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Full Length Research Paper

Impacts of land use types on ant communities in a tropical forest margin (Oumé – Côte d'Ivoire)

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Land use and particularly agriculture is a leading cause of below ground biodiversity loss. However this fauna is known to play a key role in soil fertility and to offer many other ecosystem services. In order to better understand the effects of land use on ants which are major component of the tropical soil fauna, these insects were surveyed in the eight main land use types in Oumé (Côte d'Ivoire). These included primary forest, secondary forest, multispecific tree plantations, 10-years old teak plantations, 4-years old teak plantations, food crops, cocoa plantations and fallows. Modified versions of the ants of leaf litter protocol and monolith method were used to sample the ants. Species richness, abundance, diversity and composition of ants varied among these habitats. Food crops and 4-years old teak plantations were the less species rich land use types. However they diverged in term of species composition. Forest habitats were the most species rich, reflecting their relative integrity. Ant subfamily Myrmicinae and genus *Tetramorium* were surrogate for indicating the pattern of species richness change between land uses. These results illustrated the sensibility of ants to changes in land use types and practices and encourage their inclusion in conservation orientated bio-monitoring.

Key words: Ants, soil biodiversity, land use types.

INTRODUCTION

Habitats' loss is widely recognized to be the main cause of local and global biodiversity loss (Caballos and Ehrlich, 2002). Though this loss may have natural origins (natural fires, drought, hurricane etc.), it is primarily linked to land use. Land use activities convert natural landscapes for human use or change management practices on human-dominated lands. They provide humans with their daily needs (that is, food, shelter, fibre etc.) often at the expense of degrading environmental conditions (Foley et al., 2005). Such activities include agriculture (Etter et al., 2006; Borge 2007), urbanization (Eppink et al., 2004; Sadler et al., 2006; Pavao-Zuckerman and Coleman, 2007), livestock ranching (Vermeire et al., 2008; Jabbar, 1993), logging and forest establishment (Dunn, 2004, Watt et al., 2002; Barlow et al., 2007), and mining (Majer, 1983; Andersen, 1993) etc.

In the tropics agriculture and plantation forestry are leading land use that affect biodiversity (Barlow et al., 2007). The contribution of agricultural land use to species loss is significant (Henle et al., 2008; Wilson et al., 1999; Etter et al., 2006; Borge, 2007). It has an effect on species composition through changes in the landscape structure (Burel et al., 1999; Eppink et al., 2004; Howorth and Pendry, 2006). Regarding exotic tree plantations it has been argued that they may contribute to biodiversity loss as they give rise to opportunities for species invasion (Yiang et al., 2003). But they can also be of a particular importance because they may help to retain more forest species as compared to intensive agricultural land use (Barlow et al., 2007; Lindenmayer and Franklin, 2002). Clearly, such alteration of natural systems lead to changes in structure and composition of ecological communities and can therefore affect ecosystem functioning.

Soil macrofauna is known to play a key role in soil fertility (Briese, 1982; Lévieux, 1976) and in many other ecosystem processes such as nutrient cycling, and

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carbon storage (Wasilewska, 1997; Giller et al., 1997; Isaac and Nair, 2005). Esse et al. (2000) found that soil macrofauna played a dominant role in the initial phase of ruminant manure decomposition. Besides, the interaction between organic resource quality and soil macrofauna has a large influence on the timing of organic material incorporation into the soil (Ouédraogo et al., 2004). These organisms provide essential services toward the sustainable functioning of the soil (Ritz and Griffiths, 2001). They are therefore important resources for the sustainable management of agricultural ecosystems particularly in the tropics where most farmers have limited access to inputs and are more reliant on biological functions of the soil (Giller et al., 1997; Pontanier, 2000).

Among soil macrofauna, ants represent a major component of the overall soil fauna in the tropics and they play important roles in both soil and terrestrial food webs at several levels - as herbivores in the neotropics (Hölldobler and Wilson, 1990), predators (Hölldobler and Wilson, 1990; Kaspari, 2000; Moreau et al., 2006), and mutualists (Hölldobler and Wilson, 1990; Moreau et al., 2006). They are the main dispersers of several plant species (Handel et al., 1981). They are also considered to be ecosystem engineers because they can influence nutrients availability for other organisms living in their environment (Jones et al., 1994; Lavelle, 2002). Moreover ants are known to respond quickly to habitat disturbance (Hoffmann and Andersen, 2003) including land use change (Rossi et al., 2006). Hence they can be used as bio- indicators of ecosystem integrity (Andersen et al., 2002).

The present paper focuses on ants in different categories of agricultural land use types and tree plantations in Oumé region (Centre-west Côte d'Ivoire). We address the following questions: (1) How do different land-use types affect species richness, abundance, and composition of ant communities in a tropical forest environment? (2) Is there any ant species characteristic of a land use type?

MATERIALS AND METHODS

Study site

The study was conducted in Côte d'Ivoire, precisely in Oumé area at 6°30'N, and 5°31'W. Average temperature and relative humidity are 26°C and 85%, respectively (Avenard et al., 1971; Bongoua, 2002). The climate regime is subequatorial characterized by bimodal rainfall patterns: from March to June, with a peak reaching 2015 mm in June and from September to October with a second peak attaining 1386 mm in September. The average rainfall is around 1275 mm (N'goran et al., 1997). 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; Angui et al., in prep.). The vegetation is an ombrophile forest, dense and semi-deciduous and is part of the Guinean domain (Guillaumet and Adjanohoun, 1971). Oumé was previously part of the cocoa production zone from 1965 to 1975, for this reason the region is called "the old loop of cocoa". The primary forest (suitable for cocoa farming) formerly covered 585.80 km² but has now decreased steadily down to 72.32 km², as a result of human pressure on land and on forest resources. In Oumé human induced degraded areas including cultivated areas, fallows, and degraded forests represent up to 72% of the whole area today. The zone also possesses the "Forêt Classée de la Téné" (Téné classified forest) which covers 297 km² and ranked as the second largest forest reserve in the Centre-West. Our study area covers 4 km^2 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. This constitutes a sampling grid containing 107 sampling points at 200-m intervals in the 8 most representative land use types (Figure 1).

The rural domain belongs to the local people and is consisted of 3 land use types: (1) Fallows are 2 to 5 years old abandoned land that are thereafter used for food crop farms. (2) The cocoa plantations are cash crops. Food crops are always included in the cocoa farms matrix at their earlier stage. For example peasants always plant plantain before cocoa, so that the first can provide shade to the second. (3) The food crops or mixed-crops comprise a mixture of annual and perennial food crops, such as: cassava, yam, plantain, maize and vegetables. The rural domain is characterised by low input agricultural lands. Peasants cut the forest manually to settle their cocoa farms or food crop fields. They do not use fertilizers instead they practice crop rotation and fallow system.

The SODEFOR domain comprised 5 different land use types:

(1) The primary forest is a semi-deciduous type characteristic of the humid zone. It is the original vegetation in the region but today it represents only 5% of the "Forêt Classée de la Téné".
(2) The secondary forest is constituted of both the primary forest and local fast growing tree plantation (*Terminalia ivoriensis*, *Terminalia superba*, *Gmelina arborea*) that has unfortunately undergone bush fire in 1983 and has been left to regenerate naturally. This forest represents 26% of the "Forêt Classée de la Téné".
(3) The multispecific plantations are mainly composed of native (*T. ivoriensis*, *T. superba*, *G. arborea*) and exotic (*Tectona grandis* commonly called Teak*)* plant species.
(4) The 10-years old teak plantations, and
(5) 4-years old teak plantations are different age plantations of *T. grandis.* The multispecific plantations and the two types of Teak plantations represent 62% of the whole forest. Tree plantations in the SODEFOR domain are settled under high input conditions. Those conditions include the use of heavy machines to clear the original vegetation and also the use of herbicides, organic and chemical fertilizers to improve tree growth (especially at the early stage of the plantation).

Sampling methods

Four methods were used to collect ants in the different land use systems.

A modified version of the ALL (ants of leaf litter) protocol (Agosti and Alonso, 2000) was followed to collect leaf litter ants. This protocol combined the use of winkler sacks and pitfall traps. Due to the small size of the food crop fields 5 litter samples (instead of 20 in the original version of the protocol), 1 m^2 each, were collected at 10 m interval along a 50 m transect line. Prior to their collection the leaf litter material was chopped with a machete to disturb the ants nest. The collected litter was sieved with a 1 cm grid size sieve, to remove large debris and confine the fauna into the sieved fraction. Additionally, pitfall traps were set next to each 1 m^2 where leaf litter was collected and these pitfall traps were left in the field for 48 h. The sieved litter was hung in mini-winkler bags so as to extract the fauna for 48 h, and the ants were sorted.

In order to have access to underground dwelling ant species, we used the monolith method (Fisher and Robertson, 2002; Yéo,

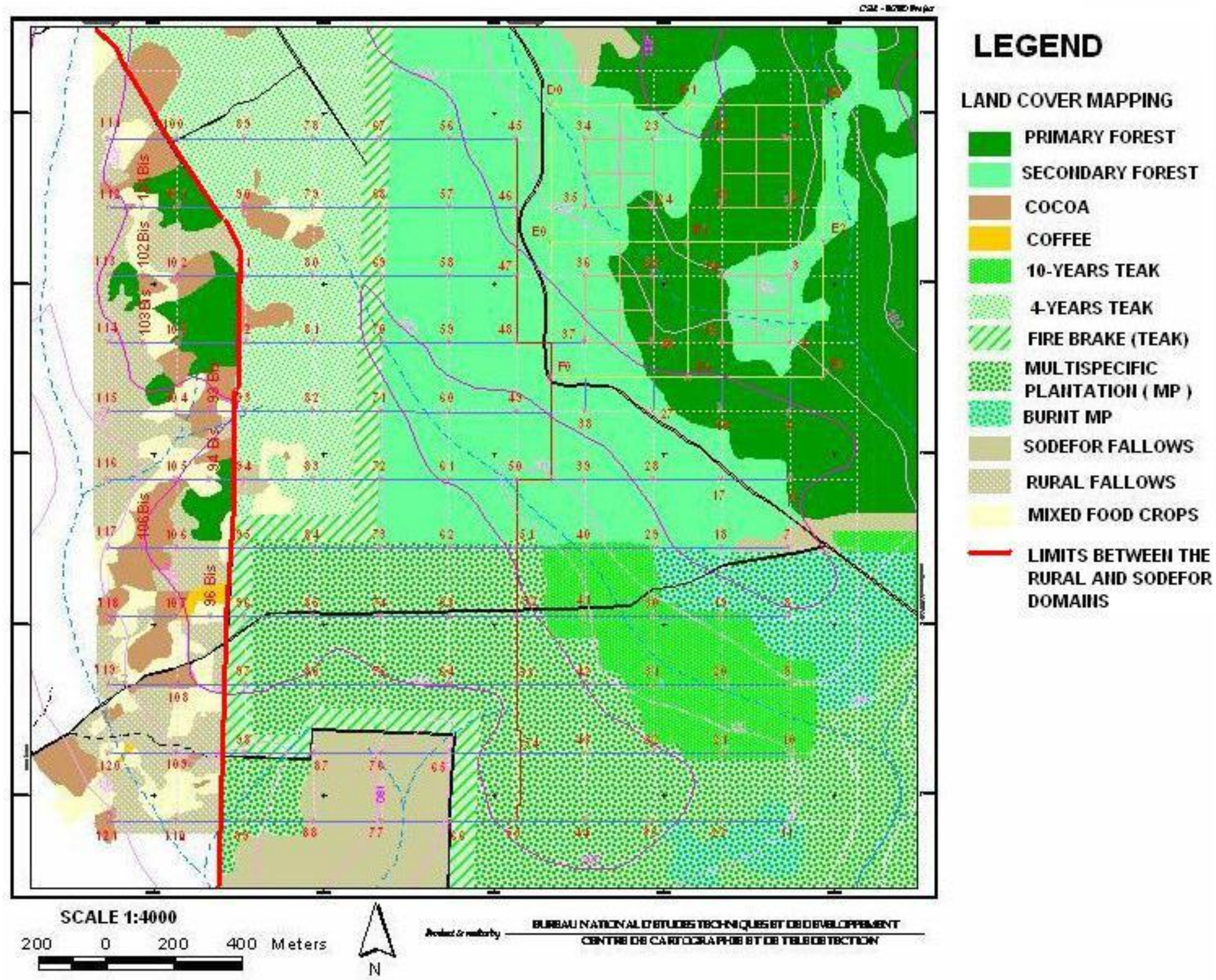

Figure 1. Map of sampling area showing the land use types and the extent of the sampling grid within the rural and the SODEFOR domains (Modified from CSM-BGBD project maps).

2006). This method consists in digging out 5 soil monoliths of 2700 cm^3 (30 × 30 × 30 cm) 10 m apart along the leaf litter transect. The soil sample is then manually searched for ants.

Both methods were standardized among land use types as they were used in four repetitions of each of them. A total of 32 points were sampled intensively within the grid using these methods. Each monolith is associated to a winkler sample and a pitfall trap, and all three represent a sampling station. Thus there were 5 sampling stations at each of the 32 sampling points. The whole grid contained 160 sampling stations and the same number of samples collected using each standardized method.

In addition to the standardized methods we also made a systematic monolith sampling in the center of all the 107 points of the grid. While the standardized methods focused on ant, this central monolith was designed to sample all the components of the soil fauna and was 25 × 25 × 25 cm in size (Figure 2 shows our sampling protocol).

We also collected ant manually in the 32 points when visiting particular micro-habitats such as dead woods, tree trunks, stones and young leaves. Systematic monolith and hand collections are the non standard methods and are termed here as general collection.

Species identification

Ant species were sorted from the other organisms and debris. Afterwards they were mounted on pins and identified to species or morphospecies level using keys (Bolton, 1994, 2000).

Data analysis

We considered the sampling stations as unites in our analysis, consequently there were 20 sampling stations for each land use type. Our measure of ant diversity is based on observed species richness; however Simpson index of diversity (1/D) was used and was computed with the software ecological methodology (Krebs, 2002).

Because of ants' social habits a strict evaluation of their abundance should be based on nests count. But practically it is impossible to count all the nests in leaf litter and the soil as many

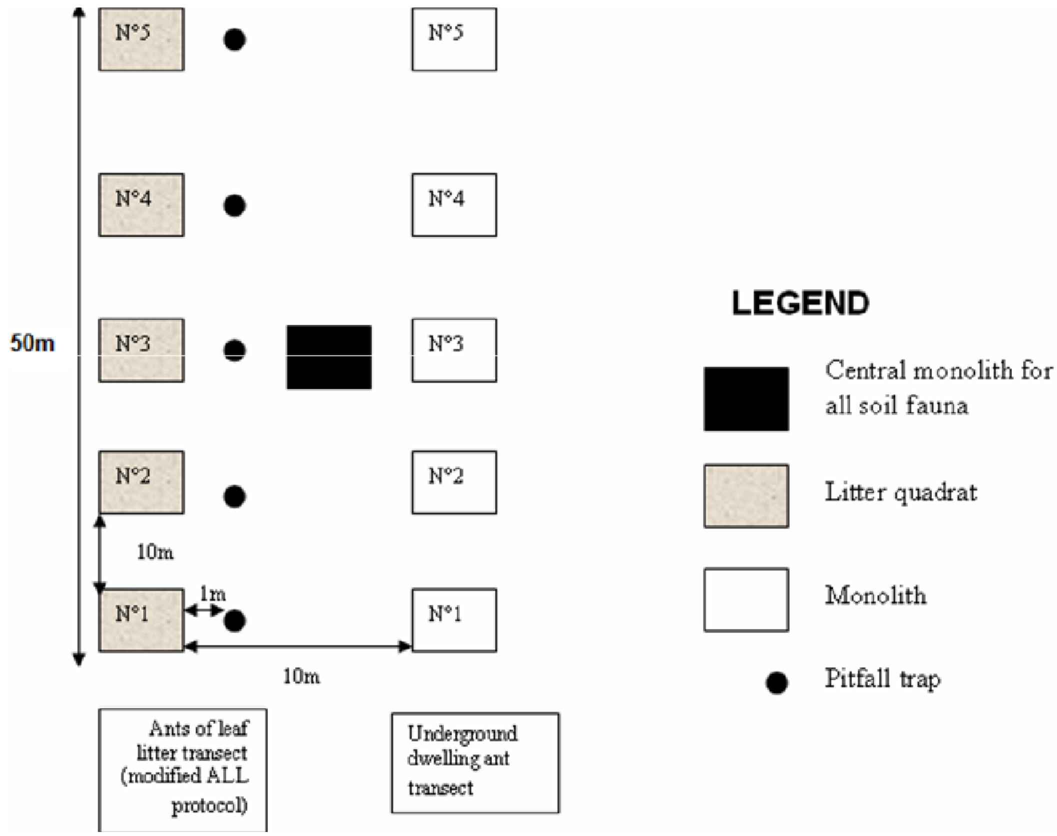

Figure 2. Sampling scheme within a point of the grid.

species have inconspicuous nests. For this reason we used species frequency of occurrence (how often a given species was encountered independently in the samples) to evaluated abundance. Occurrences were preferred because the number of individuals could be misleading when dealing with social animals such as ants that have patchy distribution (Fisher, 1999). In fact depending on species, some nests can contain a few dozens of individuals while others can have several hundreds or thousands.

Relationships among land use types based on their species composition were searched for using the analysis of proximity in STATISTICA (Statsoft-France, 1999). This method is used to arrange the land use type within a space in such a way that the distance between them shows their degree of similarity in terms of species composition. The dissimilarity matrix we used for this analysis was constructed from the Morrisita-Horn index of similarity which was computed with version7.5 of the software EstimateS (Colwell, 2004).

We use ANOVA of Kruskal-Wallis to perform among land use type comparison, and then multiple comparisons were employed for paired habitats. We used Spearman correlation to test for surrogate taxa that can indicate the general pattern of the whole ant community in different land use types. The analyses are based on the data from the standard methods used in the 32 sampling points and all methods are combined.

RESULTS

Species richness, abundance and diversity

We collected 132 ant species in the 32 points sampled intensively with standard methods and 23 additional species were specifically recorded using general collection (hand collections and central monoliths). In total 155 species belonging to 43 genera and 10 sub-families (Table 1) were recorded for the whole sampling grid. These species totaled 2286 occurrences. Among the 132 species collected using standard methods, 52 were found specifically in the SODEFOR domain while only 15 were exclusively collected in the rural domain. The two domains shared 65 species representing 49.24% of the total. Therefore there was a decrease in species richness from the SODEFOR (117 species) to the rural domain (80 species). In the rural domain the highest number of species was observed in fallow and the lowest in food crops where open area ant species such as *Tetramorium sericeiventre* and *Monomorium afrum* were exclusively recorded. The SODEFOR domain was characterized by high species richness in primary forest while this parameter was low in 4-years old teak plantations (Figure 3). Although, the pattern of species richness decrease was not statistically significant between land use types, it clearly indicates what is going on. The three most important subfamilies in term of species richness were Myrmicinae (49.28%), Ponerinae (21.43%) and Formicinae (16.43%). Based on species richness pattern within each domain, we found that species belonging to genus *Tetramorium* and the whole

Table 1. Taxonomic structure of the ants in Oumé. Scores represent the total number of occurrences in the different land use types, those in bold indicate exclusive species to the corresponding land use.

Sub-famillies	List of species	Fallow	Cocoa	Food crops	Primary forest	Secondary forest	Multispecies plantations	10-years old Teak	4-years old Teak
Aenictinae	*Aenictus* sp.*01*	0	0	0	0	1	0	0	0
	Cerapachys foreli	1	1	1	0	0	0	1	0
Cerapachyinae	*Cerapachys kenyensis*	0	0	0	0	1	0	0	0
	Cerapachys nitidulus	0	1	2	4	4	1	1	0
	Cerapachys sp.07	0	0	0	0	1	0	0	0
	Sphinctomyrmex sp.01	0	0	0	0	0	1	0	1
	Dorylus nigricans	9	11	3	2	2	3	4	0
Dorylinae	*Dorylus fuscipennis*	0	1	3	1	3	0	0	2
	Dorylus sp.*06*	2	1	3	0	0	0	0	0
	Dorylus fulvus	1	1	0	0	0	0	0	3
	Axinidris sp.*01*	0	0	0	0	1	1	0	0
	Tapinoma lugubre	7	12	11	3	2	10	0	18
Dolichoderinae	*Technomyrmex albipes*	0	0	0	1	0	0	0	0
	Technomyrmex andrei	5	1	0	13	4	0	5	0
	Technomyrmex sp.05	0	0	0	0	1	0	0	0
	Camponotus acvapimensis	7	12	21	3	2	0	3	7
	Camponotus maculatus	3	1	3	3	3	6	3	1
	Camponotus sp.04	1	0	0	0	0	0	0	0
	Camponotus sp.09	0	0	1	0	0	0	0	0
	Camponotus sp.10	1	0	0	0	0	0	0	1
	Camponotus sp.11	0	0	0	2	0	0	1	1
	Camponotus sp.13	2	0	4	0	0	1	0	2
Formicinae	*Camponotus vividus*	1	0	0	1	1	0	0	2
	Caponotus solon	1	0	0	0	0	0	0	0
	Lepisiota angolensis	1	0	0	0	0	0	0	2
	Lepisiota capensis	11	5	12	0	0	0	1	4
	Lepisiota egregia	1	0	2	0	0	0	0	0
	Lepisiota sp.03	0	0	1	0	0	0	0	1
	Lepisiota sp.07	3	2	3	0	0	1	0	1
	Lepisiota sp.08	1	0	1	0	0	0	0	1

Table 1. Continued.

	Oecophylla longinoda	2	6	2	0	1	3	2	0
	Paratrechina arlesi	1	0	0	1	4	0	0	0
	Paratrechina longicornis	0	0	0	0	0	0	1	0
	Paratrechina sp.04	2	2	1	2	0	0	0	1
	Paratrechina weissi	9	2	12	1	0	0	0	0
	Plagiolepis mediorufa	3	0	0	2	1	1	1	0
	Polyrhachis concava	1	1	1	0	0	2	0	0
	Polyrhachis laboriosa	0	0	0	0	1	0	0	0
	Polyrhachis militaris	2	0	0	0	0	0	1	0
	Polyrhachis schistacea	0	0	0	1	0	0	0	0
	Polyrhachis sp.08	0	1	0	0	0	0	0	0
Pseudomyrmecinae	*Tetraponera mocquerysi*	2	0	0	0	1	1	0	0
	Calyptomyrmex kaurus	5	2	7	8	10	2	3	0
	Cataulacus guineensis	0	1	0	1	0	0	0	0
	Cataulacus traegaordhi	3	1	0	0	0	0	0	3
	Cardiocondyla emeryi	1	0	0	0	0	0	0	0
	Cardiocondyla neferka	0	1	0	0	0	0	0	0
	Crematogaster africana	0	0	0	2	3	5	1	0
	Crematogaster rugosa	0	0	0	0	1	0	0	0
	Crematogaster sp.02	0	0	0	1	0	0	0	0
	Crematogaster sp.03	0	0	0	0	1	1	0	1
Myrmicinae	*Crematogaster* sp.06	0	0	0	0	0	0	0	1
	Crematogaster sp.09	2	0	0	1	0	0	0	0
	Crematogaster sp.14	0	4	0	0	0	1	0	0
	Crematogaster sp.17	1	0	0	0	0	0	0	0
	Crematogaster striatula	9	9	6	24	35	18	10	6
	Decamorium decem	0	4	1	1	1	7	2	1
	Monomorium afrum	0	0	1	0	0	0	0	0
	Monomorium egens	2	1	7	0	4	8	2	4
	Monomorium invidium	13	13	1	15	18	11	16	8
	Monomorium pharaonis	1	1	0	0	0	1	1	1
	Monomorium sp.05	8	10	8	2	6	10	5	12
	Monomorium sp.06	2	0	0	3	0	0	0	0

Table 1. Continued.

Monomorium sp.09	0	0	0	1	0	0	0	0
Monomorium sp.10	0	0	0	1	0	0	0	0
Monomorium sp.12	0	1	0	0	0	0	0	0
Carebara (Oligomyrmex) diabolus	0	0	0	1	0	0	0	0
Carebara (Oligomyrmex) elementeitae	0	0	0	0	2	0	0	1
Carebara (Oligomyrmex) silvestrii	0	0	0	0	1	0	0	0
Carebara (Oligomyrmex) sp.02	0	0	0	0	0	1	1	0
Carebara (Oligomyrmex) sp.08	0	0	0	0	0	0	0	1
Carebara (Oligomyrmex) thoracicus	11	10	6	14	14	14	12	1
Paedalgus saritus	0	0	0	0	2	0	0	1
Pheidole buchholzi	4	1	0	13	14	2	5	0
Pheidole excelens	5	3	6	0	0	1	0	0
Pheidole sp.7	25	13	19	16	19	29	17	27
Pheidole minuscula	0	0	0	0	0	0	1	0
Pheidole sp.02	0	0	0	3	0	0	0	0
Pheidole sp.03	0	0	0	3	1	3	9	0
Pheidole sp.06	0	0	0	10	2	0	0	0
Pheidole sp.09 *(group termitophila)*	1	7	8	13	13	9	6	2
Pheidole sp.11	1	0	0	0	0	0	0	0
Pheidole sp.12	0	1	0	1	0	2	1	0
Pheidole sp.15	0	0	0	0	0	0	1	0
Pheidole sp.8 (group termitophila)	6	10	6	3	9	11	4	4
Pristomyrmex orbiceps	1	0	1	9	10	0	0	0
Pyramica ludovici	2	0	0	0	0	0	1	0
Pyramica maynei	3	0	1	3	3	1	0	0
Pyramica minkara	0	0	0	0	1	1	0	0
Pyramica ninda	1	3	1	0	1	4	1	0
Pyramica roomi	1	1	0	1	2	0	0	0
Pyramica serrula	0	0	0	0	2	2	1	0
Pyramica sistrura	0	0	0	1	0	0	0	0
Pyramica tetragnatha	0	0	0	0	1	0	1	0
Strumigenys rufobrunea	17	5	11	9	10	14	14	13
Terataner velatus	1	0	0	0	1	0	0	0
Tetramorium aculeatum	0	0	0	1	0	0	0	0
Tetramorium Amentete	0	0	0	2	0	0	0	0
Tetramorium anxium	0	0	0	0	**1**	0	0	0

Table 1. Continued.

	Tetramorium brevispinosum	0	0	0	6	3	0	0	0
	Tetramorium calinum	1	0	0	13	2	1	0	0
	Tetramorium distinctum	0	0	0	5	2	0	0	0
	Tetramorium flavithorax	4	2	0	5	1	4	8	1
	Tetramorium guineense	0	0	0	4	2	0	0	0
	Tetramorium intonsum	2	5	1	1	4	7	1	1
	Tetramorium minimum	0	0	0	6	8	0	0	0
	Tetramorium sericeiventre	0	0	2	0	0	0	0	0
	Tetramorium sp.05	2	0	0	1	3	1	4	0
	Tetramorium sp.18 *(close to occidentale)*	2	2	6	0	0	0	0	0
	Tetramorium sp.22	0	2	0	1	0	0	0	0
	Tetramorium sp.26	0	0	0	2	3	0	0	0
	Tetramorium sp.28	0	0	0	1	0	0	0	0
	Tetramorium sp.29	0	0	0	1	0	0	0	0
	Tetramorium sp.30	0	0	0	0	2	0	0	0
	Tetramorium sp.31	0	0	0	0	1	0	0	0
	Tetramorium zambezium	15	15	15	16	11	16	8	5
Amblyoponinae	*Amblyopone mutica*	2	1	0	1	3	0	1	1
	Amblyopone santschii	0	0	0	0	1	0	1	0
Ponerinae	*Anochetus katonae*	1	1	0	7	8	2	0	0
	Anochetus siphneus	3	3	0	5	6	4	1	1
	Anochetus sp.04	0	1	0	1	0	1	0	0
	Asphinctopone silvestrii	0	0	0	3	2	0	2	0
	Centromyrmex sellaris	0	2	0	0	0	0	0	2
	Hypoponera inaudax	0	0	0	2	0	1	1	0
	Hypoponera dulcis	0	4	0	1	1	0	2	1
	Hypoponera sp.01	6	3	1	6	8	3	3	1
	Hypoponera sp.03	2	0	0	0	0	0	3	0
	Hypoponera sp.05	0	0	0	0	2	2	0	0
	Hypoponera sp.06	0	1	1	7	5	6	2	0
	Hypoponera sp.07	0	0	0	0	1	0	0	0
	Hypoponera sp.08	0	0	0	2	0	0	0	0
	Leptogenys sp.03	0	0	0	0	1	0	0	1
	Leptogenys sp.04	0	1	0	1	2	0	2	0

Table 1. Continued.

	Loboponera basalis	0	0	1	0	0	1	0	0
	Loboponera nasica	0	0	0	**1**	0	0	0	0
	Loboponera obeliscata	0	0	0	**1**	0	0	0	0
	Loboponera politula	0	0	0	1	2	0	0	0
	Odontomachus troglodytes	5	9	17	1	0	19	11	30
	Pachycondyla ambiga	0	1	0	0	1	0	0	0
	Pachycondyla brunoi	5	4	2	16	23	21	7	7
	Pachycondyla caffraria	7	3	10	3	1	12	11	5
	Pachycondyla pachyderma	0	0	0	3	1	0	0	0
	Pachycondyla silvestrii	0	0	1	0	0	6	0	0
	Pachycondyla soror	4	0	0	4	2	3	6	0
	Pachycondyla tarsata	9	15	11	0	3	15	4	16
	Platythyrea conradti	0	0	0	2	3	0	0	0
	Platythyrea modesta	0	0	0	1	1	0	0	0
	Plectroctena anops	0	0	0	0	0	0	0	**1**
	Plectroctena cryptica	0	0	0	0	2	0	0	1
	Plectroctena lygaria	0	**1**	0	0	0	0	0	0
	Plectroctena minor	0	0	0	0	0	1	1	0
	Psalidomyrmex foveolatus	9	4	4	6	7	11	6	5
	Probolomyrmex guineensis	0	0	0	3	3	0	0	0
Proceratiinae	*Proceratium* sp.01	0	0	0	0	0	0	0	**1**
	Discothyrea oculata	**1**	0	0	0	0	0	0	0

subfamily Myrmicinae to which they belong, were surrogate for indicating the decrease in species richness (Figure 3). This result was emphasized by a high correlation between total species richness pattern and that of Myrmicinae and *Tetramorium* species (Figure 4). The species accumulation curves continue to grow in the 8 land use types (Figure 5) although we had a sampling coverage of 73.29 ± 3.88. These curves also show the ordering of the land use types based on species richness and sampling effort.

Table 2 shows the species richness, abundance and diversity in each land use type for the 32 sampling points. Using ANOVA of Kruskal-Wallis, we found a statistical difference among land use types based on their species richness ($p = 0.004$). However paired comparisons showed that only the 4-years old teak plantations differed from the primary forest ($p = 0.017$) and from the secondary forest ($p = 0.04$).

Similar results were obtained with Simpson index of diversity ($p = 0.04$). Paired comparisons also indicate that the 4-years old teak plantations differed from the primary forest ($p = 0.01$) and from the secondary forest ($p = 0.04$). Abundance data also show a significant difference among land use types ($p = 0.011$). But we failed to detect any difference between paired habitats. The rank-abundance curves (Figure 6) suggest that in the 4-years old teak plantations there is a marked dominance of a few species. Besides primary forest was the land use type that better conserve ants in the SODEFOR domain while fallows did so

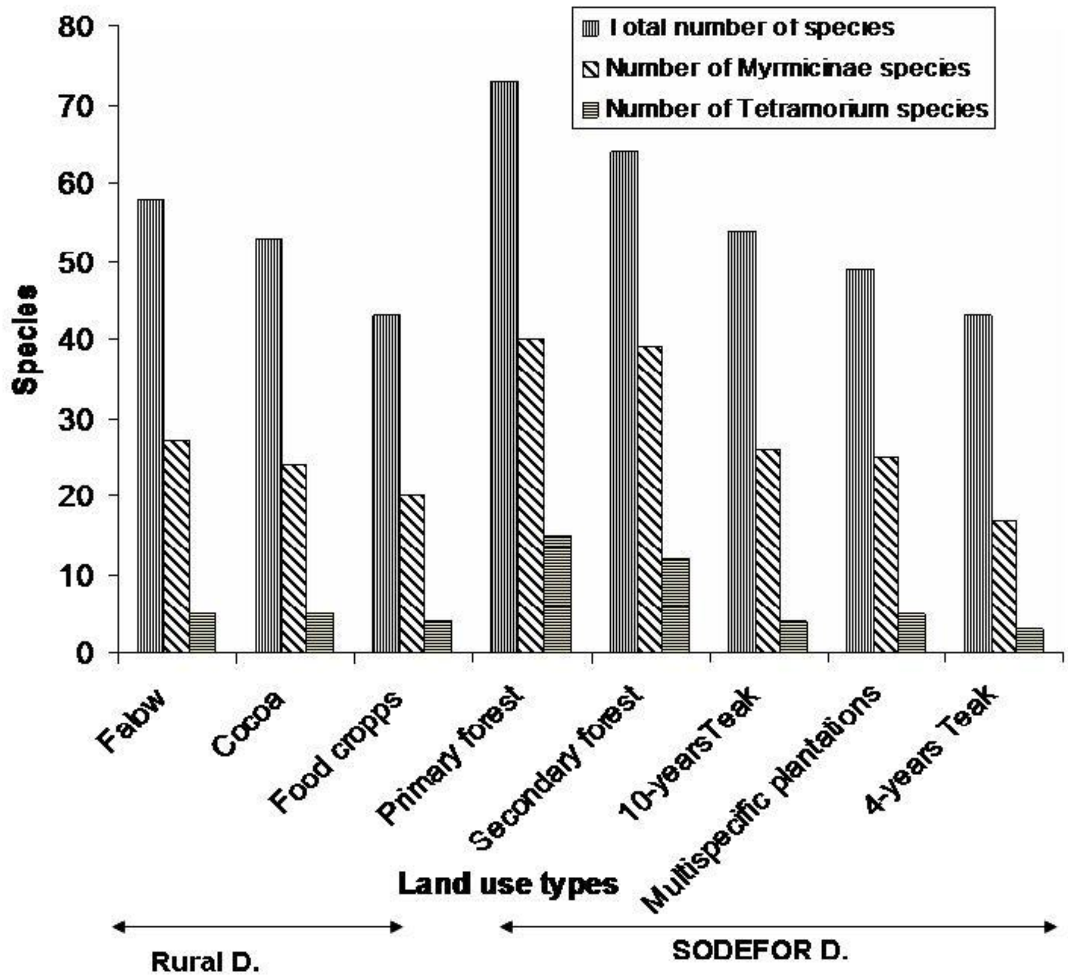

Figure 3. Pattern of species richness in different land use types.

in the rural domain.

Species composition

Based on species composition, the analysis of proximity showed that the land use types could be gathered into three groups (Figure 7). The first group comprises the primary and the secondary forests; these are species rich habitats with close species compositions. The second group contains the food crops and the 4-years old teak plantations; they are species poor habitats and they diverge in term of species composition. The third group includes habitats with intermediate species richness and they have close species composition

DISCUSSION

Among the 155 ant species collected during this survey, two of them (*Axinidris* sp. And *Plectroctena anops)* are clearly new records for Côte d'Ivoire. However it is possible that we have done further new records especially in genera with unclear taxonomy such as Pheidole, Camponotus and Crematogaster in the Afrotropical biogeographical region.

The results of this study show that ant community parameters such as species richness, abundance and species diversity varied among land use types in Oumé though comparisons between paired habitats did not always yield statistical differences. There was a decrease in species richness from the SODEFOR to the rural domain, and within each domain from the relatively well conserved land use types to the most degraded or extensively managed ones. Species belonging to genus *Tetramorium* like the whole subfamily Myrmicinae proved to be surrogate taxa for indicating the decreasing pattern of species richness. These results indicate that land use types affect the soil and leaf-litter ant communities in Oumé. This partly contradict the results of Belshaw and Bolton (1994) who surveyed the soil and leaf litter ants in primary forest sites, secondary forest sites and cocoa

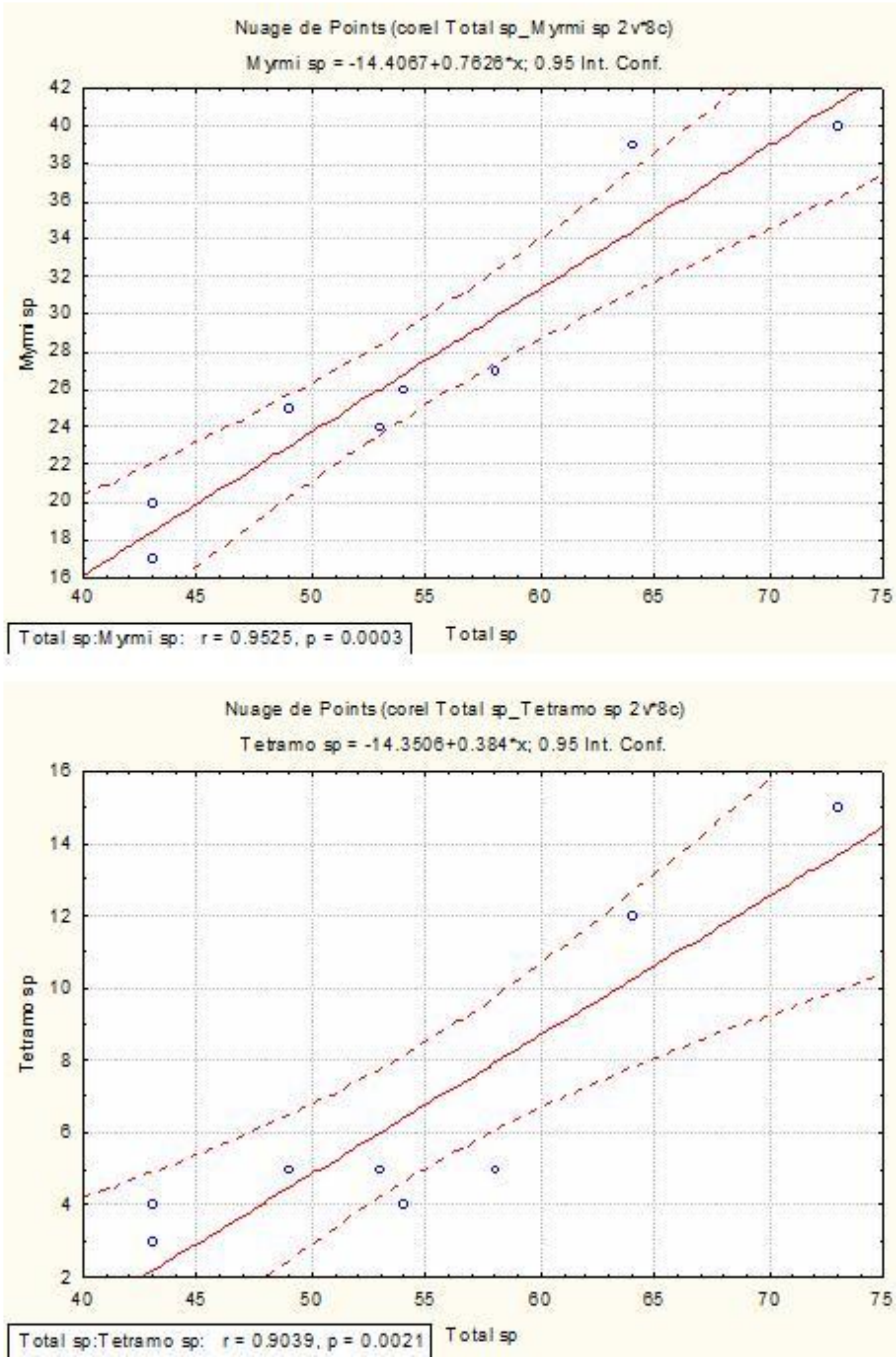

Figure 4. Correlation showing ant subfamily Myrmicinae and genus Tetramorium as surrogates for indicating species richness pattern in the different land use types

plantations in Ghana. They found no difference between the numbers of species in the three site types and concluded that forest clearance and cocoa farm establishment in Ghana had little effect on species richness and composition on leaf-litter ant fauna.

Our results are similar to those of Watt et al. (2002) who measured the impact of forest clearance and different methods of establishing forest plantations on the abundance, richness and composition of ants. The difference between the 4-years old teak plantations and the two forest sites (primary and secondary) could be explained by the method of establishment of the teak plantation (a bulldozer is used to remove most of the native vegetation before teak plantation) . This method results in a reduction of canopy cover, leaf litter and leads to soil compaction. Indeed, Angui et al. (in prep.) found

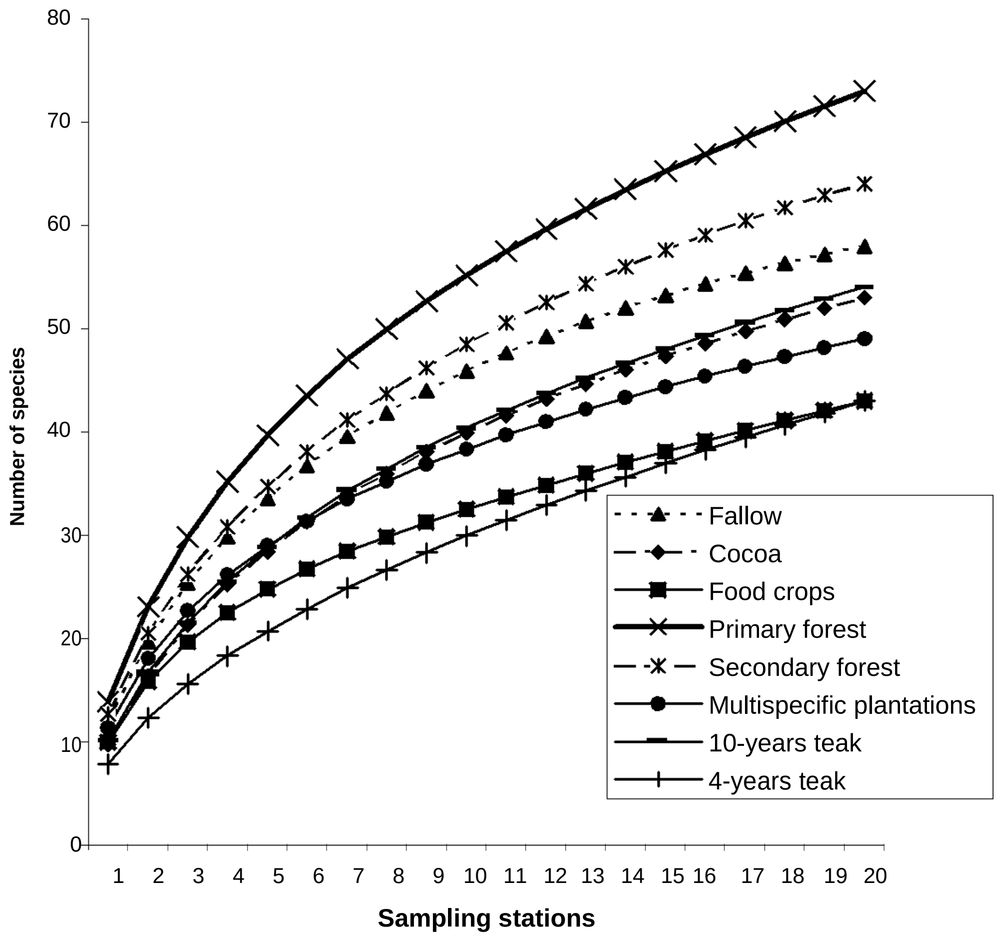

Figure 5. Species accumulation curves showing richness evolves in relation to sampling effort.

Table 2. Mean species richness, abundance and diversity of ants per land use types (n= 4).

Land use types	Species richness	Abundance	Simpson index of diversity (1/D)
Fallow	31.00 (± 2.71)	68.00 (± 1.82)	16.93 (± 2.01)
Cocoa	28.25 (± 5.19)	56.50 (± 10.47)	14.95 (± 2.54)
Food crops	23.75 (± 3.20)	57.00 (± 6.93)	12.97 (± 1.26)
Primary forest	36.75 (± 5.12)	79.25 (± 15.75)	19.00 (± 3.52)
Secondary forest	35 (± 6.83)	71.50 (± 8.50)	17.67 (± 4.17)
Multi-specific plantations	27.50 (± 4.36)	65.00 (± 2.71)	14.99 (± 1.73)
10-years old Teak	26.75 (± 3.77)	54.50 (± 5.07)	14.01 (± 1.89)
4-years old Teak	20.75 (± 4.72)	49.00 (± 10.83)	9.73 (± 2.91)

that in more disturbed habitats (food crop fields and 4-years teak plantations) soil bulk density and soil compaction were higher, as compared to fallow and primary forest (respectively in the rural and SODEFOR domain), where soil disturbance was minimum. The consequence of teak plantation establishment method on soil and leaf litter ant communities; is a lost of species and a change in species composition. Moreover the rank-abundance curves showed that in the 4-years old teak plantations very few species were particularly abundant as compared to over habitats. These are wide spread species and include *Odontomachus troglodytes, Pheidole* sp.7, *Tapinoma lugubre, Strumigenys rufobrunea, Pachycondyla tarsata* and *Monomorium invidium*. This indicates that the 4-years old teak plantations are still at the first stages of their colonization by ants species that have no special adaptations to habitats.

Ours results on species composition reinforce those

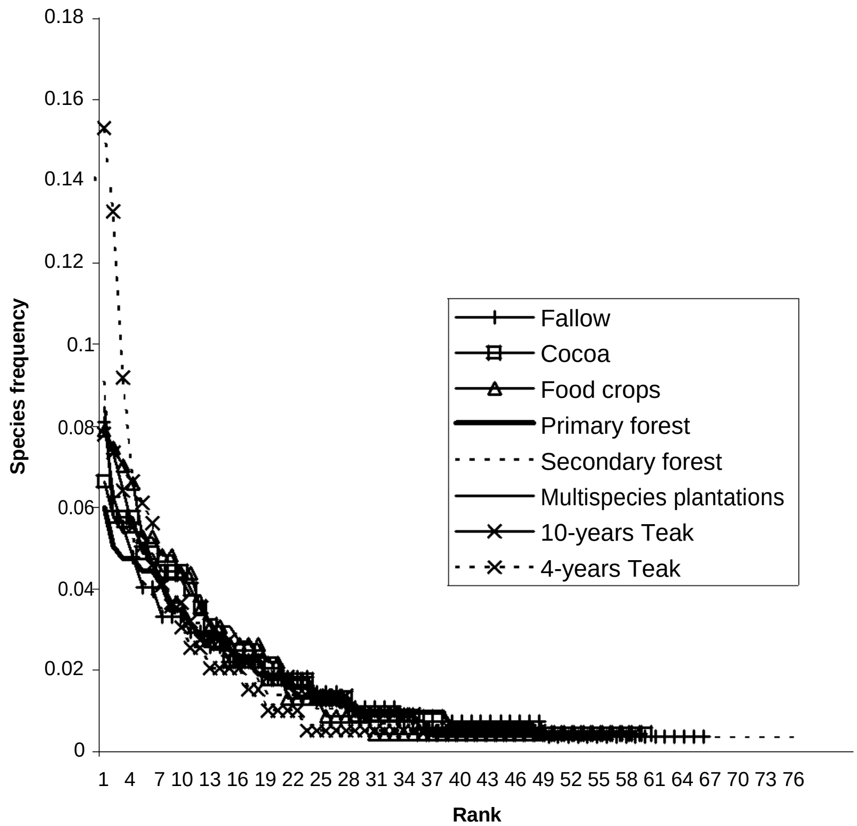

Figure 6. Rank-abundance curves in the different land use types.

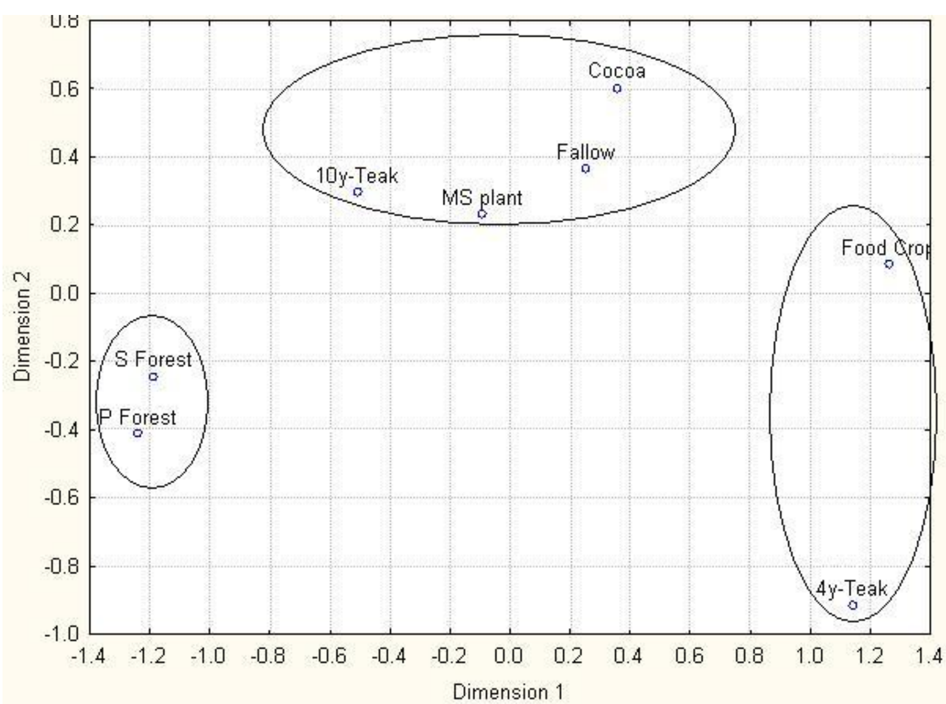

Figure 7. Scatter plots in 2 dimensions (Stress = 0.05) showing the proximity of ant species composition among land use systems (P Forest: primary forest; S Forest: secondary forest; 10y-Teak: 10 years old teak plantation; 4y-Teak: 4 years old teak plantation; MS plant: multi-specific plantation.

on richness, abundance and diversity. The analysis of proximity based on similarity in ant species composition clearly separated three groups of land use types. (1) The first one comprised the relatively well conserved habitats (primary and secondary forests) characterized by their species rich ant fauna and the similarity of their species composition. These habitats are supposed to host the native ant fauna and are believed to conserve better the ant fauna. (2) Two habitats compose the second group (4-years old teak plantation and food crops). These habitats are species poor (both 46 species) but diverge in their species composition. They represent the most disturbed habitats respectively in the SODEFOR (4-years old teak plantation) and the rural domain (food crops). Their difference in species composition can be explained by the fact that they represent two contrasting land use types. Food crop plantations are established manually by rural people. In these plantations several plants are cultured and this offers numerous feeding opportunities to ants. Conversely SODEFOR uses bulldozers for teak plantation settlement that are monocultures and offer limited food resources to ants. (3) The last group is composed of land use types with intermediate species richness and converging species composition. These habitats are at different stages of recovery from forest clearance. The X axis in Figure 4 (dimension 1) can therefore be interpreted as habitats degree of relative disturbance as it defines a clear gradient. The Y axis can be interpreted as the degree of similarity in species composition. Our findings indicate that after a few years (e.g. 10 years) the species richness and composition in teak plantations can move from species poor state to the intermediate richest one. This suggests that tree plantations like secondary forest and fallows can possibly be important for forest biodiversity conservation in tropical environment marked by deforestation. According to Lindenmayer and Franklin (2002) secondary forests and tree plantations may help to retain more forest species than alternative and more intensive agricultural land uses.

Overall ant which survey versus land uses shows the sensibility of these insects to the changes in land use types and practices and also to habitats relative state of disturbance. In particular the species *Tetramorium sericeiventre* (in the rural domain) and *Tapinoma lugubre* (in the SODEFOR domain) were characteristic of anthropogenic impacts. This is a confirmation that ants fit to the use as bioindicator of their habitat conditions and encourage their inclusion in biological monitoring for the purpose of conservation.

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