…. à la diversité acarologique des différents sites d'études

Si nous savons maintenant que le type et la qualité du couvert végétale, le climat, les facteurs mésologiques (densité apparente, profondeur du sol et teneur en eau) sont des éléments majeurs pour la répartition des acariens dans les sols, toutefois les facteurs influençant la richesse spécifique méritent d'être investigués. L'abondance des acariens étudiée dans l'article1 n'influencerait-elle pas la richesse spécifique ? Enfin, pour une bonne compréhension de la variation dans la composition des espèces, des paramètres tels que la richesse spécifique, l'indice de Shannon, l'équitabilité et la bêta diversité ont été évalués. Les différents taux de recouvrement ont été calculés afin d'apprécier la dissimilarité entre les sites d'études. Finalement une attention particulière a été accordée à l'effort d'échantillonnage pour une meilleure spéculation sur la méthodologie d'échantillonnage et d'extraction des acariens du sol.

Chapitre 5

Soil mite diversity from Ivory Coast

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Draft of a paper to be submitted to
Biodiversity & Conservation

Received …

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Abstract

Soil fauna and particularly mites remained poorly know in most african ecosystems. In order to beter understand is change regarding forest management, Lamto savannah (LAS), Oumé primary forest (OPF), teak plantation (OTK) situated in (Sudanese domain) and the Tai primary forest (TPF) (Guinean domain) were sampled twice in Ivory Coast. Mite extraction was done during one week in Berlese-Tullgren funnel systems. In whole 177 species and morphospecies were recorded, with respectivelly LAS: 85 species, OPF: 98, OTK: 51 and TPF: 66. Shannon index estimated for mites was highest in TPF (5.13) and lowest in OTK (4.63). Evenness values were close in the 4 sites: LAS (0.745), OPF (0.742), OTK (0.816), TPF (0.849). OTK and TPF were the most different sites, with only 23 mite species in common (Jaccard distance = 76). Many mite species (100/177) were exclusive and were collected in a single site. The species richness was maximum in the upper layer and decrease with soil depth. Beta diversity measured along the depth is greater than that measured along the transect. Concerning soil parameters, $\boldsymbol{\rho}_{app}$, C_{tot},$N_{tot,}$ Depth and C_{org} were correlated to the species richness.

Key words: Acari, primary forest, savannah, species richness, beta diversity, mesologicals parameters, Ivory Coast.

Introduction

The soil is a reservoir of biodiversity (André et al. 2002, Coleman and Whitman 2005, Ritz 2009) and is even considered by some ecologists and genetists as the biggest biodiversity reservoir on earth (Feeney et al. 2006, Lescroart 2009). Due to multiple reasons, our knowledge about the soil fauna and in particular on mites is shamefully poor (André et al. 1997, Giller et al. 1997). Soil mites are an important component of the ecosystem, because of their relevant role as regulators of key functional processes (Lavelle 1996; Andrén and Balandreau 1999; Fitter et al. 2005; Palacio-Vargas et al. 2007; Bardgett 2008). Generally they contribute to organic matter decomposition and mineralization (Santos and Whitford 1981; Seastedt 1984; Whitford and Parker 1989; Tian et al. 1998; Joo et al. 2006; Wang et al. 2009) and regulation of microfauna and microflora (Seastedt 1984; Lavelle and Spain 1991; Gobat et al. 2004). As the macrofauna (Tondoh et al. 2007), soil mites community is often considered to be a useful bioindicator of ecosystem conditions and changes (Lebrun and van Straalen 1996; van Straalen 1998; Parisi et al. 2005).

The knowledge of soil mites assemblages composition in relation with vegetation structure, soil type and enthropic perturbation is fundamental to the understanding of ecosystems functioning and the proposal and follow up of management stratégies. However, rather little is known about that important taxocenose of the soil (Giller 1996).

The soil mite community density, richness and the structure is influenced by the climate (Wauthy 1981; Sinclair and Stevens 2006; Bokhorst 2008), the vegetation type, mesological factors such as the porosity and pH (Ducarme et al. 2004), water content (Noti et al. 2003), or altitude (Illig et al. 2010). Soil and its mesofauna undergo numerous perturbations due to man activities, land use, forestry and agricultural practices (Cortet et al. 2002, Minor and Cianciolo 2007).

Most analyses of soil mite diversity have been carried in Europe and North America (see table 2 in André et al. (2002), in contrast to Africa where few studies have be conducted (Athias 1975, 1976; Athias et al. 1976; Noti et al. 1996; Badejo 1990, 1994; Badejo & Tian 1999; Badejo & Ola-Adams 2000; Noti et al 2003). In Ivory Coast, most works concerning the soil biological diversity were devoted to macroinvertebrates (Yeo 2006; Tondoh et al. 2007; Dosso et al. 2010; Kra et al. 2010; Tra bi et al. 2010).

Four objectives have been developed in this study: (1) description of the soil mite diversity, (2) the analyses of between-site similarity, (3) the analyses of variations in diversity (alpha and beta diversity) in relation with habitat characteristics, (4) the impact of the mesological parameters.

The hypotheses advanced in this study are: (1) the more diversified and stable is a site, the higher is its richness species in mites; (2) the less a soil is disturbed, the greater its diversity; (3) soil mite richness is correlated with mesological parameters and mite density. To test these hypotheses, sites presenting contrast level of management from primary forest to Savannah under restor process and teak plantations were selected in different ecological zone of western Ivory Coast.

Material and methods

The study areas

This study was conducted in Ivory Coast where four sites, all located in arboreal areas were sampled in 2008. The Lamto savannah (LAS), Oumé primary forest (OPF), Oumé teak plantation (OTK), are located in the Sudanese domain whereas Taï primary forest (TPF) is situated in the Guinean domain. All sites were described in details by N'Dri and André (submitted). Geographical distances between sites are illustrated in Figure 3A.

Sampling method and mite extraction

Soil samples were taken with a steel corer (∅ 3.5 cm), from 1080 soil cores (4 sites x 15 biological profiles x 9 layers x 2 campaigns). For each profile, 9 cores were taken (the litter sample with a variable height and eight 48-cm^3 samples, 0-5 cm, 5-10 cm, 10-15 cm, 15-20 cm, 20-25 cm, 25-30 cm, 30-35 cm, 35-40 cm. For each site, the profiles were sampled over a 14-m transect, at 1-m interval. Sampling was repeated two times (January to March 2008 and August to October 2008). In other words, 135 soil cores were sampled (15 profiles x 9 layers) for each site and campaign.

Mites present in core soil were extracted using the Berlese–Tullgren funnels. Extraction lasted 1 week (after 7 days, no animal was captured in preliminary samples).

Mite identification

Contrary to usual practice, all stases (developmental stages) were identified. In most cases, mites were recognized to the species level even if there is no major key available for African species. So the species were described with morphological criteria and differentiated from each other by codes. Keys to oribatid genera was offered by Balogh & Balogh (1992). At the family level, keys by Krantz (1978), Dindal (1990) and Krantz & Walter (2009) were consulted. Special attention was given to Oribatida and Gamasida, two important groups of soil mites.

Mesological parameters

Soil water content (WC) and apparent density ($\boldsymbol{\rho}_{app}$) of the 960 mineral soil samples were estimated after 48 h drying at 105°C (Baize 1988, Duchaufour 1991, Harmand & Njiti 1998). The pH (water) (Baize 1988, Duchaufour 1991) was estimated with a pHmeter (Hanna) after calibration in 960 mineral soil cores adjacent to samples. More details are given by N'Dri and André (submitted). Other chemical analyses (80 samples) for extreme depths (0-5 cm and 35-40 cm) were realized by the “Centre Provincial de l’Agriculture et de la Ruralité” in La Hulpe (Belgium). Organic and total Carbon were measured through ISO norm 10 694. Total nitrogen was measured through ISO norm 13 878. Soil organic matter (SOM) may estimated using the formula C_{org} x 1.7 as made previously by Noti *et al.* (2003).

Data analysis

Alpha diversity (within community diversity) (Whittaker, 1972) was estimated in each site through species richness, *S*, the local diversity was measured by the Shannon (1948) index, *H’*, and evenness measured by the Pielou (1969) index, *J’*, i. e. the ratio *H’/H’max*. The program SpeDiv (André, 1997) was used to compute these indices.

Similarity between sites was estimated through the Jaccard index (Jaccard 1901)

Sj = A / A+B+C

where A = number of species common to the two sites; B = number of species found in the first site; C = number of species collected in the second site. The similarity index is calculated from a presence/absence matrix comprising 177 species. The same matrix was also used to determine common and exclusive species. The Jaccard distance (dissimilarity between sites), is obtained by subtracting the Jaccard index (in %) from 100.

The term “beta diversity” has been used to refer to a wide variety of phenomena (Tuomisto 2010). As defined originally by Whittaker (1972), beta diversity corresponds to the variation in species composition in a given area. It was estimated by the Standard deviation observed in a given site. Two approaches were used: (1) the beta diversity between the layers (vertical distribution) and (2) beta diversity observed along transects (horizontal distribution).

Species richness means were compared using test-t and a one-way ANOVA test. Rank Pearson correlation was used to study the relationships between species richness and soil physico-chemical and biological parameters. All tests were conducted using Statistica 7.1 by StatSoft, Inc.

Sampling effort was estimated using Estimates (Colwell 1997). Estimator's range was obtained by estimators discussed by Colwell and Coddington (1994). Evaluation the level of the sampling effort was made by the abundance-based coverage estimator, ACE (Chao et al. 1993).

Before most analysis, the data from the two campaigns were pooled in order to eliminate zero values. Nevertheless, the factorial correspondence analysis (FCA), and related tests, was applied on physico-chemical parameters in the two campaigns due to different behavior of WC during the two seasons. FCA was run with the R package (Casgrain and Legendre 2001).

Results

The species accumulation curves

The cumulative number of species varied significantly between sites (Anova1, $N = 270$, $P < 0.05$), from 51 species (OTK) to 98 (OPF) (Figure 1). The richness observed in OPF was even higher than mean values of S_{obs}. However, the richness estimated with ACE varies from 90 species (OTK) to 155 (OPF) and represents between 50 and 66 % of expected richness (Table 1). The estimator range was determined by Jack2 (upper limit) and Jack1 (upper limit) and there was no sign of leveling off at this level.

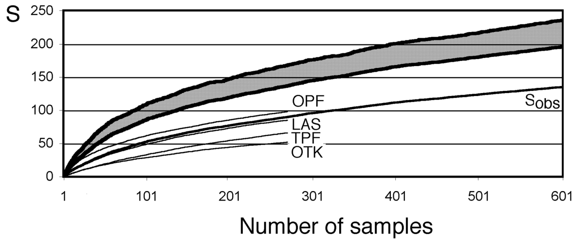

Figure 1. Cumulative number of soil mite species. LAS: Lamto savannah, OPF: Oumé primary forest, OTK: Oumé teak plantation, TPF: Taï primary forest.

Table 1. Cumulative number of species (CNS) and sampling effort. Anova one way-test for the S_{obs} values.

	LAS	OPF	OTK	TPF	ALL SITES
CNS measured by S_{obs}	85 c	98 a	51 b	66 b	177
CNS estimated by ACE	129	155	90	131	271
Ratio (%)	66	63	57	50	65

Significant at levels 0.05, when letters are different.

Species richness

Globally, 177 mite species were collected in the four sites. The highest richness was recorded in OPF with 98 species. Followed LAS with 85 species, TPF with 66 species and OTK with only 51 species (Figure 2A). The richness observed in OPF is significantly higher than in OTK ($N = 9$; $P < 0.05$) and in TPF ($N = 9$; $P < 0.05$).

Oribatida richness in the different sites was LAS: 40, OPF: 59, OTK: 25, TPF: 34) (Figure 2B). Oribatida had a higher richness than Gamasida (LAS: 33, OPF: 29, OTK: 20, TPF: 26) (Figure 2C).

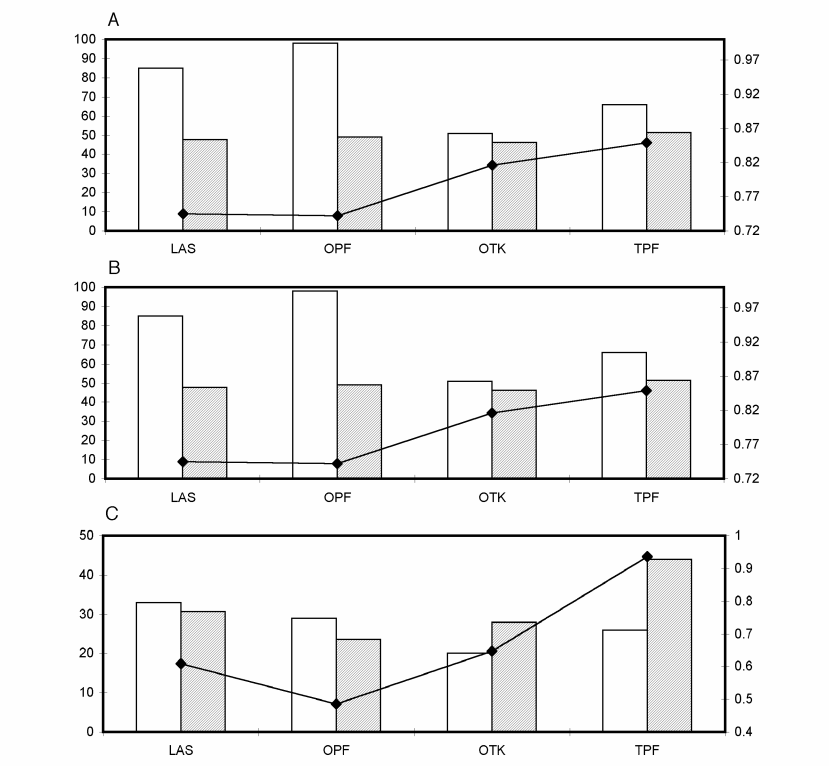

Figure 2. Richness (S, white histogram), diversity (H', shaded histogram) and evenness (J, curve) for mites (A), Oribatida (B) and Gamasida (C) in the different sites. Left scale: number of species, units of diversity x 10; right scale: evenness.

Species diversity and evenness

Shannon index estimated for mites was highest in TPF (5.13) and lowest in OTK (4.63) (Figure 2A). It was significantly higher in TPF than in the three other sites (N = 9 ; P > 0.05).

Generally, the Shannon index was greater in Oribatida than in Gamasida and reached 5.05 in OPF, 4.70 in LAS, 4.03 in TPF and 4.02 in OTK. Contrary to Oribatida, Gamasida had a higher value in TPF (4.40) and a lowest value in OPF (2.36).

Evenness values were close in the 4 sites: LAS (0.745), OPF (0.742), OTK (0.816), TPF (0.849). Nevertheless, mite evenness was significantly lower in OPF than in OTK ($N = 9$, $P < 0.05$). Contrary to the high richness observed in OPF, diversity and evenness seemed to be important in TPF. In Oribatida, evenness is greater than in Gamasida, especially in LAS (0.88), OPF (0.85) and OTK (0.86).

Similarity between sites

OTK and TPF were the most different sites, with only 23 mite species in common (Jaccard distance = 76, Figure 3B). Lowest values are found between OPF and LAS (Jaccard distance = 72). Other distances showed intermediate values.

If Oribatida only are considered, TPF and OTK were the most distant sites (Jaccard distance = 72, Figure 3C). LAS and TPF exhibited the minimum dissimilarity (65) for the Oribatida and the maximum (82) for the Gamasida (Figure 3D).

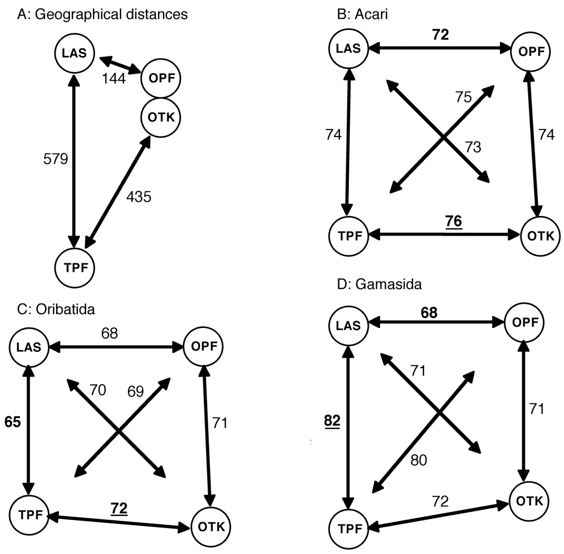

Figure 3. Geographical distance (km) between sites (A) and Jaccard distance (100 x the complement of Jaccard index) between sites for mites (B), Oribatida (C) and Gamasida (D). Extreme values in bold, greatest value underlined. LAS: Lamto savannah, OPF: Oumé primary forest, OTK: Oumé teak plantation, TPF: Taï primary forest.

Common and exclusive species

Many mite species (100/177) were exclusive and were collected in a single site. Maximum values (bold in Figure 4) were observed in OPF and LAS.

Numerous exclusive species were also found either in Oribatida (44/85) and Gamasida (36/66) (Figure 4B, C). However, the maximum number of exclusive species for Oribatida was recorded in OPF while it was found in LAS and, secondarily, in TPF for Gamasida. Gamasida were also remarkable because the order of exclusive species was LAS, TPF, OPF and OTK contrary to Oribatida which followed the same order as mites, OPF, LAS, TPF and OTK.

The mite number common to two sites was lowest in OTK and OPF (29 species) and greater in LAS and OPF (40 species). In Oribatida, the highest number of common species (24) was observed between LAS and OPF, whereas in Gamasida the greatest value of common species (16) was found between de OTK and TPF.

Species collected in all sites were relatively few, 15 mite, 9 oribatid and 6 gamasid species.

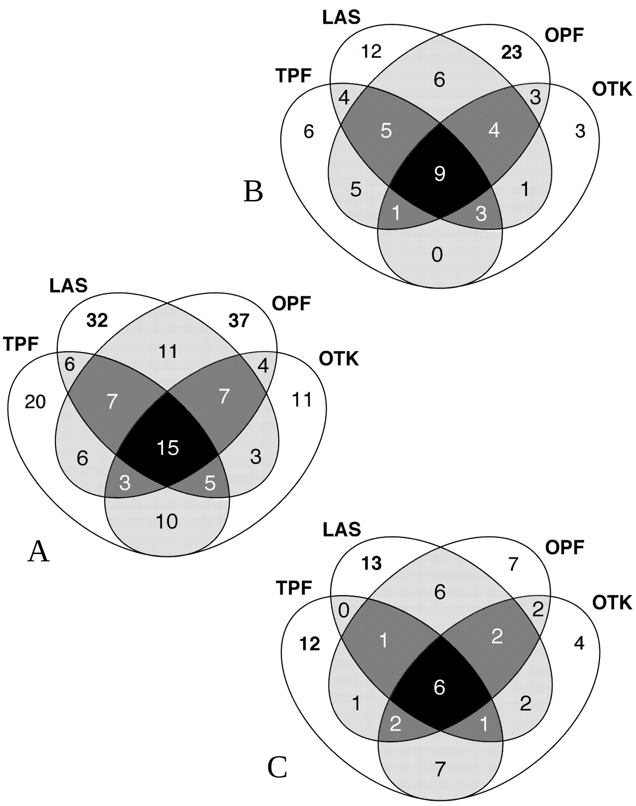

Figure 4. Common and exclusive species in mites (A), Oribatida (B) and Gamasida (C) observed in the 4 sites. Highest values in bold. LAS: Lamto savannah, OPF: Oumé primary forest, OTK: Oumé teak plantation, TPF: Taï primary forest.

Beta diversity and depth

Globally, the species richness was high in surface (OPF: 60 species in litter, OTK: 28, TPF: 32), except in LAS where the maximum value was observed in the 0-5 cm layer (49 species, Figure 5). Lowest richness values were recorded deep in mineral soils. In all sites, species richness decreased with depth ($N = 9$; $P < 0.05$). There is a significant difference between sites when superficial layers (litter and the 0-5 cm layer) were compared ($N = 30$; $P < 0.05$), except between OTK and TPF.

The same trend was observed in Oribatida (OPF: 42 species in litter, OTK: 17, TPF: 22) and Gamasida (OPF: 15, OTK: 9, TPF: 8), except again in LAS where a peak was noted in the 0-5 cm layer (Oribatida: 23 species, Gamasida: 17). In all sites and in both mite groups, species richness decreased significantly with depth ($N = 9$, $P < 0.05$). Beta diversity associated with the richness observed in the different layers was 17.65 in LAS, 16.57 in OPF, 11.57 in TPF and 8.73 in OTK. These values, estimated through the SD, are high and sometimes greater than means (17.33 in LAS, 27.88 in OPF, 10.55 in TPF and 9.33 in OTK).

Beta diversity and transects

In contrast to depth, the beta diversity observed along the different transects was weak: 6.78 in OPF, 5.51 in LAS, 4.88 in TPF and 2.46 in OTK. Compared to means (21.00 in OPF, 13.66 in LAS, 7.86 in TPF and 7.93 in OTK), these values are very low and always inferior (Figure 6).

The maximum and minimum species richness measured along the transects were respectively: LAS (5 vs 25), OPF (10 vs 35), OTK (4 vs 13) and TPF (2 vs 19).

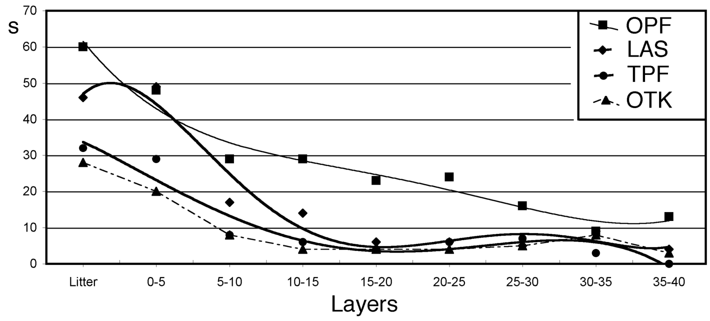

Figure 5. Species richness variation and vertical distribution. LAS: Lamto savannah, OPF: Oumé primary forest, OTK: Oumé teak plantation, TPF: Taï primary forest.

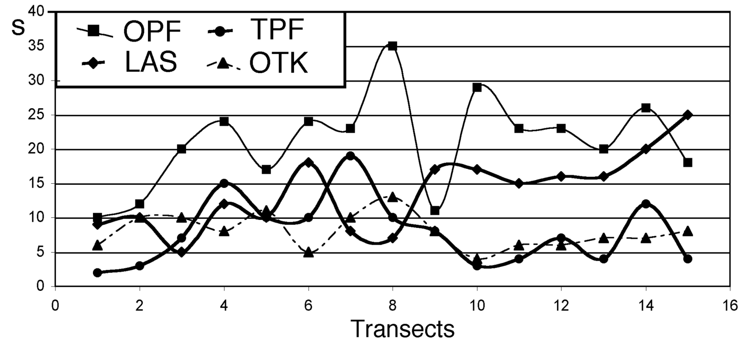

Figure 6. Species richness variation along the transect. LAS: Lamto savannah, OPF: Oumé primary forest, OTK: Oumé teak plantation, TPF: Taï primary forest.

Richness and mesological parameters

In dry season, $\boldsymbol{\rho}_{app}$, D (depth), C_{tot}, and N_{tot} affect significantly the soil mite richness (Table 2). In rainy season however, C/N played a minor role while

WC was pivotal and added to previous parameters. Correlations are not linear (Figure 7).

Pearson correlation on the 4 sites and 2 campaigns between richness and density is high ($N = 8$, $r = 0,78$, $p < 0.05$).

Table 2. Relation between species richness and mesological parameters measured in all sites (N=40). Curves are power (P), exponential (E) or linear (L) and are related to R^2 values. P values concern Pearson rank correlation.

Dry season					Rainy season				
Parameters	**Curve**	**R^2**	**P**		**Parameters**	**Curve**	**R^2**	**P**	
ρ_{app}	P	0.56	0.01	**	**Depth**	E	0.62	0.01	**
C_{org}	P	0.35	0.01	**	C_{org}	P	0.61	0.01	**
N_{tot}	P	0.35	0.01	**	N_{tot}	P	0.59	0.01	**
Depth	E	0.32	0.01	**	**WC**	P	0.56	0,01	**
WC	E	0.11	0.11	NS	ρ_{app}	P	0.52	0.01	**
C/N	E	0.09	0.07	NS	**C/N**	P	0.25	0.03	*
pH	L	0.02	0.34	NS	**pH**	E	0.05	0.24	NS

Significant at levels 0.05 (*), 0.01 (**)

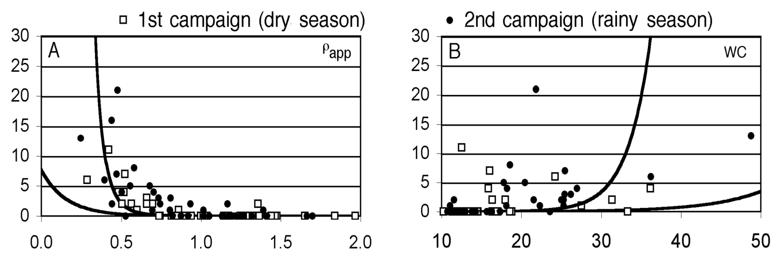

Figure 7. Influence of apparent density (A, ρ_{app}) and water content (B, WC) on soil mite richness (s) in the two campaigns (dry vs rainy season). Trend lines are adjusted to data.

Multivariate analyses (FCA) confirm the trends and show the influence of $\boldsymbol{\rho}_{app}$, D, C_{tot}, N_{tot} in both seasons and WC in rainy season (Figure 8). In dry season, axis 1 contributes to 54.49% of the total variance and axis 2 to 21.20%. In rainy season, they contribute respectively to 66.15 and 16.41%. Depth (D) was correlated linearly with apparent density ($\boldsymbol{\rho}_{app}$).

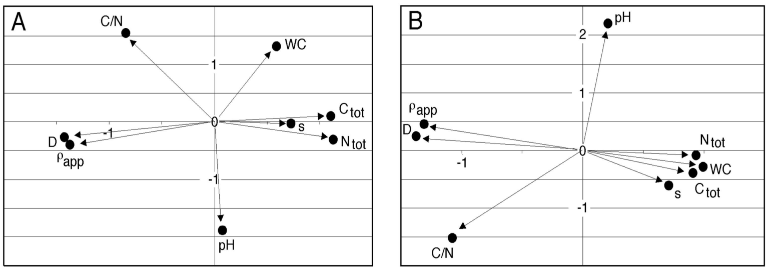

Figure 8. FCA axes 1 and 2 applied to mesological parameters and soil mite richness (s) in the two campaigns, dry (A) vs rainy (B) season. apparent density ($\boldsymbol{\rho}_{app}$), Depth (D), Species richness (S), Water content (WC), Carbon total (C_{tot}), Azote total (N_{tot}), Potentiel Hydrogen (pH) and ratio Carbon / Azote (C/N).

Discussion and conclusion

Arboreal sites chosen in this approach belong to the hotspots retained by Myers et al. 2000), i. e. to African west forests. Nevertheless, the fauna from Ivory Coast remains obscure even for the distribution of birds, the best known group for Africa (only four points in Figure 5-3 of Stork 1997).

Whatever the area, the study of different taxonomic groups leads to different conclusions depending on the body size, the function of the group and other attributes (Blackburn et al. 1993, Kati et al. 2004, Kessler at al. 2009). Soil mites, those “little things which run the world” (Kinnear 2004), do not escape the problem.

Site and alpha diversity

It turns out that OPF sheltered more mite (98 species) and oribatid (59) species than all other sites. Such a high richness might be due to the heterogeneity of soil organic matter linked to a multispecies woody vegetation. The absence of human activities in OPF is probably another factor acting in favor of the development of soil mites. Significative correlations between richness and mesological parameters confirm this approach. Last, the weakest richness (51 mite species) was observed in the teak plantation (OTK) where the level of human disturbances is high.

TPF is remarkable by its low richness (66 mite species only) but the highest Shannon index value. This recalls the findings of Medianero et al. (2007) who reported a weak positive correlation between the number of litter-dwelling arthropods in a tropical rainforest and incident light.

The Lamto savannah presents a high level of biodiversity with numerous common species with the Oumé and Taï primary forest underlining that this site undergo a restauration process from a clear savannah to a true forest since it received a protection status.

Several studies have demonstrated the high richness of soil mites in temperate forests (Ducarme et al. 2004a: 40 vs 50 mite species, Ducarme et al. 2004b: up to 74 mite species, Lebrun 1965: 48 oribatid species; Lindo and Winchester 2006: 70 oribatid species; Minor and Cianciolo 2007: 74 oribatid but only 19 gamasid species). This could be due to the thickness of the litter and its quite slow turnover while tropical rain forests show a very rapid litter degradation. The species richness observed in Ivory Coast forests is however lower than the richness reported in DRC by Noti et al. (2003, 86 to 94 oribatid species in forest and woodland, 105 in savannah).

Beta diversity, vertical and horizontal distributions

Robert H. Whittaker (1972) defined beta diversity as the variation in species composition among sites in a geographic area. Usually beta diversity is viewed as a measure of the variation in species composition between discrete samples (Magurran 2004). It is a key concept for understanding the functioning of ecosystems, for the conservation of biodiversity, and for the ecosystem management (Legendre et al. 2005). The beta diversity measured within the layers is greater than those measured along the transect in all sites. Weak values in the beta diversity observed horizontally suggest a relative uniformity of the species composition and could be attributed to the consequence of biological interactions. As to Pitman et al. (1999, 2001), they suggest that communities are dominated by a limited suite of competitively superior species.

The hight beta diversity observed between layers in all sites probably reflects fluctuations in the species composition. It has to be associated with different vertical distributions of mites. LAS is remarkable as, contrary to other sites, it showed a peak in richness in the 0-5 cm layer, thus below the litter, and knew the highest beta diversity in vertical distribution. Savannah undergoes direct insulation and this accords with Athias' (1975, 1976) observations that soil temperature is a limiting factor for soil mites in Lamto.

In contrast, the beta diversity associated with transects and reflecting the horizontal distribution of mites is weak.

Diversity, density and mesological factors

In tropical areas as in temperate forests, porosity seems to play a key role in the determination of soil mite richness, our results are in agreement with those of Ducarme et al. (2004a). In contrast to findings by these authors. pH do not intervene in our results. Other important mesological parameters are C_{tot} and N_{tot} contents. The role of WC deserves a special comment as water intervenes only during the rainy season.

That the richness is correlated with density or the number of collected specimens as also observed by Ducarme et al. (2004a) and Medianero et al. (2007).

Acknowledgements

Thanks to Dr. J. E. Tondoh who suggested the research project and to the *Université d'Abobo Adjamé* and the *Centre de Recherche en Ecologie* at Abidjan. Thanks also to R. Jocqué, Y. Samyn, and D. Van Den Spiegel for advices and grants. Financial support from FEM/UNEP funded project CSM-BGBD, FRS/UCL, Philippe Lebrun Fund, GTI/IRScNB, ABIC/MRAC is gratefully acknowledged.