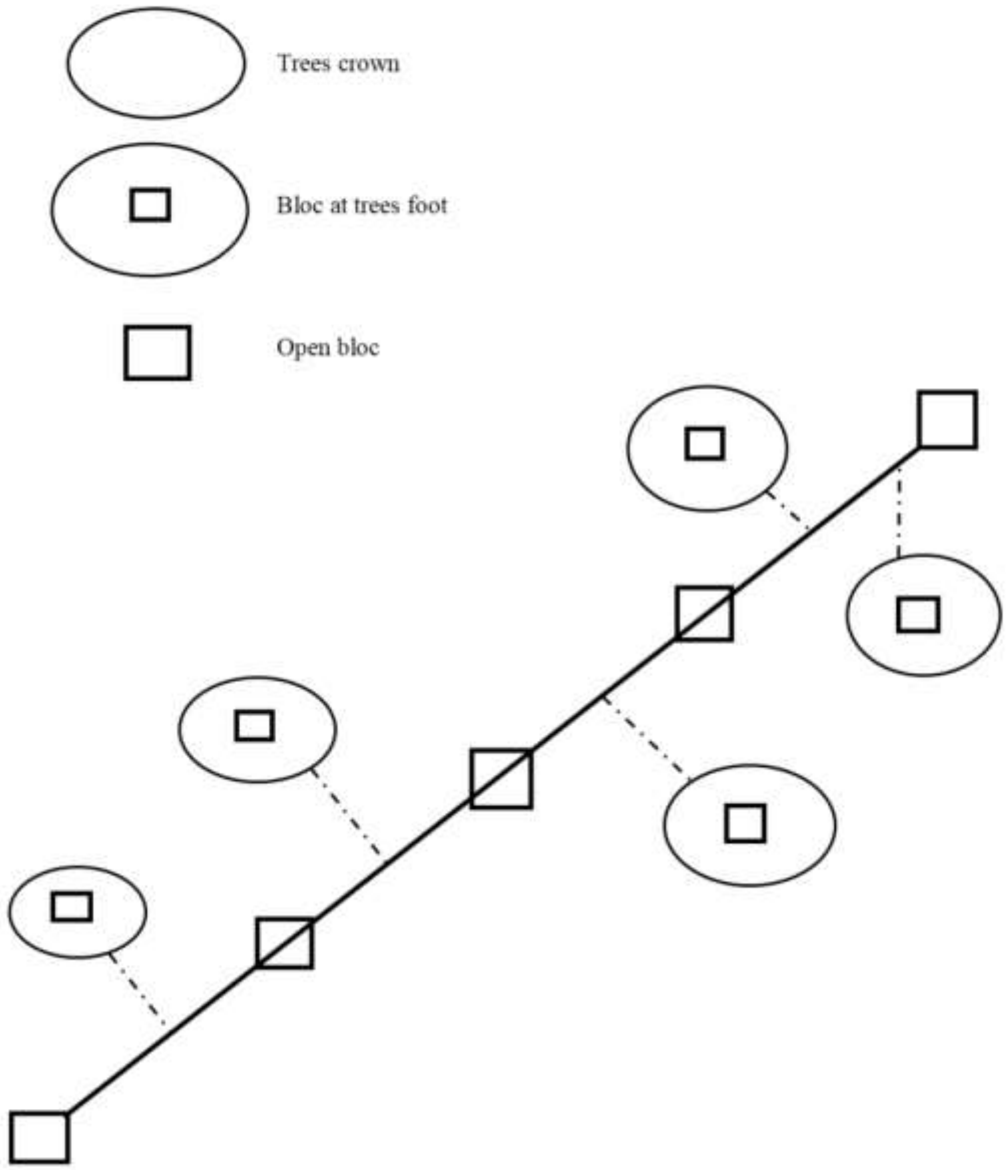

Figure 2. Soil macrofauna sampling device

Table 1a. Soil physicochemical characteristics of the different situations of the site I. Numbers with the same letter per line are not significantly different (n=3, p<0.005)

	site I							
	PC		YF		IFA		OF	
Parameters	0-10	20 cm	0-10	20 cm	0-10	20 cm	0-10	20 cm
	$10,5^{a}$	21^{b}	11^{a}	21^{b}	11^{a}	$21,9^{b}$	$10,8^{a}$	22^{b}
Clays (%)	(0.23)	(0.55)	(0.21)	(0.51)	(0.22)	(0.51)	(0.24)	(0.55)
	$9,5^{a}$	10^{a}	$8,5^{a}$	$10,2^{a}$	8^{a}	$9,2^{a}$	$7,7^{a}$	$9,4^{a}$
Fine silts (%)	(0.77)	(0.78)	(0.78)	(0.41)	(0.79)	(0.4)	(0.75)	(0.4)
	16^{a}	15^{a}	$15,5^{a}$	15^{a}	16^{a}	$15,1^{a}$	$16,1^{a}$	$15,3^{a}$
Coarse silts (%)	(0.27)	(0.14)	(0.3)	(0.14)	(0.27)	(0.14)	(0.28)	(0.14)
	52^{a}	41^{b}	52^{a}	42^{b}	53^{a}	$42,8^{b}$	$52,6^{a}$	$42,4^{a}$
Fine sands (%)	(0.42)	(0.77)	(0.47)	(0.76)	(0.46)	(0.77)	(0.48)	(0.77)
	12^{a}	13^{a}	13^{a}	$11,8^{a}$	12^{a}	11^{a}	$12,8^{a}$	$10,9^{a}$
Coarse sands (%)	(0.52)	(0.97)	(0.51)	(0.96)	(0.51)	(0.97)	(0.52)	(0.96)
	$0,55^{a}$	$0,61^{a}$	$0,56^{a}$	$0,62^{a}$	$0,55^{a}$	$0,63^{a}$	$0,58^{a}$	$0,64^{a}$
C (%)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
	$0,51^{a}$	$0,56^{a}$	$0,52^{a}$	$0,57^{a}$	$0,53^{a}$	$0,56^{a}$	$0,54^{a}$	$0,58^{a}$
N (‰)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
	$10,8^{a}$	$10,9^{a}$	$10,8^{a}$	$10,9^{a}$	$10,4^{a}$	$11,3^{a}$	$10,8^{a}$	11^{a}
C/N	(0.2)	(0.18)	(0.2)	(0.19)	(0.2)	(0.19)	(0.2)	(0.18)
	120^{a}	131^{a}	120^{a}	$132,8^{a}$	$121,1^{a}$	$133,4^{a}$	$123,7^{a}$	$134,3^{a}$
Total-P (ppm)	(1.7)	(1.39)	(1.7)	(1.4)	(1.7)	(1.3)	(1.7)	(1.4)
	$9,5^{a}$	$2,9^{b}$	$9,6^{a}$	3^{b}	$9,8^{a}$	$3,1^{b}$	$10,1^{a}$	$3,9^{b}$
Olsen-P (ppm)	(0.26)	(0.45)	(0.26)	(0.5)	(0.26)	(0.5)	(0.25)	(0.5)
	$2,5^{a}$	$3,7^{a}$	$2,6^{a}$	$3,8^{a}$	$2,8^{a}$	4^{a}	$2,9^{a}$	$4,1^{a}$
Ca (meq/100g)	(0.18)	(0.18)	(0.18)	(0.18)	(0.18)	(0.17)	(0.18)	(0.18)
	$0,7^{a}$	$1,1^{a}$	$0,8^{a}$	$1,1^{a}$	$0,8^{a}$	$1,2^{a}$	$0,9^{a}$	$1,4^{a}$
Mg (meq/100g)	(0.08)	(0.17)	(0.17)	(0.18)	(0.08)	(0.18)	(0.07)	(0.17)
	$0,22^{a}$	$0,15^{a}$	$0,23^{a}$	$0,16^{a}$	$0,24^{a}$	$0,17^{a}$	$0,25^{a}$	$0,18^{a}$
Exchangeable K	(0.01)	(0.013)	(0.012)	(0.013)	(0.01)	(0.012)	(0.01)	(0.012)
	$5,2^{a}$	$5,5^{a}$	$5,4^{a}$	6^{a}	$5,5^{a}$	$6,1^{a}$	6^{a}	7^{a}
Total-K (meq/100g)	(0.34)	(0.62)	(0.34)	(0.62)	(0.33)	(0.61)	(0.34)	(0.62)
	$3,7^{a}$	$4,9^{a}$	$3,8^{a}$	5^{a}	$3,9^{a}$	$5,1^{a}$	$4,1^{a}$	$5,9^{a}$
CEC	(0.17)	(0.45)	(0.17)	(0.45)	(0.16)	(0.44)	(0.16)	(0.45)
	$5,9^{a}$	$5,8^{a}$	6^{a}	6^{a}	6^{a}	$6,5^{a}$	$6,6^{a}$	$6,7^{a}$
pH H_2O	(0.32)	(0.42)	(0.32)	(0.42)	(0.32)	(0.41)	(0.31)	(0.42)
	$5,3^{a}$	5^{a}	$5,5^{a}$	$5,1^{a}$	$5,6^{a}$	$5,2^{a}$	$5,7^{a}$	$5,3^{a}$
pH KCl	(0.17)	(0.12)	(0.17)	(0.12)	(0.16)	(0.11)	(0.17)	(0.12)

Table 1 b. Soil physicochemical characteristics of the different situations of the site II. Numbers with the same letter per line are not significantly different (n=3, p<0.005)

	site II							
	PC		YF		IFA		OF	
Parameters	0-10	20 cm	0-10	20 cm	0-10	20 cm	0-10	20 cm
Clays (%)	$10,5^{a}$ (0.1)	$10,1^{a}$ (0.12)	$10,5^{a}$ (0.1)	$10,2^{a}$ (0.13)	$10,5^{a}$ (0.1)	$10,3^{a}$ (0.12)	$10,7^{a}$ (0.1)	$10,4^{a}$ (0.12)
Fine silts (%)	$9,5^{a}$ (1.09)	8^{a} (0.32)	$8,5^{a}$ (1.07)	$8,8^{a}$ (0.31)	$7,2^{a}$ (1.05)	$8,4^{a}$ (0.32)	$7,3^{a}$ (1.06)	$8,4^{a}$ (0.33)
Coarse silts (%)	15^{a} (1.6)	16^{a} (0.47)	15^{a} (1.5)	$14,9^{a}$ (0.48)	18^{a} (1.3)	$15,8^{a}$ (0.46)	$17,5^{a}$ (1.5)	$15,5^{a}$ (0.47)
Fine sands (%)	46^{a} (0.32)	47^{a} (0.65)	46^{a} (0.33)	$45,6^{a}$ (0.66)	$45,4^{a}$ (0.31)	$45,7^{a}$ (0.65)	$45,5^{a}$ (0.33)	$45,8^{a}$ (0.64)
Coarse sands (%)	19^{a} (0.51)	$18,9^{a}$ (0.66)	20^{a} (0.52)	$20,5^{a}$ (0.65)	$18,9^{a}$ (0.53)	$19,8^{a}$ (0.65)	19^{a} (0.5)	$19,9^{a}$ (0.65)
C (%)	$0,54^{a}$ (0.008)	$0,42^{a}$ (0.005)	$0,53^{a}$ (0.008)	$0,41^{a}$ (0.005)	$0,54^{a}$ (0.004)	$0,41^{a}$ (0.01)	$0,55^{a}$ (0.007)	$0,42^{a}$ (0.01)
N (‰)	$0,53^{a}$ (0.005)	$0,44^{a}$ (0.008)	$0,52^{a}$ (0.005)	$0,43^{a}$ (0.008)	$0,52^{a}$ (0.007)	$0,44^{a}$ (0.01)	$0,53^{a}$ (0.005)	$0,45^{a}$ (0.006)
C/N	$10,2^{a}$ (0.09)	$9,5^{a}$ (0.096)	$10,2^{a}$ (0.1)	$9,5^{a}$ (0.09)	$10,4^{a}$ (0.1)	$9,3^{a}$ (0.1)	$10,3^{a}$ (0.09)	$9,4^{a}$ (0.09)
Total-P (ppm)	75^{a} (1.5)	80^{a} (0.6)	77^{a} (1.6)	81^{a} (0.5)	78^{a} (1.5)	81^{a} (0.6)	$78,6^{a}$ (1.58)	$81,4^{a}$ (0.7)
Olsen-P (ppm)	8^{a} (0.45)	$2,8^{b}$ (0.17)	7^{a} (0.46)	$3,2^{b}$ (0.17)	$7,1^{a}$ (0.45)	3^{b} (0.17)	$7,2^{a}$ (0.46)	$3,1^{b}$ (0.27)
Ca (meq/100g)	$2,1^{a}$ (0.17)	$2,2^{a}$ (0.21)	$2,3^{a}$ (0.17)	$2,6^{a}$ (0.22)	$2,4^{a}$ (0.17)	$2,5^{a}$ (0.22)	$2,5^{a}$ (0.17)	$2,7^{a}$ (0.22)
Mg (meq/100g)	$0,6^{a}$ (0.08)	$0,7^{a}$ (0.08)	$0,5^{a}$ (0.08)	$0,8^{a}$ (0.08)	$0,6^{a}$ (0.08)	$0,6^{a}$ (0.08)	$0,7^{a}$ (0.08)	$0,7^{a}$ (0.07)
Exchangeable K	$0,16^{a}$ (0.017)	$0,12^{a}$ (0.005)	$0,17^{a}$ (0.017)	$0,13^{a}$ (0.01)	$0,18^{a}$ (0.02)	$0,12^{a}$ (0.01)	$0,2^{a}$ (0.02)	$0,13^{a}$ (0.01)
Total K (meq/100g)	$7,1^{a}$ (0.12)	$6,8^{a}$ (0.33)	$7,2^{a}$ (0.13)	$7,5^{a}$ (0.34)	$7,3^{a}$ (0.13)	$7,4^{a}$ (0.34)	$7,4^{a}$ (0.12)	$7,5^{a}$ (0.35)
CEC	$3,3^{a}$ (0.13)	3^{a} (0.32)	$3,4^{a}$ (0.12)	$3,6^{a}$ (0.32)	$3,5^{a}$ (0.13)	$3,6^{a}$ (0.32)	$3,6^{a}$ (0.12)	$3,7^{a}$ (0.33)
pH H_2O	7^{a} (0.22)	$6,7^{a}$ (0.12)	$6,5^{a}$ (0.21)	$6,8^{a}$ (0.13)	$6,6^{a}$ (0.21)	$6,8^{a}$ (0.13)	$6,7^{a}$ (0.22)	7^{a} (0.14)
pH KCl	6^{a} (0.22)	$5,6^{a}$ (0.08)	$5,5^{a}$ (0.22)	$5,7^{a}$ (0.08)	$5,6^{a}$ (0.22)	$5,7^{a}$ (0.08)	$5,8^{a}$ (0.22)	$5,8^{a}$ (0.09)

Table 1c. Soil physicochemical characteristics of the different situations of the site III. Numbers with the same letter per line are not significantly different (n=3, p<0.005)

	site III							
	PC		YF		IFA		OF	
Parameters	0-10	20 cm	0-10	20 cm	0-10	20 cm	0-10	20 cm
	6,5^{a}	8,5^{a}	6,5^{a}	6,5^{a}	7,2^{a}	6,6^{a}	6,7a	7,1^{a}
Clays (%)	(0.33)	(0.9)	(0.33)	(0.9)	(0.33)	(0.9)	(0.33)	(0.9)
	6,5^{a}	5,4^{a}	6^{a}	6^{a}	6,5^{a}	6,1^{a}	6,7^{a}	6,7^{a}
Fine silts (%)	(0.29)	(0.53)	(0.3)	(0.53)	(0.28)	(0.53)	(0.3)	(0.53)
	14^{a}	14,5^{a}	15,1^{a}	13^{a}	15,2^{a}	13,1^{a}	15,3^{a}	14,8^{a}
Coarse silts (%)	(0.6)	(0.9)	(0.61)	(0.9)	(0.61)	(0.9)	(0.6)	(0.9)
	37^{a}	36,6^{a}	38,9^{a}	38^{a}	39,1^{a}	38^{a}	39,3^{a}	39,3^{a}
Fine sands (%)	(1.06)	(1.1)	(1.06)	(1.1)	(1.06)	(1.1)	(1.06)	(1.1)
	36^{a}	35^{a}	33,5^{a}	36,5^{a}	32^{a}	36,2^{a}	32^{a}	32,1^{a}
Coarse sands (%)	(1.88)	(2)	(1.88)	(2)	(1.88)	(2)	(1.88)	(2)
	0,44^{a}	0,33^{a}	0,42^{a}	0,31^{a}	0,43^{a}	0,32^{a}	0,42^{a}	0,32^{a}
C (%)	(0.01)	(0.008)	(0.01)	(0.008)	(0.01)	(0.008)	(0.01)	(0.008)
	0,46^{a}	0,36^{a}	0,44^{a}	0,35^{a}	0,45^{a}	0,35^{a}	0,46^{a}	0,36^{a}
N (‰)	(0.01)	(0.006)	(0.01)	(0.005)	(0.01)	(0.005)	(0.01)	(0.006)
	9,5^{a}	9,2^{a}	9,5^{a}	9^{a}	9,6^{a}	9^{a}	9,2^{a}	9,1^{a}
C/N	(0.17)	(0.1)	(0.17)	(0.09)	(0.17)	(0.09)	(0.17)	(0.1)
	100^{a}	85,5^{b}	101^{a}	85^{b}	102^{a}	85,6^{b}	102,4^{a}	85,8^{b}
Total P (ppm)	(1.07)	(0.34)	(1.07)	(0.34)	(1.08)	(0.34)	(1.08)	(0.34)
	4,1^{a}	3,5^{a}	4^{a}	3,6^{a}	4,1^{a}	3,7^{a}	4,2^{a}	3,8^{a}
Olsen P (ppm)	(0.08)	(0.13)	(0.08)	(0.12)	(0.08)	(0.13)	(0.08)	(0.12)
	1,6^{a}	1,5^{a}	1,3^{a}	1,2^{a}	1,4^{a}	1,3^{a}	1,5^{a}	1,4^{a}
Ca (meq/100g)	(0.13)	(0.13)	(0.13)	(0.13)	(0.13)	(0.13)	(0.13)	(0.13)
	0,65^{a}	0,6^{a}	0,45^{a}	0,4^{a}	0,5^{a}	0,5^{a}	0,6^{a}	0,6^{a}
Mg (meq/100g)	(0.1)	(0.1)	(0.09)	(0.09)	(0.1)	(0.1)	(0.1)	(0.1)
	0,17^{a}	0,85^{b}	0,16^{a}	0,8^{b}	0,15^{a}	0,9^{b}	0,17^{a}	0,9^{b}
Exchangeable K	(0.01)	(0.05)	(0.01)	(0.05)	(0.01)	(0.05)	(0.01)	(0.05)
	5,5^{a}	5,6^{a}	5,3^{a}	5,5^{a}	5,4^{a}	5,5^{a}	5,5^{a}	5,6^{a}
Total K (meq/100g)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)
	2,6^{a}	2,6^{a}	2,4^{a}	2,2^{a}	2,3^{a}	2,1^{a}	2,5^{a}	2,2^{a}
CEC	(0.13)	(0.22)	(0.13)	(0.22)	(0.13)	(0.22)	(0.13)	(0.22)
	6,5^{a}	6^{a}	6,5^{a}	6^{a}	6,5^{a}	6^{a}	7^{a}	6,5^{a}
pH H_2O	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)	(0.25)
	5,1^{a}	5^{a}	5,8^{a}	5,6^{a}	5,7^{a}	5^{a}	5,8^{a}	5,1^{a}
pH KCl	(0.33)	(0.29)	(0.33)	(0.29)	(0.33)	(0.29)	(0.33)	(0.29)

PC: permanent cultivated field; YF: young fallow; IFA: improved fallow with *Andropogon gayanus*; OF: old fallow.

4.2 Floristic Characteristics

With exception of permanent fields, the floristic records obtained characterize the vegetation of fallow lands (table 2). However, there are species characteristic of old fallows such as *A. gayanus* in herbaceous plants and *Pterocarpus erinaceus* in woody plants. This flora remains fairly uniform and less diversified compared to other vegetal formations in the region. In the 3 sites, old fallows, despite their advanced resting stage compared to young fallows, do not present a significant floristic richness.

Table 2. floristic characteristics of the sites studied (most represented species)

		Site I		
	PC	YF	IFA	OF
Vegetation	*Sorghum bicolor*	*Rottboelia exaltata,* *Vittellaria paradoxa*	*Acacia polyacantha,* *Acacia sieberiana,* *Pennisetum polystachyon,* *Desmodium velutinum*	*Andropogon gayanus,* *Piliostigma thonningii,* *Vitellaria paradoxa,* *Anogeissus leiocarpus*
		Site II		
	PC	YF	IFA	OF
Vegetation	*Gossypium spp* *Pennisetum typho ïdes*	*Andropogon pseudapricus,* *Tephrosia pedicellata*	*Vitellaria paradoxa,* *Pterocarpus erinaceus,* *Prosopis africana*	*Andropogon gayanus,* *Pennisetum polystachyon,* *Andropogon pseudapricus,* *Tephrosia pedicellata,* *Terminalia avicenno ïdes,* *Vitellaria paradoxa*
		Site III		
	PC	YF	IFA	OF
Vegetation	*Zea* mays	*Andropogon pseudapricus,* *Borreria stachydea,* *Anogeissus leiocarpus,* *Terminalia avicenno ïdes,* *Vitellaria paradoxa*	*Vitellaria paradoxa,* *Pterocarpus erinaceus,* *Terminalia avicenno ïdes,* *Prosopis africana*	*Andropogon gayanus,* *Borreria stachydea,* *Paspalum orbicurae,* *Bulbostylis filamentosa,* *Vitellaria paradoxa*

PC: permanent cultivated field; YF: young fallow; IFA: improved fallow with *Andropogon gayanus*; OF: old fallow.

4.3 Soil Macrofauna Specific Diversity

One hundred seventy-two (172) different morphotypes were founded (table 3). We notice a dominance of arthropods, with 56 species of Coleoptera and 24 species of social insects on 115 species of insects and 31 species of Chelicerae. The specific richness was determined for each microsite (under trees and in open areas), each site and each situation (treatment).

Table 3. Description of different morphotypes identified

Description	Number
Beetles: -15 larvae -38 adults -3 pupae	56
Arachnids: -25 spiders -3 mites -1 white round larva	29
Ants	17
Diptera	10
Heteroptera	9
Termites	7
Thysanurans	5
Hymenoptera	2
Earthworms	5
Iules	4
Lepidoptera	3
Centipedes	2
Chilopodae	2
Homoptera	2
Orthoptera	2
indeterminate larvae	2
Pseudoscorpion	1
geophile	1
Scorpio	1
antlion	1
Dermaptera	1
Embiopter	1
Isopod	1

4.4 Population Density

There are on average more individuals in sites I and II, with respectively 595 and 492 individuals/m ²than in site III with only 232 individuals/m ²(figure 3)

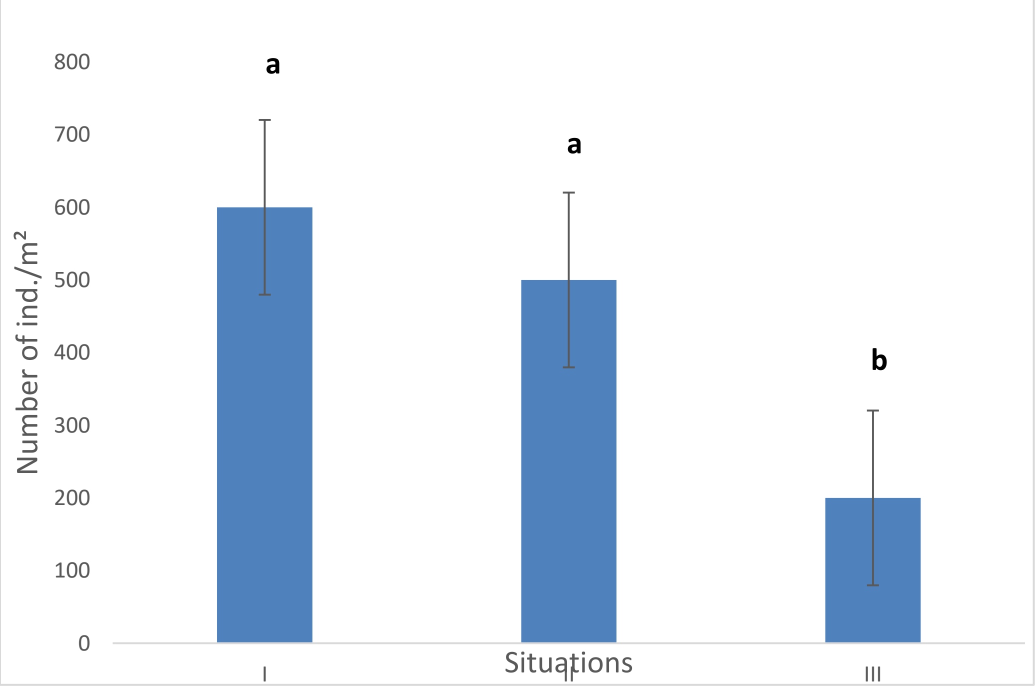

Figure 3. Density of invertebrates in the studied sites. Histograms with the same letter are not significantly different at the 5 % level

4.4.1 Population Density According to the Different Groups

The different taxonomic groups are distributed in the same way. Termites dominate with a density three times higher than that of earthworms in sites I and II (300 termites for 200 earthworms) and twice as much in site III (100 termites for 50 earthworms) (figure 4). The densities of each group of invertebrates follow the gradient of fertility.

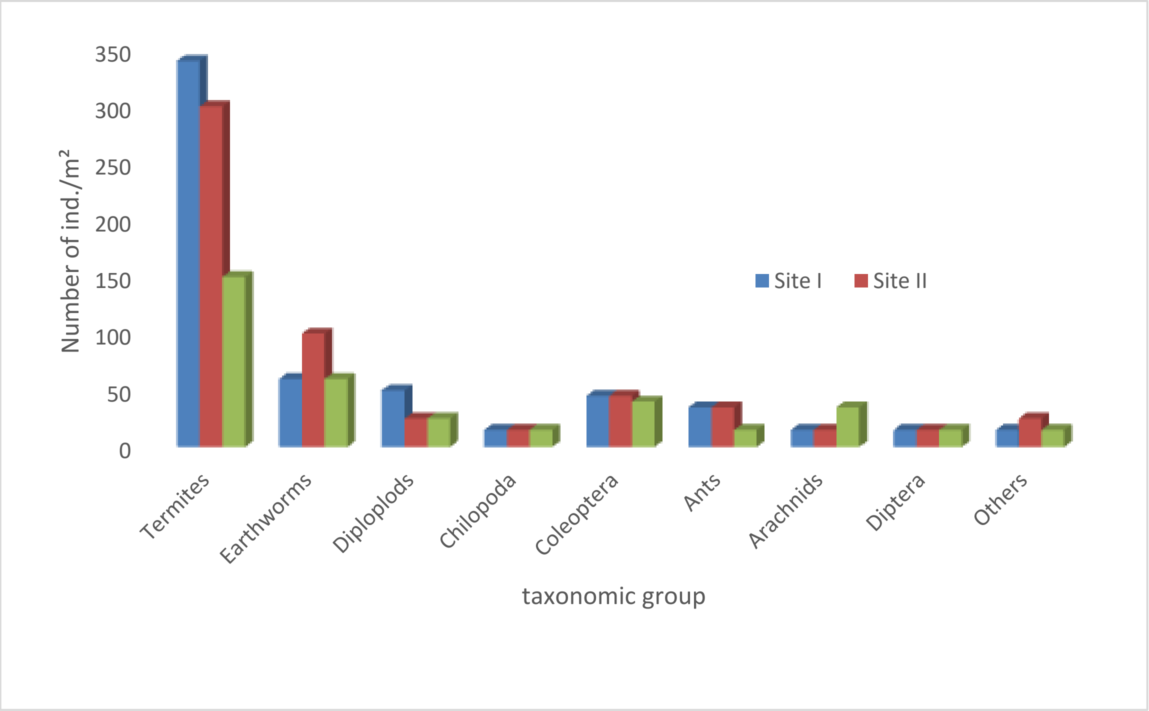

Figure 4. Distribution of population densities according to the different taxonomic groups in the sites

Senapati *et al.* 1996 and Decaens *et al.* 1996 defined the index which gives an idea of the quality of the soil which corresponds to the ratio of earthworms/termites. Table 4 gives the indices of the soil quality for the different sites. The index is generally lower in the fields and higher in the old fallows

Table 4. Average soil quality index of the different sites

	Site I	Site II	Site III
OF	0.04	0.13	3
YF	0.096	0.66	0.10
IFA	0.90	0.48	0.39
PC	0.028	0.013	0.15

PC: permanent cultivated field; YF: young fallow; IFA: improved fallow with *Andropogon gayanus*; OF: old fallow.

4.4.2 Effects of Site, Treatment and Proximity to Trees

The analysis of variance carried out on the densities of the various groups of invertebrates shows that the site and the treatment factors have significant to very highly significant effects (table 5).

Table 5. Results of the 3 factors variance analysis of macroinvertebrate densities (p = 0.05) (1 = site factor; 2 = treatment factor; 3 = tree factor)

	1	2	3	1*2	1*3	2*3	1*2*3
Termites	0.0016**	0.0002**	0.52 ns	0.028*	0.99 ns	0.002**	0.07 ns
Earthworms	0.045*	0***	0.12 ns	0.0026**	0.033**	0.003	0.17 ns
Diplopods	0***	0***	0.15 ns	0***	0.00001***	0.85 ns	0.006**
Chilopoda	0.021*	0.00001***	0.28 ns	0.01*	0.88 ns	0.11 ns	0.009**
Coleoptera	0.0018**	0.00005***	0***	0.11 ns	0.55 ns	0.31 ns	0.103 ns

ns: not significant; * : significant ; **: very significant; ***: very highly significant

The results of the analysis of variance on the average of macroinvertebrate densities per site are presented in tables 6 a, b and c

Table 6 a. Analysis of variance on the means of density of macroinvertebrates according to the site. Values with the same letter per line are not significantly different at the 5% level

	Site I	Site II	Site III
Termites	281.93^{a} (43.4)	326.07^{a} (39.48)	94.69^{b} (50.7)
Earthworms	89.71^{a} (13.11)	66.06^{ab} (13.11)	53.84^{b} (19.32)
Diplopods	21.51^{b} (9.36)	58.84^{a} (10.55)	20.65^{b} (9.36)
Chilopods	9.95^{ab} (11.17)	15.92^{a} (9.36)	7.13^{b} (9.36)
Coleoptera	50.70^{a} (12.45)	50.70^{a} (10.55)	28.07^{b} (11.17)
Ants	18.21^{a} (29.09)	23.27^{a} (22.38)	15.92^{a} (11.17)
Arachnids	4.14^{a} (6.09)	7.66^{a} (7.13)	3.24^{a} (6.09)
Diptera	4.61^{a} (7.13)	9.36^{a} (9.95)	2.80^{a} (6.60)
Others	11.17^{a} (10.55)	7.66^{a} (11.17)	6.08^{a} (6.08)
Total density	491.93^{a} (19.82)	595.54^{a} (16.67)	232.42^{a} (27.06)

Between the various treatments, young fallows with an average total density of 835 individuals/m ^{2}contain twice as much fauna as permanently cultivated fields (446 ind./m ^{2}) and improved fallows of *A. gayanus* (449 ind./m ^{2}) and up to four times more than old fallows (196 ind./m ^{2}) (figure 5 and table 6 b).

The density of Termites, Earthworms, Diplopods and Chilopods are identical for the young fallow and improved fallows with *A. gayanus* because they contain the highest densities of each of these taxonomic groups. Similarly, we notice that these are the permanently cultivated fields that contain the most Coleoptera, with 72 individuals/m ^{2} against 48 in the young fallows, 31 in the improved fallows with *A. gayanus* and 28 in the old fallows (figure 5).

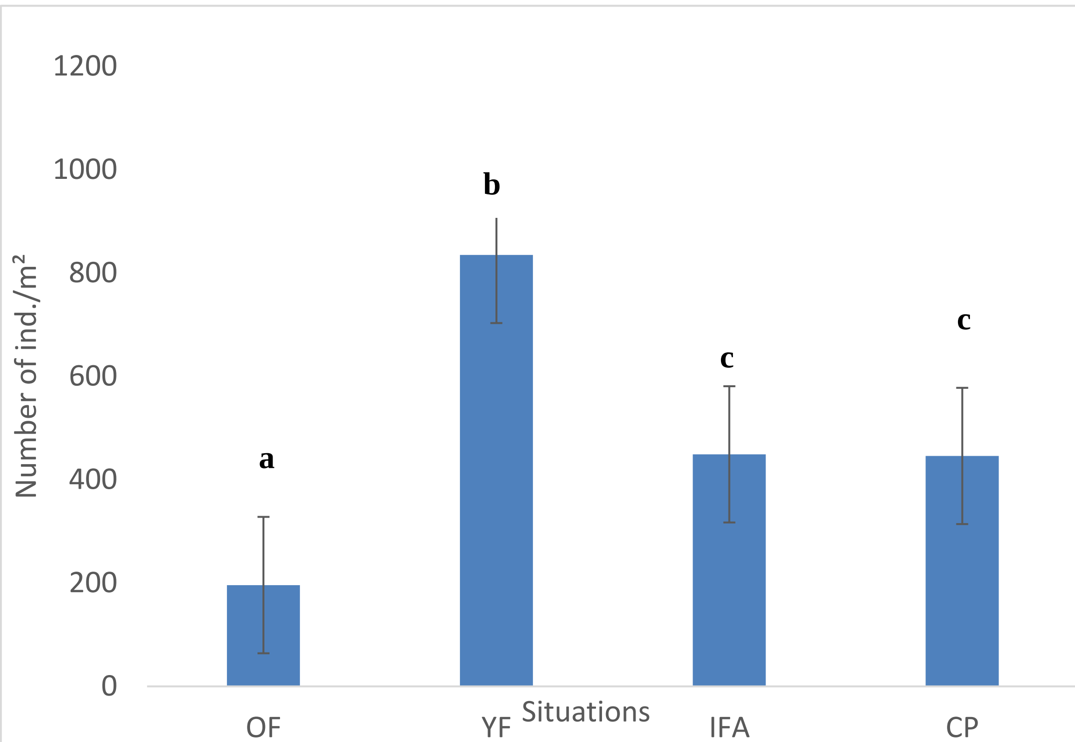

Figure 5. Distribution of population densities according to treatments. PC: permanent cultivated field; YF: young fallow; IFA: improved fallow with *Andropogon gayanus*; OF: old fallow. Histograms with the same letter are not significantly different at the 5 % level

Table 6b. Results of variance analyses on population densities according to the treatment. Values with the same letter per row are not significantly different at the 5% level

	OF	PC	YF	IFA
Termites	82.65^{c} (34.60)	288.8^{ab} (35.77)	501.75^{a} (58.84)	140.36^{bc} (53.84)
Earthworm	31.22^{b} (14.49)	15.2^{c} (16.67)	171.98^{a} (17.43)	176.36^{a} (13.11)
Diplopods	21.51^{b} (9.36)	11.8^{c} (11.80)	52.25^{a} (9.36)	52.25^{a} (8.78)
Chilopods	4.14^{b} (5.58)	4.61^{b} (7.13)	20.65^{a} (12.45)	16.67^{a} (13.79)
Coleoptera	28.06^{c} (7.13)	71.93^{a} (14.49)	47.7^{b} (9.95)	31.22^{bc} (13.11)
Ants	12.45^{a} (19)	25.13^{a} (21.06)	24.19^{a} (17.43)	16.67^{a} (22.38)
Arachnids	4.14^{a} (6.6)	4.14^{a} (4.61)	7.13^{a} (8.22)	4.14^{a} (6.60)
Diptera	5.09^{a} (7.13)	8.78^{a} (11.80)	4.14^{a} (5.09)	5.09^{a} (6.09)
Others	7.66^{a} (7.66)	8.20^{a} (7.11)	5.58^{a} (7.13)	6.60^{a} (9.36)
Total density	196.92^{a} (14.49)	438.66^{a} (23.27)	835.37^{a} (21.51)	449.36^{a} (25.13)

PC: permanent cultivated field; YF: young fallow; IFA: improved fallow with *Andropogon gayanus*; OF: old fallow.

The presence of trees significantly affects the distribution of Coleoptera regardless of the treatment or the site, with on average three times more individuals per m ²at the foot of trees (Table 6 c). For the other groups, no significant difference appears although the total density is higher in all groups except Arachnids.

Table 6c. Results of variance analyses on population densities according to the presence of trees. Values with the same letter per row are not significantly different at the 5% level

	Trees Foot	Open area
Termites	226.17^{a} (44.83)	185.43^{a} (43.44)
Earthworms	78.21^{a} (14.49)	60.58^{a} (16.67)
Diplopods	34.60^{a} (9.36)	28.07^{a} (9.95)
Chilopods	11.80^{a} (7.66)	9.36^{a} (11.80)
Coleoptera	64.19^{a} (9.95)	26.08^{b} (12.45)
Ants	26.08^{a} (23.27)	13.11^{a} (19)
Arachnids	4.14^{a} (5.58)	5.09^{a} (7.66)
Diptera	7.66^{a} (9.95)	3.68^{a} (4.61)
Others	9.36^{a} (10.55)	7.13^{a} (8.22)
Total density	462.21^{a} (19.82)	338.53^{a} (21.51)

The interaction between site and treatment factors is significant for the measurement of the density of Termites, Earthworms, Diplopods and Chilopods. The young fallow in the site I contained significantly more individuals (Termites, Chilopods and Diplopods) than all other treatments, which is easily understandable given the high density of termites (1998 individuals/m ²) (table 7).

Table 7. Results of the test comparing the means of densities according to the site/treatment interaction. Values with the same letter per row are not significantly different at the 5% level

	Site I				Site II				Site III			
	OF	YF	IFA	PC	OF	YF	IFA	PC	OF	YF	IFA	PC
Termites	147^{bc}	1998^{a}	97.27^{bc}	342^{b}	185.4^{b}	275.1^{b}	226.2^{b}	513.8^{b}	12.45^{bc}	226.1^{b}	126.6^{bc}	136.8^{bc}
earthworm	15.2^{d}	159.4^{ab}	255.7^{a}	15.2^{d}	40.77^{cd}	350.5^{a}	215.3^{ab}	11.2^{d}	44.83^{cd}	84.95^{bc}	94.69^{bc}	19.82^{d}
Diploplods	16.67^{de}	176.3^{a}	94.69^{b}	28.07^{cde}	44.83^{cd}	26.08^{cde}	23.27^{cde}	4.61^{f}	11.17^{e}	24.19^{cde}	53.84^{c}	8.78^{e}
Chilopods	5.09^{b}	49.18^{a}	16.7^{b}	7.13^{b}	6.6^{b}	20.65^{b}	13.11^{b}	2.37^{b}	1.14^{b}	5.09^{b}	20.65^{b}	4.61^{b}

PC: permanent cultivated field; YF: young fallow; IFA: improved fallow with *Andropogon gayanus*; OF: old fallow.

The interaction between these factors does not affect the Beetle populations. In this group, the aggregate distribution (at trees foot) is not influenced by the different sites. The effect of the interaction between sites and the presence of trees is very significant within the Earthworm and Diplopods populations (table 7). For earthworms, all distributions are homogeneous, with an average of 64 individuals per m^2, except for those at trees foot on the site II (110 individuals/m^2) and in the open area on the site III (37 individuals/m^2) where the averages are significantly different. The "tree presence" effect plays a role according to the land management method in the case of earthworm and termite populations. Finally, the three factors combined significantly influence the distribution of Diplopoda and Chilopoda.

4.5 Macrofauna Vertical Distribution

Regardless of the site studied, the vertical distribution of the macrofauna is the same: the first 10 cm contains more animals with an average of 60% of the total density. The litter and the 20-30 cm layer contain fewer individuals (8 and 12% respectively). The intermediate level is the 10-20 cm layer with 20%. However, there are some exceptions in the permanent cultivated field of the site II and the improved fallow with *A. gayanus* in the open area of the site III where the 10-20 cm layer contains more individuals (respectively around 40 and 60%) (table 8).

Table 8. Soil macrofauna vertical distribution (%)

				Site I				
	Under trees				Open area			
	Litter	10 cm	20 cm	30 cm	Litter	10 cm	20 cm	30 cm
OF	10%	58%	22%	10%	5%	70%	18%	7%
PC	8%	20%	32%	40%	5%	65%	20%	10%
YF	5%	70%	21%	4%	5%	80%	10%	5%
IFA	10%	70%	10%	10%	5%	80%	10%	5%
				Site II				
	Under trees				Open area			
	Litter	10 cm	20 cm	30 cm	Litter	10 cm	20 cm	30 cm
OF	8%	60%	10%	22%	10%	65%	15%	10%
PC	2%	38%	35%	25%	1%	45%	40%	14%
YF	12%	70%	10%	8%	10%	65%	17%	8%
IFA	30%	50%	10%	10%	5%	60%	30%	5%
				Site III				
	Under trees				Open area			
	Litter	10 cm	20 cm	30 cm	Litter	10 cm	20 cm	30 cm
OF	10%	65%	15%	10%	1%	60%	38%	1%
PC	1%	70%	19%	10%	1%	65%	24%	10%
YF	18%	72%	5%	5%	1%	90%	5%	4%
IFA	16%	39%	35%	10%	5%	30%	60%	5%

PC: permanent cultivated field; YF: young fallow; IFA: improved fallow with *Andropogon gayanus*; OF: old fallow.

5. Discussion

The sites studied have a high faunal diversity with 172 morphotypes sampled. Our sample is comparable to that of Mathieu (2004) in the forests and pastures of Central Amazonia where he obtained 156 morphotypes. On the scale of the 3 sites we have less than 100 different species, this number decreases further at the plot scale. On average, there are 30 different species in the old fallow, 42 in the young fallow, 31 in the improved fallow with *A. gayanus*, and 50 in the field. These results are surprising given that cultivation generally decreases species diversity, but understandable because the fields are the richest in Coleoptera. Trees are refuge areas for beetles, especially in fields and young fallow land, but the population density is not higher there. The study area is thus characterized by a fairly high diversity of soil macroinvertebrate populations. The soil fertility can explain the differences observed. Thus, there is a decreasing distribution along the fertility gradient (site I: 595 individuals/m^2; site II: 492 individuals/m^2 and site III: 232 individuals/m^2). This is very noticeable for termites, earthworms and beetles. In general, permanently cultivated fields and old fallow lands are the least populated, whereas regenerating environments, symbolized by young fallow lands and improved fallow with *A. gayanus* have more abundant populations. Ayuke *et al* (2009) also noted the same in their study. The hydromorphic nature of the soil may also explain these differences observed. A humid soil is favorable for the burial of macrofauna populations. This humidity, associated with plant debris, contributes to improving the structure of the soil. Because loose and well-aerated soil favor the exploration of deep layers. But beyond a certain depth, the absence of debris makes the soil structure very compact and difficult to explore by the macrofauna. As Szyszko-Podgórska *et al.* (2018) showed in their study, which corroborates our observations.

On the other hand, the fact that high densities of macrofauna are found in the 0-10 cm soil layer can be explained by the important presence of roots at this level of the soil, defined as the biologically active zone for plants. This is because plant debris consisting of leaves and roots are buried at this depth. It is therefore a rich zone for plants and soil macrofauna. Beyond 10 cm the distribution of macrofauna is less important because the root activity which maintains the biological life of the soil is low. The distribution then decreases from the surface to the depth. Our work is similar to that of Sembiring *et al* (2021) who showed that the thickness of an Andisol strongly influences the vertical distribution and diversity of the macrofauna.

This positive effect of permanent cultivated field populations can be partly explained by the maintenance of trees, which play a role in species conservation (Lavelle *et al.*, 1998). The low degree of intensification and the regular supply of manure may explain why the crop has little impact on the macroinvertebrate populations. It is also assumed that the environment as a whole is already degraded, which would explain the low effect of annual crops. A sampling of natural environments that have never been cultivated before would allow this to be verified.

The succession of the fallow vegetation follows a chronological order that helps the repopulation of the soil macrofauna. From the field abandonment to the 5 years old fallow, we have vegetation dominated by grasses. These grasses are nests that serve as refuges and starting points for the populations of soil macrofauna. In our case, the dynamics of the soil macrofauna begins at the foot of the trees in the recently abandoned fields. Gradually, during the succession of fallow vegetation, the different species and types of macrofauna will proliferate until they colonize the spaces that are favorable for their reproduction. Thickets of perennial grasses and the feet of trees are the best areas that we have identified. Zulu *et al.* (2022) have observed the same pattern.

The invertebrate population of the improved fallow with *A. gayanus* does not differ significantly from that of the young fallow, except for Termites which are less numerous. It is, therefore, possible that the fodder of this grass, which is less appreciated by Termites, is more appreciated by other decomposers who can thus incorporate it into the soil. The nature of the vegetation in young fallows compared to those improved with *A. gayanus* may explain this similarity. The easy decomposition of plant debris by certain species of macrofauna justifies their abundance in the 5 years old fallow. Because the latter is covered by vegetation composed of annual and perennial herbaceous plants and some woody plants. In contrast, the improved *A. gayanus* fallow is exclusively dominated by perennial grasses. It is, therefore, assumed that the food resources available to the macrofauna in the two fallows are identical according to the vegetation stage. This finding is consistent with those of Mathieu (2004) in Brazil.

6. Conclusion

This study provided answers about the behavior of soil macrofauna under different land management practices. In general, soil invertebrates respond well to anthropogenic environments. The young fallow and the improved *A. gayanus* fallow maintain a certain diversity of populations. The natural systems that are being reconstituted have the most individuals. Hence, there are significantly more Termites, while all other groups are evenly distributed. Plots under permanent cultivation have a very negative effect on the distribution of earthworms and Diplopods, compared to other species. The old fallow land, on the other hand, had few individuals compared to the other situations, but its diversity was equivalent to that of the young short natural fallow land.

Our two hypotheses are thus verified, despite the lack of a clear difference in the macrofauna population between the young fallow and the fallow improved with *A. gayanus* at the same age.

To maintain the invertebrate population and to encourage their expansion from cultivated plots to fallow areas, we suggest leaving strips of *A. gayanus* along the cultivated areas. This would provide a starting point for large-scale colonization once the crops are abandoned. A more detailed study of the dynamics of the different groups in these different lands management modes could provide us with more information on the processes involved by these invertebrates in the regulation of soil fertility in Bondoukuy.

References

Anderson, J. M., & Ingram, J. S. I. (1993). *Tropical Soil Biology and Fertility: A Handbook of Methods* (2nd ed.). Wallingford, CAB International, 240 p.

Ayuke, F. O., Karanja, N. K., Muya, E. M., Musombi, B. K., Mungatu, J., & Nyamasyo, G.H.N. (2009). Macrofauna diversity and abundance across different land use systems in Embu, kenya. *Tropical and Subtropical Agroecosystems, 11*, 371-384.

Braun-Blanquet, J. (1932). *Plant sociology. (Translation by H. S. Conrad, G. D. Fuller)*. Mac Graw-Hill Book Co. Inc. New York, 439 p.

Bouyer, S. (1958). Corrélations entre les résultats culturaux et les teneurs en phosphore du sol dans le cas des sols ferrugineux tropicaux du Sénégal. *Trans. Int. Soc. Soil Sci. Comm. II and IV, 2*, 244-249.

C.E.A.E. (2003). *Détermination de la matière organique par dosage du carbone organique dans les sols agricoles : méthode Walkley-Black modifiée, MA. 1010 – WB 1.0*. Ministère de l'Environnement du Québec, 10 p.

Cirad. (2017). *Catalogue des analyses courantes*. Cirad édition, 16 p.

Dabin, B. (1963). Appréciation des besoins en phosphore dans les sols tropicaux. Les formes du phosphore dans les sols de Côte d'Ivoire. *Cahiers ORSTOM. Pédologie, 1*(3), 27-42.

Delassus, L. (2015). *Guide de terrain pour la réalisation des relevés phyto-sociologiques*. Conservatoire botanique national de Brest, 25 p.

Fournier, A., Floret, C., & Gnahoua, G-M. (2001). *Végétation des jachères et succession post culturale en Afrique tropicale*. La Jachère en Afrique Tropicale, Floret et Pontanier Ed., 123-168 pp.

Guinko, S. (1984). *Végétation de la Haute Volta. T I. et II.* Thèse de doctorat es Sciences Naturelles, Université de Bordeaux III: 318 p.

Kissou, R. (1994). *Les contraintes et potentialités des sols vis à vis des systèmes de culture paysans dans l'Ouest Burkinabé "cas du plateau de Bondoukuy"*. Memoire IDR/IRD Université de Ouagadougou, 94 p.

Ladmirant, A., & Legrand, J. M. (1969). *Carte géologique de la Haute Volta, au 1/200000* BRGM Ouagadougou.

Lavelle, P., Barois, I., Blanchart, E., Brown, G., Brussaard, L., Decaëns, T., ... & Villenave, C. (1998). Les vers de terre, une ressource dans les agrosystèmes tropicaux. *Nature et Ressources*, *1*(34), 26-41.

Lavelle, P., Villenave, C., Rouland, C., & Derouard, L. (2000). Dynamique des peuplements. *Fallows in tropical Africa*, *1*, 236.

Mathieu, J. (2004). *Etude de la macrofaune du sol dans une zone de déforestation en Amazonie du Sud-Est, au Brésil dans le contexte de l'agriculture familiale*. Thèse de doctorat, UPMC-Paris 6, 237 p.

Ouattara, K., Ouattara, B., Assa, A., & Sédogo, P. M. (2006). Long-term effect of ploughing, and organic matter input on soil moisture characteristics of a Ferric Lixisol in Burkina Faso. *Soil and Tillage Research*, *88*(1-2), 217-224. https//doi.org/10.1016/j.still.2005.06.003

Ouédraogo, C. (1998). *Cartographie géologique de la région Sud-Ouest du Burkina Faso au 1/200000*. Synthèse géologique. AQUATER/BUMIGEB.

Rouland, C., Ikhouane, A., & Nayalta, N. (1993). Etude biologique des populations d'*Ancistrotermes guineensis* présentes dans les plantations de la Sonasut (SAHR-Tchad). *Actes Colloques Insectes Sociaux, 8*, 79-87 pp.

SAS (2020). *Procedures in the SAS/STAT guide personal computers. Version 9.4*. SAS Institut Inc., Cary, NC, 378 p.

Scheffe, H., (1959). *The analysis of Variance*. Wiley, New York, 477 p.

Scherrer, B. (1989). *Biostatistique*. Gaëtan Morin Ed. Quebec, 850 p.

Sembiring, M., Munawroh, H., Mukhlis, Hidayat, B., & Sabrina, T. (2021). Soil macrofauna diversity in Andisol after eight years of Mount Sinabung eruption in Sumatra, Indonesia. *Biodiversitas, 22*, 3024-3030. https://doi.org/10.13057/biodiv/d220603

Serpantié, G., Douanio, M., & Madibaye, D. (1997). *Recherches sur la culture de Andropogon gayanus Kunth. var. tridentatus Hack. en zone soudanienne. Essais participatifs d'installation de peuplements (Bondoukuy et Bereba, Burkina Faso)*. Atelier régional Idessa-Cirdes sur les cultures fourragères, Korogho, 1-18 pp.

Serpantié, G. (2003). *Persistance de la culture temporaire dans les savanes cotonnières d'Afrique de l'Ouest. Etude de cas au Burkina Faso.* Thèse de Doctorat d'Agronomie, Institut National Agronomique, Paris-Grignon, 342 p.

Szyszko-Podgórska, K., Kondras, M., Dymitryszyn, I., Matracka, A., Cimoch, M., & Żyfka-Zagrodzińska, E. (2018). Influence of soil macrofauna on soil organic carbon content. *Environmental Protection and Natural Resources*, *29*(4), 20-25. https://doi.org/10.2478/oszn-2018-0018

Tersiguel, P. (1994). *Le pari du tracteur. La modernisation de l'agriculture cotonnière au Burkina Faso*. Collection à travers champs. Orstom Ed. Paris, 279 p. https://doi.org/10.4000/books.irdeditions.15480

Zombré, P. (1995). *Notice explicative de carte morphopédologique du bas glacis de Bondoukuy*. 10 p.

Zulu, S. G., Motsa, N. M., Sithole, N. J., Magwaza, L. S., & Ncama, K. (2022). Soil Macrofauna Abundance and Taxonomic Richness under Long-Term No-Till Conservation Agriculture in a Semi-Arid Environment of South Africa. *Agronomy*, *12*(3), 722. https://doi.org/10.3390/agronomy12030722