Plantation de teck et perturbation écologique des sols

Une grande partie de la forêt secondaire de Goulikao a été détruit suite à un incendie survenu en 1983. La présence du *Chromolaena Odorata* (Asteraceae) à 96% sur toute la grille d'étude de Oumé et plus particulièrement dans le domaine rural révèle une forte dégradation des sols. Comme conséquence l'on assiste à une rupture des chaînes trophiques et des cycles biogéochimiques. Un vaste programme de reboisement à base d'essence de teck a été entrepris dans cette localité par la Société pour le Développement des Forêts (SODEFOR). Les nombreuses perturbations du sol liées à la mise en place des parcelles de teck et la faible restitution des éléments niméraux au sol suscitent des inquiétudes. Ce présent article apporte un éclaircissement sur l'usage des plantations de teck à caractère monospécifique comme solution alternative à la disparution des forêts naturelles.

Chapitre 7

Teak plantation vs. primary forest in Oumé, Ivory Coast.

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Abstract

Soil mite was investigated In two sites situated in Ivory Coast. The first one OPF (Oumé Primary Forest), and the second, OTK (Oumé Teak Plantation) was only characterized by a hight disturbance. The sampling was repeated twice. The Berlese Tullgren was used for extracting the mite during one week. After the sorted and description, mite richness are greatest in OPF. The mite density was important in the litter and decreased to the depth in the two sites. All in all, 120 mites species were described in the two sites (98 species in OPF vs 51 in OTK). The mite Shannon index calculated was relativelly similar in the two sites (4.91 in OPF vs 4.63 in OTK). Mite evenness is significantly lower in OPF than in OTK ($N = 9$; $P < 0.05$). Mite exclusive species was higher (91/120) with 29 mites, 17 Oribatida and 12 Gamasida are represented the common species. Whatever the level of partitionning (macrohabitat or microhabitat), the species indicators observed were great in OPF than in OTK.

Key words: Acari, forest, teak plantation, density, species richness, species indicators

Introduction

Deforestation and soil disturbance are a endless threat to species diversity in the tropics. According to FAO (2000), the annual deforestation rate in Africa is about twice as high as the global rate (0.3 versus 0.7%). One of the recommandations of the Convention on Biological Diversity is that measures have to be taken in order to conserve natural forests, mainly tropical forests, which are among the diversity species hotspots considered as a global priority for conservation (Sayer and Wegge, 1992; Myers et al., 2000). To cope with this situation, strategies and concepts such as “enrichment planting, forest plantation and rehabilitation of degraded ecosystems” have been developed. In 1990, the global extent of tree planting is estimated at about 135 million hectares. (FAO, 1993; Gauthier, 1991; Pandey, 1995) with 5% in Africa. Among woody plants grown, the teak (*Tectona grandis*) occupies a prominent place. However, many problems (loss of soil nutrients, soil erosion, site degradation, decrease growth and yield) related to the planting of teak have been reported.(Chacko, 1995; Kaosa-ard, 1995; Nair, 1995). Very early Baden-Powell (1874) declared "Teak is a bad tree forest, it does not improve the soil and its leaves do not translate easily into humus ". Many studies have shown that decomposition is influenced by litter properties, climatic factors and soil biota (Wardle and Lavelle, 1997; Gonzalez and Seastedt, 2001). Also the disturbance of the soil related to the establishment of teak plantations is important. Several studies have reported the impact of tillage (Hülsmann and Wolters, 1998; Bengtsson, 2002; Mando et al., 2005; Morris et al., 2007) and soil compaction (Whalley et al., 1995; Dexter, 2004; Lipiec et al., 2006) on the fauna. Therefore the role of monospecific timber plantations of teak as an alternative solution to the disappearance of natural forests is raising questions. Several studies described the impact of teak plantations on soil fauna (Ananthakrishnan, 1996; Badejo and Ola-Adams, 2000; Attignon et al., 2004, 2005 ; Widyastuti et al., 2006; Tondoh et al., 2007; Kra et al., 2010). In general, the organic matter is the main trophic source for endogenous fauna and would therefore strongly related to the diversity of vegetation cover. The objective of this study is to assess the impact of teak plantations on the soil mites abundance and diversity compared to primary forest. Also it would look if teak plantation can serve as an alternative solution to the disappearance of natural forests.

Material and methods

Study area

The study site was located in the Oumé Région, mid-west Ivory Coast, precisely near the village of Goulikao (6°31’ N, 5°30’ W) at 200 m asl. The average rainfall over 10 years (1998–2007) was 1448 mm. The annual rainfall in 2008 was about 1592 mm, whereas the average monthly temperature was about 26°C. In this area, two sites was investigated. The first, Oumé primary forest (OPF) is a semi deciduous forest, and where Man-made activities are very weak and limited to some tracks. The second, Oumé teak plantation (OTK) was 14-year-old if we considere the study’s years (2008) and where disturbances was greatest. The two sites were adjacent 200m appart. Soils are ferralitic (Assié et al., 2008). More description is given by N’Dri and André (submitted1).

Sampling method

Soil mite was taken with a steel corer (∅ 3.5 cm), from 540 soil cores (2 sites x 15 sets x 9 layers x 2 campaigns). For each sets, 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. At each site, the sets 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).

Mite extraction and identification

Mite were extracted using the Berlese–Tullgren funnels during one week. (Extraction timing was tested in preliminary study). All stases (developmental stages) were descrived and regarded as species adults. The immature abundance was very low (1.65% of mite) to affect the mite biodiversité. Soil mites were identified at the species level by using Keys to oribatid genera (Balogh and Balogh, 1992), Krantz (1978), Dindal (1990) and Krantz and Walter (2009) were consulted for identification at the family level. Some acarologists were consulted, at the “Institut National des Sciences Naturelles de Belgique” and the “Musée Royal de l’Afrique Centrale”.

Mesological parameters

The pH (water), water content (WC) and apparent or bulk density (Baize, 1988; Duchaufour, 1991; Harmand and Njiti, 1998) were measured for each parameter on 480 mineral soil. Other chemical analyses based on 40 samples (0-5cm and 35-40cm) were made by the “Centre Provincial de l’Agriculture et de la Ruralité” in La Hulpe (Belgium). Method ISO norm 10 694 and 13 878 were respectivelly used to measure Organic and total Carbon. Soil organic matter (SOM) was estimated using the formula C_{org} x 1.7 as made previously by Noti *et al.* (2003). More details is given by N’Dri and André (submitted1).

Data analysis

Species richness, *s*, and local diversity: Shannon index (1962) and evenness Pielou (1969) was measured as to concerne the alpha diversity (Whittaker, 1972). This indice was computed by using the SpeDiv program (André, 1997). 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 with 120 species. The same matrix was also used to determine common and exclusive species. The dissimilarity between site, is obtained by subtracting the Jaccard index (%) from 100. The density and alpha diversity means were compared using test-t. All tests were conducted using Statistica 7.1 by StatSoft, Inc. FCA was run with the R package (Casgrain and Legendre 2001) in oder to compare the difference in the species composition from the two sites. The program IndVal (Dufrene & Legendre, 1997) was used to identify indicator species from the different habitats sampled. Before most analysis, the data from two campaigns were pooled because the seasonal effect was already made by N'Dri and André (submitted1).

Results

Mite density

In the two sites and campaigns, the mite density was greater in the litter and decreased with depth (Table 1). Whatever the campaign, the highest densities were observed in OPF, and particular in the second campaign (34 400 mites/dm^3). They differed significantly ($P< 0.05$) from densities in OTK. The same trend was observed in the Oribatida and Gamasida.

Table 1. Density (mean individuals/m²) in litter and mineral soils (0-40 cm) of the major groups of mites in the two sites and two seasons. Totals and percentages are also given. (N'Dri and André Submitted)

	Litter	0-5	5-10	10-15	15-20	20-25	25-30	30-35	0-40	Total	%
DRY SEASON											
OPF											
Gamasida	1 941	1 941	832	971	277	485	693	485	416	8 042	39
Oribatida	3 120	2 288	971	1941	832	1456	485	347	485	11 924	58
Acari	5 200	4 298	1803	3120	1109	1941	1179	832	971	20 451	100
OTK											
Gamasida	1 387	1 387	139	69	0	69	69	0	139	3 258	57
Oribatida	832	555	0	69	69	0	0	69	0	1 595	2
Acari	2 496	2 218	139	139	69	139	347	69	139	5 754	13
RAINY SEASON											
OPF											
Gamasida	6 794	6 239	1 525	485	832	277	69	69	277	16 569	48
Oribatida	6 378	4 576	1 040	277	1 525	485	901	485	69	15 737	46
Acari	13 796	11 647	2 912	763	2 426	832	1 109	555	347	34 386	100
OTK											
Gamasida	1 525	1 040	347	139	69	69	277	485	69	4 021	44
Oribatida	1 941	1 387	277	69	139	0	139	69	0	4 021	44
Acari	3 536	2 426	624	208	208	277	624	1 109	69	9 082	100

Alpha diversity

At the end of extraction, 120 mites species were reported in the two sites (98 species in OPF vs 51 in OTK). Species richness in OPF and OTK was significantly different ($N = 9$; $P < 0.05$). Oribatida and Gamasida richness were also different in OPF (59 vs 25 species) and in OTK (29 vs 20) (Figure 1A).

The Shannon index calculated for mites was similar in the two sites (4.91 in OPF vs 4.63 in OTK). This trend was also observed on the mite evenness (0.74 in OPF vs 0.81 in OTK. Nevertheless, mite evenness is significantly lower in OPF than in OTK ($N = 9$; $P < 0.05$). Oribatida Shannon index was higher in OPF (5.05), whereas evenness were similar in the two site (OPF: 0.85 vs OTK: 0.86). In contrast to this observation, Shannon index (2.79) and evenness (0.64) were more greater in OTK (Figure 1BC).

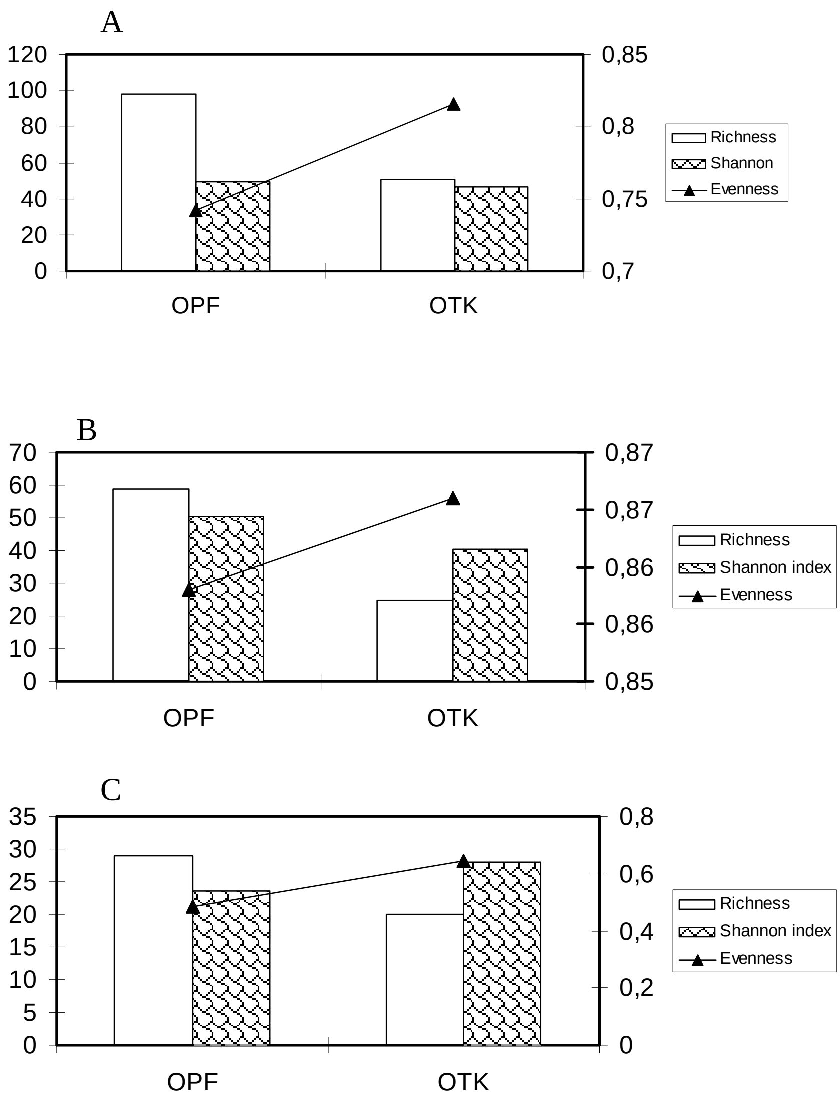

Figure 1. Richness (s, white histogram), diversity (H', shaded histogram) and evenness (J, right scale) for mites (A), Oribatida (B) and Gamasida (C) in the different sites. Left scale: number of species, units of diversity x10, right scale: evenness.

Similarity and species in common

The Jaccard distance between OPF and OTK was 74 if we considered the soil mite. The distance remains similar (71) if we retained the Oribatida and Gamasida (N'Dri and André submitted2).

The number of exclusive mite species was higher in OPF (69 species) than in OTK (22). The common species in both sites were 29 mites, 17 Oribatida and 12 Gamasida (Figure 2).

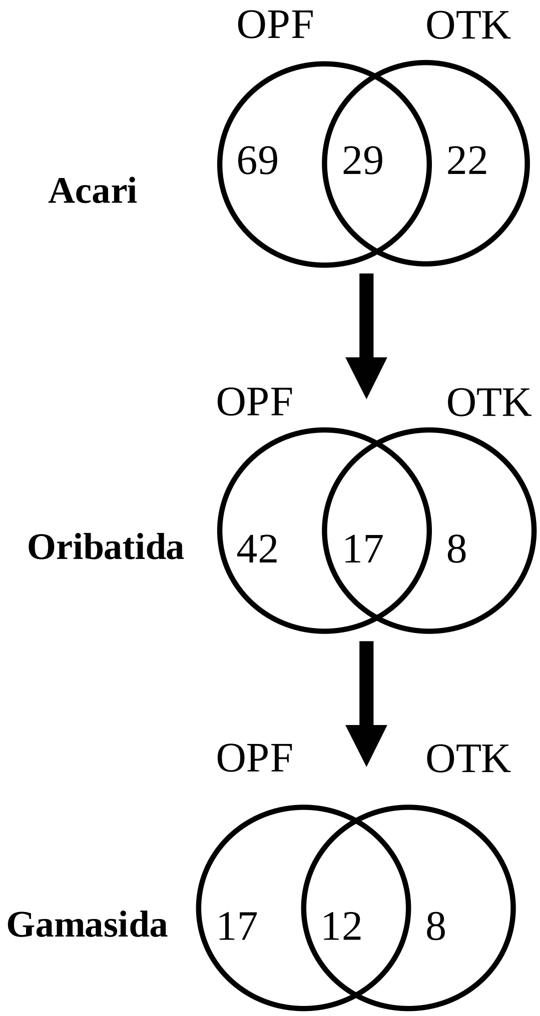

Figure 2. Common and exclusive species in mites , Oribatida and Gamasida observed in the 2 sites.

Indicator species

According to N'Dri and André (paper in preparation), 15 species were indicators of OPF, if we considere the macrohabitats (sites). Only two indicators species was attributed to OTK. A second partition in 2 microhabitats, litter vs mineral soil was made. In this case if sites are considered, only Gamaside sp3 and Actinedide sp8 are respectivelly indicators species of litter and mineral soil in OTK. In contrast 16 indicators species were identified in OPF mineral soil.

Ordination

After FCA projection on to axis 1 and 2, samples from the two sites are opposed along axis 1 (Variance of axis: 12.65%) and OPF and OTK are very distinct (Figure 3).

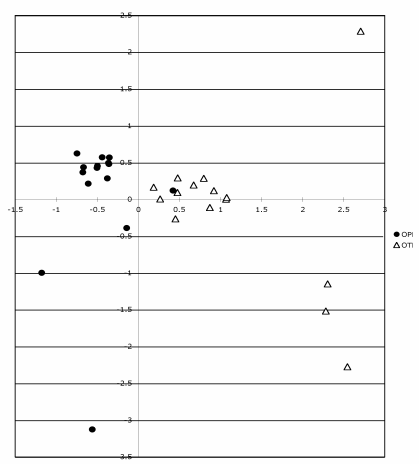

Figure 3. FCA axes 1 and 2 applied to soil mite richness (s) in the two site (OPF: black round and OTK: white triangle).

Discussion

Litter height and decomposition

Whatever the campaign, the litter height was greatest in OPF (9.3 cm in dry season vs. 5.91 in rainy season) than in OTK (7.33 vs. 3.83) (N'Dri and André submitted1). The importance quantity of the litter observed in OPF could be explained by the vegetation structure and plant species identity on the composition of the communities. The same trend was observed by Franklin et al. (2005) in the Amazonian savanna. In contrast to the forest and savanna, the teak plantation (OTK) is monospecific and the rate of litter decomposition is weak (Aksornkoae et al. 1972: 95% of teak litter decomposition observed in Thaïlande vs 100% in tropical humid forest situated in Trinité and Ghana: Cornforth, 1970; Nye, 1961). Nevertheless The dry weight loss of teak litter under field was great compared to some timber (94% for albizia, 64% for eucalypt and 96% for teak). The influence of belowground biodiversity on ecosystem functioning and stability has been taken in consideration (Ekschmitt and Griffiths, 1998; Hooper et al., 2000; Barrios, 2007). The litter type influences the dynamics of soil mites (Gonzalez and Seastedt, 2001; Taylor and Wolters, 2005). This study related that, only in OPF, the litter height was significantly correlated to mite density in dry season (Table 2).

Table 2. Correlation between mite density (mean individuals/dm^3) and mesological variables in the two sites and two seasons. (N'Dri and André submitted).

	OPF				OTK			
	N	*r*	*P*		*N*	*r*	*P*	
DRY SEASON								
Entire profile								
Litter height	15	0.53	0.038	*	15	0.18	0.518	
App. density	8	-0.88	0.003	**	8	-0.70	0.048	*
Water content	8	0.78	0.020	*	8	0.77	0.023	*
pH	8	0.81	0.014	*	8	0.62	0.099	
Depth	9	-0.77	0.015	*	9	-0.68	0.041	*
RAINY SEASON								
Entire profile								
Litter height	15	-0.29	0.283		15	-0.13	0.629	
App. density	8	-0.89	0.002	**	8	-0.52	0.186	
Water content	8	0.94	0.001	***	8	0.63	0.091	
pH	8	0.4	0.316		8	0.46	0.248	
Depth	9	-0.8	0.008	**	9	-0.66	0.050	

Significant at levels 0.05 (*), 0.002 (**), 0.001 (***)

The nutrients (C_{org}, C_{tot}, N_{tot}, C/N and SOM) were more abundant in Oumé forest than in teak plantation (Table 3). Former studies have showed the increase in decomposition rate, nutrient cycling and primary productivity in forest ecosystems (Seastedt, 1984; Moore et al., 2004; Kreuzer et al., 2004). Attignon et al. (2004) also emphasize a more rapid breakdown of the litter in natural forest than in teak plantation. Compared to Oumé forest, the low abundance and species richness observed in teak plantation accords with the results of Ananthakrishnan (1996).

Table 3. Mean and SE values of chemical parameters measured in the two extreme layers of mineral soils in the two sites and two seasons.
(N’Dri and André submitted)

		OPF			OTK	1
DRY SEASON						
0-5 cm						
C_{org} (g/kg)	26.60	±	2.69	16.80	±	1.39
C_{tot} (%)	2.66	±	0.27	1.68	±	0.14
N_{tot} (%)	0.27	±	0.03	0.18	±	0.02
C/N	9.69	±	0.23	9.35	±	0.05
SOM (g/kg)	45.22	±	4.58	28.56	±	2.37
35-40 cm						
C_{org} (g/kg)	6.18	±	0.72	5.44	±	0.14
C_{tot} (%)	0.62	±	0.07	0.54	±	0.01
N_{tot} (%)	0.06	±	0.01	0.05	±	0.01
C/N	10.93	±	1.00	12.31	±	0.94
SOM (g/kg)	10.51	±	1.22	9.25	±	0.24
RAINY SEASON						
0-5 cm						
C_{org} (g/kg)	36.80	±	6.30	16.60	±	0.87
C_{tot} (%)	3.68	±	0.63	1.72	±	0.14
N_{tot} (%)	0.37	±	0.06	0.18	±	0.01
C/N	9.92	±	0.33	9.50	±	0.28
SOM (g/kg)	62.56	±	10.70	28.22	±	1.48
35-40 cm						
C_{org} (g/kg)	5.30	±	0.00	5.44	±	0.14
C_{tot} (%)	0.53	±	0.00	0.54	±	0.01
N_{tot} (%)	0.04	±	0.00	0.04	±	0.01
C/N	13.60	±	1.14	12.95	±	1.35
SOM (g/kg)	9.01	±	0.00	9.25	±	0.24

4.2. Soil disturbance and compaction

The impact of human activities on soil biological and physico-chemical processes has been demonstrated by numerous studies (Kladivko, 2001; Mando et al., 2005; Lipiec et al., 2006; Morris et al., 2007). However, Bengtsson (2002) states that disturbances are ubiquitous in most ecosystems and can be considered from three viewpoints: (1) Frequent pulse disturbances (2) Large infrequent disturbances (3) Press disturbances. The scale and intensity of disturbances can, in turn, significantly affect the response of organisms and resulting successional patterns (Egerton-Warburton and Allen, 2000).

The mean apparent or bulk density observed in the two sites were respectively in dry season : (1.22 in OPF vs 1.04 in OTK) and rainy season (1.04 in OPF vs 1.05 in OTK) (N'Dri and André, submitted1). The bulk density of the soil upper layer (0-5 cm) were respectively in dry season : (0.58 in OPF vs 0.78 in OTK) and rainy season (0.46 in OPF vs 0.84 in OTK). In general bulk density is considered to be the inverse of the porosity. Therefore the high value observed in OTK supposes a low porosity and a high compaction (Dexter, 2004). The negative impact of compaction on soil mites has been confirmed by many studies (Aritajat et al., 1977b; Whalley et al., 2005). This negative impact can explain the low value of mite density and richness recorded in upper layers of OTK (N'Dri and André, Submitted1,2).

The soil water content recorded in OTK was greater than in the Oumé forest (dry season: 12.51% in OTK vs. 7.03 in OPF; rainy season: 18.21% in OTK vs. 15.29 in OPF) (N'Dri and André Submitted1). This trend is also related to soil high compaction in OTK and to the greatest speed of water infiltration in OPF.

4.3. Influence on other biota

Even if Macroinvertebrates influence decomposition through changing the abundance of microdecomposers (Lawrence and Wise, 2000), few studies are devoted to the soil macrofauna sheltered in teak plantations and compared to African (Attignon et al., 2004, 2005) and Ivorian (Tondoh et al., 2007; Kra et al., 2010) forests. Earthworm abundance and diversity were higher in OTK than in OPF (Tondoh et al., 2007). The same trend was observed by Kra et al. (2010) on Coleoptera. The presence of earthworms in degraded areas (OTK) could be attributed to the persistence of native species (*Millsonia omodeoi, Dichogaster terrae-nigrae, Dichogaster baeri*) and the availability of soil organic matter fractions (Tondoh et al., 2007). According to agricultural practices, compacting and uncompacting processes succeeded or compensated one another (Hallaire et al. 2004). In summary, the earthworm abundance and species richness increase whereas those of mites decrease.

Lastly, an example from Benin revealed that the density of fungus-growers species (Macrotermitinae) was significantly higher in teak plantations than in semi-deciduous forest (Attignon et al. 2004, 2005).

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