Changes in mite richness and diversity along a gradient of land-use intensity from mid-west Ivory Coast

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Abstract: The conversion of natural forest to agricultural land, and different management practices contribute extremely to soil physico-chemical and biological degradation. One of the key factors influencing this alteration is land use intensity. The objective of this study was to evaluate the changes in soil mite abundance, richness and diversity orchestrated by land use intensification. Eight agroecosystem with an increased land use intensity index were selected: Primary forest – Secondary forest – Multi-species planted trees – 10-year old teak plantations – 4-year old teak plantations – Cocoa plantations – Recurrent fallows – Mixed crops fields. On each land use type 5 grills point were sampled. The results showed that soil mite density decreased significantly ($P < 0.05$) from Primary forest to Mixed crops field, showing that mite abundance was hugely influenced by the degree of agroecosystem stability. The average number of species per sampling point varied significantly ($P = 0.0013$) from Primary forest (9.6 ± 0.8) to Mixed crops fields (1.4 ± 0.5). The same pattern was observed with the Shannon index, which was ranked between Primary forest (2.92 ± 0.21) and Mixed crops fields (0.45 ± 0.28). Cumulative α diversity varied from 5 species in Mixed crops fields to 22 species in Primary forest. The β diversity (turnover or dissimilarity) were generally high and varied from 42.3% (Primary forest and Secondary forest) to 82.3% (Multi-species planted trees and Mixed crops fields). The results demonstrated that higher was the land use intensity index, the lower were the mite abundance, diversity and species richness. Interactions between mite abundance and diversity and trophic resource characteristics, shade and soil organic carbon is discussed.

Key words: Agroecosystems, community structure, land use intensity, mite biodiversity, natural forest.

Introduction

Biodiversity loss remains a major concern worldwide during this decade (Gaston & Spicer 2004; Loreau 2005). Indeed, all agree that it is important to better understand (i) how and why biodiversity is changing and (ii) what are the ecological and social consequences of changes in biodiversity. According to Gaston & Spicer (2004) species losses and others types of declines in biodiversity result from four main causes, mainly: (i) direct exploitation, (ii) habitat loss and degradation, (iii) introduced species, and (iv) extinction cascades. In Sub-Saharan Africa, population pressure on forest land for intensive agriculture promotes highly and frequently a degradation of edaphic biodiversity (Gergócs & Hufnagel 2009; Gulvik 2007; Maathai 2005) and the loss of soil fertility (Bedano *et al.* 2006). In Côte d'Ivoire, the mid-West region houses one of the most important Primary forest reserves of the country, which is well-suited for coffee and cocoa
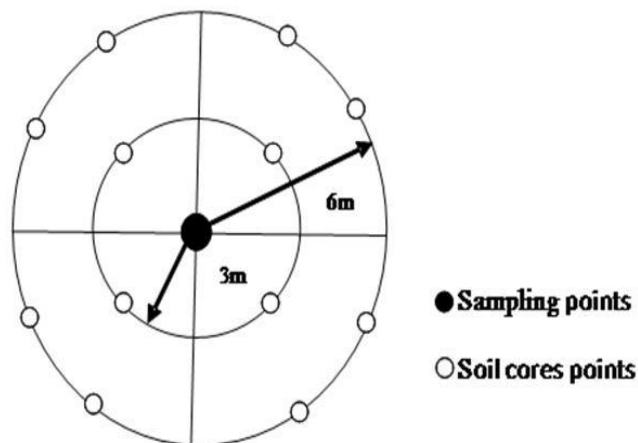
Fig. 1. A layout of the mites sampling design. Circle and diagonal are virtual.

farming. With time, part of this natural forest has been completely degraded, due to overexploitation. The Primary forest formerly covered 586 km² but has now decreased steadily down to 72 km², as a result of human pressure on land and has to a great extent been transferred to cocoa farming. In Oumé region, human induced degraded areas including cultivated areas, fallows, and degraded forests represent up to 72% of the whole area today. Accordingly, the soil physico-chemical and biological characteristics are highly modified.

Soil organisms and especially mites play a key role in the ecosystem functioning by involving in the litter fragmentation, organic matter decomposition, nutrients recycling, and the soil microflora and microfauna regulation (Gréggio et al. 2008; Seastedt 1984; Yang & Chen 2009). Very sensitive to seasonal variations (Bachelier 1978; Ghezali & Soumya 2012) and soil modification (Bedano et al. 2006), they are seen as good indicators of the soil and environmental quality (Djelloul & Hafsa 2012; Zhao et al. 2013). The abundance, diversity and community structure of free-living mites (Acari) respond considerably to land management practiced, such as tillage, cutting, pesticide and fertilizer application (Adetola et al. 1995; Bedano et al. 2006; Behan-Pelletier 1999; Minor & Cianciolo 2007; Minor et al. 2004; Zhao et al. 2013). Furthermore, the life history traits of individual species can be used to predict the effect of land management on species assemblages (Siepel 1995). Soil mites (such as Oribatida) species have low mobility (Berthet

1964) and low dispersion (Lebrun & van Straalen 1995) and could be eliminated by tillage, cutting, burning or damage, specifically those with a life cycle longer than one year (Behan-Pelletier 1999). The high connection between soil mites and the food web such as trophic niche differentiation has been pointed out by several scientists (Lebrun & van Straalen 1995; Schneider et al. 2004). Soil organic matter amount decreased with agricultural practice (Bedano et al. 2006). Some researchers have found that decreasing or increasing of the soil organic matter amount do not affect Oribatida species richness and diversity (Cole et al. 2008; Osler & Murphy 2005). These results are in contradiction with observations made by Behan-Pelletier (1999), N' Dri et al. (2011, 2013). Thus, in order to understand the response of land-use intensity on mite abundance, diversity and community structure, this investigation was conducted through eight land-use types consisting of natural forests, planted forest, agroecosystem (mono or multi-specific) and fallows system. We hypothesized that (i) the lower the land-use intensity (intensity index), the higher will be the soil mite abundance and diversity (ii) the turnover between land-use types will be greater if their intensity index values are very distinct.

Materials and methods

Study site

The study was conducted in Oume region of mid-West Côte d'Ivoire, in the village of Goulikao at 6°17′N, and 5°31′W. Altitude ranged from 100 to 180 m above sea level. Climate is subequatorial with bimodal rainfall patterns (March to June and September to October). The average rainfall over 27 years (1976–2003) ranged from 849 to 1764 mm. The annual rainfall in 2004 was about 1541 mm, whereas the average monthly temperature was about 26 °C. The soils of the region are classified as ferralitic (Lecomte 1990). In general soils are clayey (30–60 %), acidic to slightly neutral (pH 4.7–7.8), with adequate levels of organic matter (2–3 %) (Ouallou 1997). The vegetation is an ombrophile forest, dense and semi deciduous and is part of the Guinean domain (Guillaumet & Adjanohoun 1971). The study area covers 400 ha and spans from the "Forêt Classée de la Téné" in the SODEFOR (Society for the Development of Forest) domain to the agricultural lands in the rural domain.

Experimental design

Soil sampling was conducted within a site of 400 ha subdivided into a grid system laid within different land-use types. The SODEFOR domain comprised five different land-use types: Primary forest (PF), Secondary forest (SF), Multi-species planted trees (MTP), 10-year old teak plantations (TK94), 4-year old teak plantations (TK00), whereas the rural domain comprised three land-use types: Cocoa plantations (CP), mixed crops fields (MCF) and Recurrent fallows (F). Five sampling points were randomly chosen on each of the eight land-use types identified across the landscape, giving a total number of 40 sampling areas. Each sampling areas separated from the other by a distance of 200 m. 12 soil cores from the topsoil (0–5 cm) were collected with a steel corer ($\varnothing$ 5 cm) at each sampling point (Fig. 1) and mixed to obtain composite samples. 500 cm^3 (100 cm^2 × 5 cm depth) of the composited samples were taken for the mite extraction. This investigation was conducted in 2005, particularly in a wet period.

Soil mite extraction and identification

Extraction of soil mites was carried out in modified Berlese-Tullgren funnels apparatus with a mesh size of 2 mm (N'Dri *et al.* 2011). The soil cores were heated from above with 25W bulbs, controlled gradually at 31 °C to 39 °C. The extraction lasted 10 days. The organisms were collected in 70% ethanol, counted, and identified to major groups (Oribatida, Mesostigmata, Prostigmata and Astigmata), family, genus and morphospecies levels by using keys and illustrations provided in Balogh & Balogh (1992), Dindal (1990), Krantz (1978), Krantz & Walter (2009) and Walter *et al.* (2013).

Land-use intensity index

Land-use intensity index (LUI) was obtained by integration of the cultural practices and agroecological remarks at each sampling point. LUI was calculated by using this formula:

$$LUI = \frac{D+F+I+P}{N}$$

Where D is length (year) of present land utilization, F is fire use in land preparation, I is inorganic fertilizer option, P is pesticide use option and N is number of variables used for the calculation of the LUI.

A part from D, each variable is a binary function: indeed, these variables indicate a value of 1 when the event happened and 0 when the option was not used. According to the landscape unit, the land-use intensity index was ranked from 0 to 0.4. Respectively we noticed: Primary forest (0), Secondary forest (0.1), Multi-species planted trees (0.3), 10-year old teak plantations (0.3), 4-year old teak plantations (0.3), Cocoa plantations (0.3), Recurrent fallows (0.3) and Mixed crops fields (0.4). More details were given by Tondoh *et al.* (2011).

Data analysis

The mite diversity at each sampling point (α diversity) was estimated using three expressions of species richness: (1) the average α diversity, expressed as the mean number of species per sampling point; (2) the Shannon–Wiener index of diversity (Pielou 1966) and (3) the cumulative α diversity (total number of species recorded per land-use type). The β diversity or turnover was estimated through the dissimilarity (Jaccard distance) between sites, by subtracting the Jaccard index (%) from 100. The γ diversity was performed at landscape scale through mite species accumulation curves. The Berger-Parker Dominance Index for each taxonomic group was done (Kaczmarek & Marquardt 2010). Generic level taxa that provided 10% or more of the total abundance in a site are regarded as dominant. The constancy value was considered high when the ratio was comprised within 80–100%. The EstimateS 6.0b1 software (Colwell 2000) was used to estimate the species accumulation after 500 simulations. Principal component analysis (PCA) was used to examine and display through ordination plots, the relationship or effects of land-use type on mite community and land-use intensity. These analyses used the module 'PCA' of the software ADE-4 (Thioulouse *et al.* 1997). All tests were conducted using the software Statistica 7.0 (StatSoft Inc. 1984–2004).

Results

Soil mite abundance

Soil mite density decreased significantly ($P < 0.05$) from Primary forest to mixed crops fields (Fig. 2). The Primary forest hosted the highest mite

Table 1. Diversity parameters of mite populations across the land-use types. *H*: Shannon–Wiener index, *S*: average number of mite species, S_{cum}: cumulative number of mite species richness.

	H (mean ± SE)			*S* (mean ± SE)			S_{cum}
Primary forest	2.92	±	0.21[c]	9.6	±	0.8[c]	22
Secondary forest	2.36	±	0.26[bc]	7.0	±	1.4[bc]	19
Multi-species planted trees	2.23	±	0.22[bc]	5.6	±	0.8[b]	15
10-year-old teak plantations	1.75	±	0.48[b]	4.8	±	1.3[b]	15
4-year-old teak plantations	2.08	±	0.2[c]	5.4	±	0.9[b]	11
Cocoa plantations	1.76	±	0.29[b]	4.0	±	0.8[ab]	11
Fallows	2.11	±	0.3[b]	5.6	±	1.6[b]	19
Mixed crop fields	0.45	±	0.28[a]	1.4	±	0.5[a]	5

Means values with the same letter are not significantly different.
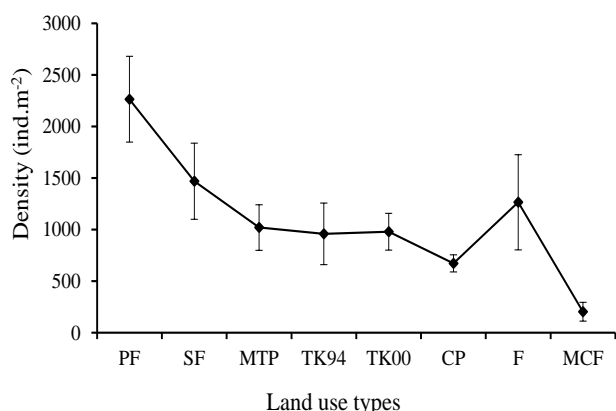

Fig. 2. Soil mite abundance recorded along the gradient of land use types. PF–Primary forest, SF–Secondary forest, MTP–Multi-species planted trees, TK94–10-year old teak plantations, TK00–4-year old teak plantations, CP–Cocoa plantations, MCF–Mixed crops fields and F–Recurrent fallows.

density (2264 ± 416 ind. m^{-2}). Following by Secondary forest (1468 ± 370 ind. m^{-2}), fallows (1264 ± 461 ind. m^{-2}), Multi-species planted trees (1020 ± 221 ind. m^{-2}), 4-year old teak plantations (979 ± 178 ind. m^{-2}), 10-year old teak plantations (959 ± 298 ind. m^{-2}) and Cocoa plantations (673 ± 83 ind. m^{-2}). The lowest mite density was observed in mixed crops fields (204 ± 91 ind. m^{-2}). Oribatida, Gamasida, Acaridida and Actinedida reflected the major groups of communities. The community pattern revealed that soil mite relative abundance represented, respectively 10 (MCF) – 60% (TK00) for Oribatida, 14 (MTP) – 42% (CP) for Gamasida, 21 (TK00) – 60% (MCF) for Acaridida and 2 (PF/TK00) – 14% (MTP) for Actinedida.

Absent in Secondary forest and mixed crops fields, the Actinedida reflected the least abundant group. Trophical groups ratio analysis revealed, respectively, for (phytophagous, saprophagous) and (predatious, fungivorous): Primary forest (63.1 vs. 36.9), Secondary forest (72.2 vs. 27.8), Multi-species planted trees (72 vs. 28), Cocoa plantations (51.5 vs. 48.5), 10-year old teak plantations (74.5 vs. 25.5), 4-year old teak plantations (81.2 vs. 18.8), Recurrent fallows (69.4 vs. 30.6) and mixed crops fields (70 vs. 30).

Diversity of mite communities

The average number of species per sample (100 cm^2 × 5 cm depth) varied significantly ($P = 0.0013$) from primary forest (9.6 ± 0.8) to mixed crops fields (1.4 ± 0.5). The same pattern was observed with the Shannon index, which was ranked between Primary forest (2.92 ± 0.21) and mixed crops fields (0.45 ± 0.28). Cumulative α diversity varied from 5 species in mixed crops fields to 22 species in Primary forest (Table 1). The β diversity (turnover or dissimilarity) was generally high and varied from 42.3% to 82.3% (Table 2). The lowest turnover (42.3%) was observed between Primary forest (PF) and Secondary forest (SF) whereas the highest dissimilarity (82.3%) was observed between Multi-species planted trees (MTP) and mixed crops fields (MCF). The estimated number of mite species in the whole landscape was 33.
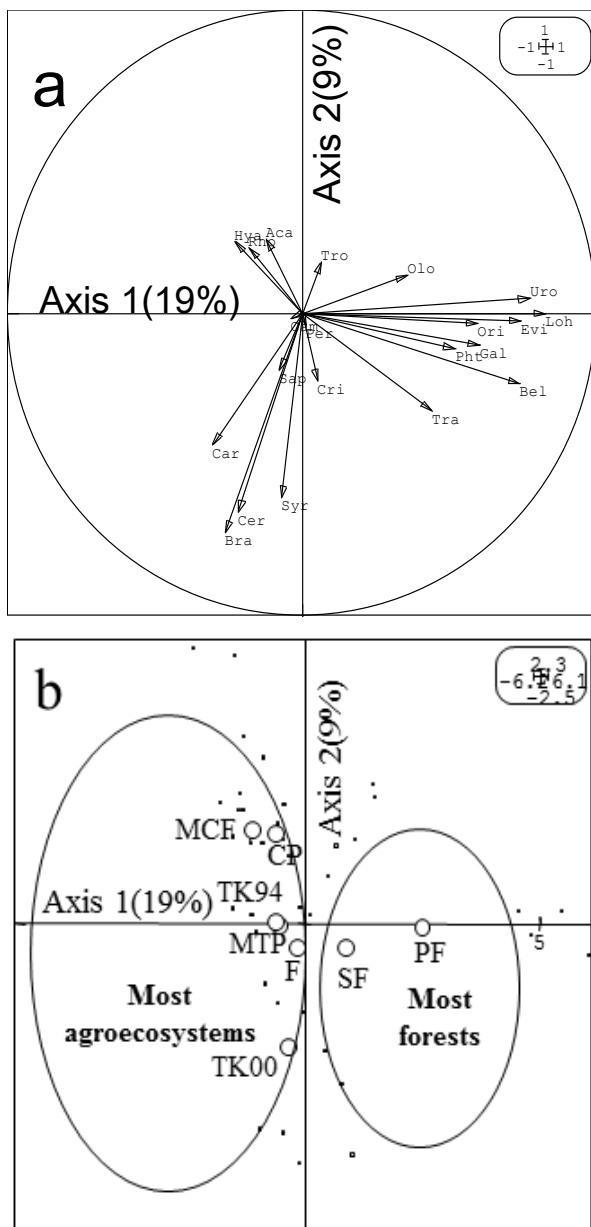
Fig. 3. Multivariate analysis (PCA). **a.** Correlation circle presenting the general pattern of distribution in mite families through the eight land use types. **b.** Projection of land use types on the factorial planes 1–2. Mite families codes as follows: Olo-Ologamasidae, Cam-Camisiidae, Per-Perlohmanniidae, Loh-Lohmanniidae, Pht-Phthiracaridae, Bel-Belbidae, Bra-Brachychtoniidae, Ori-Oribatellidae, Cer-Ceratozetidae, Gal-Galumnidae, Aca-Acarididae, Hya-Hyadesiidae, Sap-Saproglyphidae, Car-Carpoglyphidae, Syr-Syringobiidae, Cri-Criptoturopidae, Tro-Trombidiidae, Evi-Eviphidae, Tra-Trachyuropodidae, Uro-Uropodidae, Rho-Rhodacaridae.

Table 2. Index of complementarity (ß diversity)[1] between pairs of land-use types.

	SF	MTP	TK94	TK00	CP	F	MCF
PF	42.3	57.6	57.6	62.5	56.5	48.1	78.2
SF		58.3	58.3	52.3	52.3	48.0	80.0
MTP			50.0	55.5	55.5	64.0	82.3
TK94				63.1	37.5	58.3	75.0
TK00					62.5	57.1	66.6
CP						57.1	66.6
F							73.6

PF–Primary forest, SF–Secondary forest, MTP–Multi-species planted trees, TK94–10-year old teak plantations, TK00–4-year old teak plantations, CP–Cocoa plantations, MCF–Mixed crops fields and F–Recurrent fallows.

[1]The ß diversity or turnover was estimated through the dissimilarity (Jaccard distance) between sites, by subtracting the Jaccard index (%) from 100.

Patterns of mite assemblages across the landscape

A correlation matrix was applied on the data composited of 21 parameters (i.e. mite families) and 8 objects (i.e. land-use types). The correlation circle illustrated in (Fig. 3a) presents a moderate assemblage pattern of the mite species within the landscape. The first two axis contribute to 28% of the total inertia, 19% for the first and 9% for the second that reveal a difference in species composition since the parameters were either positively or negatively correlated to the axis. Globally, two main groups emerged: the first consisting of Uropodidae, Lohmanniidae, Eviphidae, Oribatellidae, Galumnidae, Phthiracaridae and Belbidae were positively correlated to the first axis, whereas the second composited of Carpoglyphidae, Brachychtoniidae, Ceratozetidae and Syringobiidae were negatively correlated to the second axis. The ordination basis on mite (families) abundance allowed discriminating the land-use types across the landscape (Fig. 3b). In this context, one factor, especially "the disturbance" following the axis 1, separated undisturbed and low disturbed habitats from intermediate and highly disturbed systems.
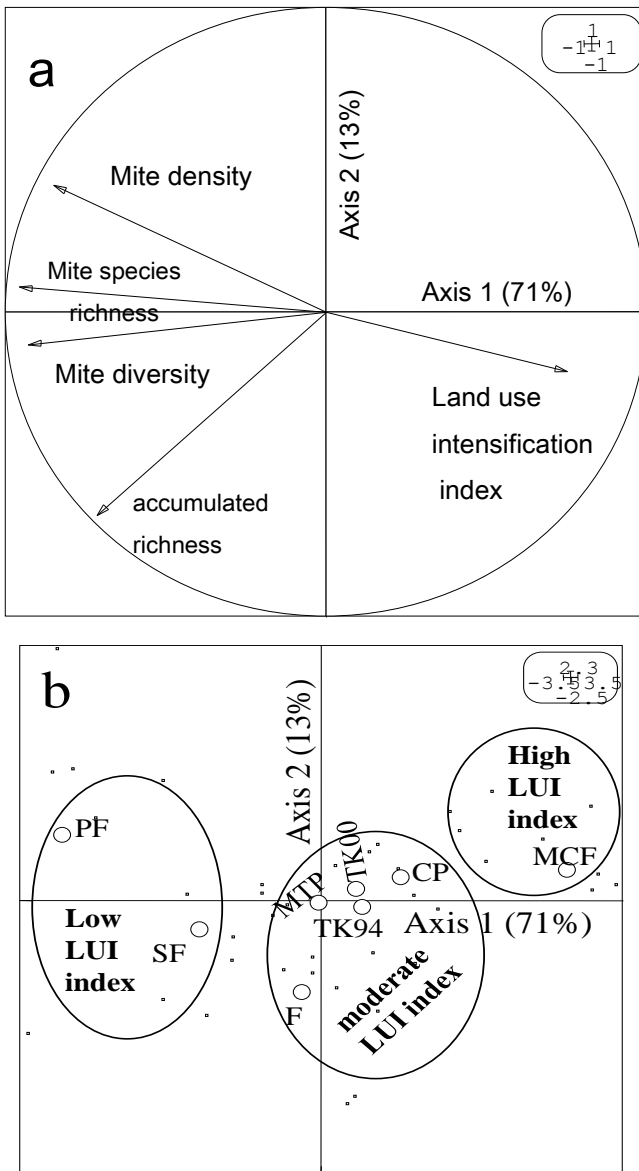
Fig. 4. Ordination diagram based on PCA of land use type and community diversity including environmental index. **a.** Correlation circle; **b.** sampling plots projection following the factorial planes 1–2. PF–Primary forest, SF–Secondary forest, MTP–Multi-species planted trees, TK94–10-year old teak plantations, TK00–4-year old teak plantations, CP–Cocoa plantations, MCF–Mixed crops fields and F–Recurrent fallows.

The Berger Parker index

The value of the Berger-Parker Dominance Index varied from two (Primary forest, Secondary forest, 10-year old teak plantations, Recurrent fallows) to five (mixed crops fields). At the scale of the landscape (eight sites), nine species were

dominants: *Trichouropoda* sp.1 (13.5%), *Afrotrachytes* sp.1 (10.0–21.2%), *Leonardiella* sp.1 (12.1–20.0%), *Trombidium* sp.1 (10.0%), *Carpoglyphus* sp.2 (10.0–14.5%), *Galumna* sp.1 (10.4%), *Trichoribates* sp.1 (11.1–25.5%), *Damaeus* sp.1 (10.0–14.6%), *Lohmannia* sp.1 (14.6–50.0%). The dominant group represented 27.3% of the total species richness (Table S1). The structure of these species revealed that one species was dominant and ubiquitous, particularly *Lohmannia* sp.1 whereas two species, *Galumna* sp.1 and *Trombidium* sp.1 were dominant and specialist (observed in a single land-use type). If we considered the constancy, *Trichouropoda* sp.1, *Afrotrachytes* sp.1, *Galumna* sp.1, *Damaeus* sp.1 and *Lohmannia* sp.1 had a high constancy (ratio between 80 to 100%) and represented 15.2% of the global species richness.

Relationships between mite communities and forest perturbation

A PCA performed on the 5 variables (i.e. community parameters) and 8 objects (i.e. land-use types) revealed that mite density, species richness, diversity and accumulated richness were negatively correlated to the first axis (71%), whereas land-use intensity index was positively correlated to this one (Fig. 4a). Hence, land-use intensity index value was contrasted to the rest of community parameters. In other words, when land-use intensity index increased, values of species richness, mite density and diversity decreased. Along the second axis (13%), community parameters were either negatively or positively correlated. The first two axes accounted for 84% of the total inertia. The distribution of land-use types following the first axis revealed the existence of three main groups (Fig. 4b). The first consisted only to Primary forest; the second composed to Secondary forest and Recurrent fallows. The third group comprised Multi-species planted trees, 4- and 10-year old teak plantations, Cocoa plantations and mixed crops fields. The land-use type distribution was clearly ranked along the second axis, sharing the natural forest and fallow system to timber plantations and mixed crops fields.

Discussion

In this study, the speculation on soil mite richness, diversity and community structure could be appreciated following two points, (1) land use

type and the soil mite variation, (2) mite response induced by the land use intensity.

First point – land use type and the soil mite variation

Several publications have identified the high abundance and diversity of mites in forest soils (Arroyo & Iturrondobeitia 2006; Minor & Cianciolo 2007) compared to agricultural land. This trend agreed with our observation and could be explained by the availability and heterogeneity (food web) of soil organic matter sources in Primary forest with vegetation consisting of several tree species. This creates favourable microclimate for development of a high number of mite species (Hansen 2000; Hansen & Coleman 1998). Indeed, their research revealed that oribatid richness was positively correlated with microhabitat heterogeneity. The complexity of ecological niches and refuges enhance the stability of the soil structure and promotes therefore the development of many mites (Schneider *et al.* 2004). This does not seem to be the case with timber plantations such as Multi-species planted trees (MTP), 10-year old teak plantations (TK94) and 4-year old teak plantations (TK00) where a probable food web limitation would be observed. In fact, the omnipresence of casts from two earthworm species (*Millsonia omodeoi* and *Dichogaster terraenigrae*) in these different agroecosystems contribute to increased soil compaction (Guéi *et al.* 2012; Tondoh *et al.* 2007) and making soil nutrients less available.

The abundance and diversity peak of mites in fallow crops (dominated by the invasive shrub *Chromolaena odorata*) would be due to population growth, characterized by spatial heterogeneity and vegetation regrowth where factors such as the quality and quantity of litter and age of fallow crops play a key role (Koné *et al.* 2012). The fallows based on *C. odorata* with 1–3 years old improved soil biota abundance and richness (Koné *et al.* 2012). The soil mite community from 4-year old teak plantations (TK00) was more abundant than 10-year old teak plantations (TK94). This difference could be explained by the plantation age variation and the great litter production observed in 10-year old teak plantations (TK94). In contrast to other plan-tations, 4-year old teak plantations (TK00) was established on *C. odorata* fallows crops. Improved physico-chemical and biological soil properties by this Adventist were

demonstrated by Koné *et al.* (2012). Even if the study performed by Schneider *et al.* (2007) revealed the absence of relationship between mite biological diversity and shade, the shade factor could indirectly govern soil moisture and temperature, two variables hugely significant for soil mite development (Athias 1975, 1976; Badejo & Akinwole 2006; Ermilov & Łochynska 2008).

In fact, the higher soil moisture, the more abundant mite density and species richness have been found (Noti *et al.* 2003; N'Dri *et al.* 2011). Following the second axis (Fig. 3b), the ordination shows a clear sharing between natural ecosystems foresters with a great shade due to the large canopy and other agrosystems characterized by moderate or absence shade. This observation was similar to results by Badejo & Akinwole (2006). These authors concluded that canopy cover affected the sensitivity of soil dwelling mites on the floor with regard to vertical gradients of light, microclimate and foliage quality. The low abundance and diversity of mites in mixed crops fields (MCF) was supported by this idea.

Second point – mite response induced by the land use intensity

Land use intensity has negative consequences on the soil matrix (Bedano *et al.* 2006; Minor & Cianciolo 2007; Minor *et al.* 2004). Its impacts occur at three levels: (i) physical (ii) chemical (iii) and biological. Physically, we point out the alteration of soil structure, followed by aggregate dispersion. This disturbance promotes a restriction of soil porosity and therefore limits the movement of water and oxygen. The soil disturbance caused by the different types of tillage practices, whether conventional or not, limits the availability of total nitrogen, organic carbon, organic matter and the emergence of soil fauna (Kladivko 2001). It is clear that the effect of increasing land use intensity index on mites was negative in this study. Indeed a lower land use intensity index resulted in larger mite abundance; diversity and species richness (see Fig. 3a, b). The investigation made by Yao *et al.* (2010) in the same area and period shown a high rate of soil organic carbon, total nitrogen, mineral carbon and mineral nitrogen in natural forests (Primary and Secondary forest), followed by a relative decrease in agroecosystems (Multi-species planted trees, 10-year old teak plantations, 4-year old teak plantations and Cocoa plantations) and a low rate (see Table 3) in Mixed crops fields

Table 3. Average values ± SE of topsoil (0–10 cm) characteristics across the landscape. Soil Organic Carbon (SOC), Total Nitrogen (TN), mineralized Carbon and Nitrogen (C min, N min). Adapted from Yao et al. (2010).

Land use type	SOC (g kg^{-1})	TN (g kg^{-1})	C min (µg g^{-1})	N min (µg g^{-1})
Primary forest	24.1 ± 3.4[a]	2.7 ± 0.5[a]	257.76 ± 56.8[a]	107 ± 25.6[a]
Secondary forest	25.84 ± 4.3[a]	2.75 ± 0.4[a]	258.4 ± 48.9[a]	108.66 ± 27[a]
Multi-species planted trees	20 ± 3.1[b]	2.1 ± 0.4[b]	194.71 ± 101.7[a]	105.37 ± 16.5[a]
10-year-old teak plantations	16.92 ± 2.4[c]	1.51 ± 0.2[c]	179.59 ± 90.4[b]	54.11 ± 16.2[b]
4-year-old teak plantations	18.9 ± 2.7[b]	1.9 ± 0.3[b]	183.8 ± 89.7[b]	58.3 ± 15.6[b]
Cocoa plantations	14.79 ± 6.4[c]	1.39 ± 0.7[c]	154.94 ± 65.5[c]	49.79 ± 21.9[c]
Fallows	15.6 ± 5.3[c]	1.4 ± 0.6[c]	121.64 ± 78.3[c]	37.9 ± 23.2[d]
Mixed crop fields	12.92 ± 7.4[d]	1.16 ± 0.8[d]	86.06 ± 30.9[d]	25.43 ± 10.5[d]

Values followed by the same letter(s) are not significantly different (ANOVA, $P < 0.05$).

(MCF). According to Tondoh *et al.* (2011) declining of carbon stock was due to agricultural land intensification, whereas Behan-Pelletier (1999) pointed out that the Oribatid community emerged in soil rich in organic matter. This observation agrees with our data. However, contrary to Osler & Murphy (2005), land use intensity index associated moderately to the weakness of trophical resource are the likely cause of the decline in the abundance and species richness. In definitive, it is important to involve in this investigation the study of microhabitats (Athias 1975, 1976; Hansen 2000; Hansen & Coleman 1998) and soil topography (Illig et al. 2010), thus allowing a better understanding of changes observed in the abundance and diversity of soil mites. For sustainable management of agroecosystems, it would be interesting (i) to plant woody leguminous in an agroforestry context (ii) associate cover crops at the beginning planting (iii) identify transects or permanent passages for the harvest and production collect (iv) use bio pesticides for plant treatment. Thereby promoting improved soil quality by maintaining edaphic fauna biodiversity and ecosystem services.

Acknowledgements

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Supporting Information

Additional Supporting information may be found in the online version of this article.

Table S1. The Berger-Parker index (D) and Constancy (C) of soil mites in the study site.