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Effect of ants diversity on termites damage in different cocoa agroforestry systems (Southwest, Côte d'Ivoire)

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Abstract
New environmental conditions favour the emergence of many constraints linked to cocoa cultivation in Côte d'Ivoire. In this new environmental context, reflections are directed towards sustainable management strategies. The objective of this study is to evaluate the effect of ant biodiversity on termite damage in cocoa farms under different shade systems in order to consider biological control. Twenty-nine (29) species of termites and 63 species of ants were identified after data collection. Analysis of termite attacks on cocoa trees reveals that 41.82% of cocoa trees show termite attacks. Intermediate system 2 is the least attacked by termites. Moreover, the abundance and diversity of ants was highest in this system. Ants' abundance has an effect on reducing termite damage in the intermediate system 2. Considerable reduction of termite damage in cocoa trees could be achieved through biological control favored by a suitable management system.

Keywords: Ants, damage, termites, agroforestry systems, cocoa

Introduction
Cocoa cultivation concerns nearly 5 million farmers around the world [1]. It occupies an essential place in the life of farmers, from whom 40 to 50 million people around the world derive most of their income from it. Africa represents around 70% of the world market for brown beans. Côte d'Ivoire is the world's largest producer, accounting for 35.6% of global cocoa production, ahead of Ghana, Indonesia, Nigeria and Cameroon. Economically, cocoa farming represents 40% of export earnings and contributes more than 15% to GDP [2]. It is a main source of income for thousands of small farmers in rural areas.
Indeed, this sector mobilizes nearly 1 million farmers who provide income to 5 million people, i.e. about 1/5 of country's population [3].
Unfortunately, 'Ivorian miracle' of the 1960s and 1970s was based on extensive exploitation of the forest for benefit of export crops, of which cocoa is the most important [4]. Thus, while the country was becoming cocoa producer leader, forest resource almost entirely disappeared. It is the raison that cocoa cultivation is accused to devour Ivorian forests [5, 6].
In this post-forest environmental context, rural demographic pressure and crop intensification have led to new environmental constraints related to cocoa farming. These environmental constraints, accentuated by climate change, have favored several types of pests and diseases appearance in cocoa farms. In general, the main constraints of cocoa production in Côte d'Ivoire can be classified into two categories according to their origin. These are, abiotic constraints characterized by fluctuations in market prices, the scarcity of available forests and biotic constraints marked by diseases action and insect pests of cocoa tree [7]. Among these insect pests of the cocoa tree, species of termites have been observed [8]. Indeed, despite their important ecological roles [9], termites have been considered as pests due to their damage caused. Studies show that termites are one of the biggest plagues in tropical agriculture and agroforestry [11]. About 200 termite's species have been identified as pests of food, vegetable and industrial crops [10]. Crop losses due to termites are estimated at 20 - 45%. [12, 13]. In this context of termite's emergence in cocoa farms, reflections are oriented towards sustainable management strategies. This study was carried out as part of the global project "sustainable cocoa in Nawa region" and aims to evaluate the effect of ants' biodiversity on termite damage in different cocoa shade systems.

Materials and Methods
1. Study area and sampling sites
The study was conducted in Nawa region of southwestern Côte d'Ivoire in the localities of Takoragui, Petit Bouaké, Bobouho 1 and Gnaboya (Figure 1). Nawa is between latitude 5° - 6° N and longitude 7° - 8° W. This region is one of the main cocoa-producing areas in Côte d'Ivoire. Nawa region provides around 20% of national production [14]. Located in the Guinean forest zone, Nawa region has an equatorial climate with a bimodal rainfall of two rainy seasons and two dry seasons. Average rainfall of Nawa is between 1300 and 1600 mm / year with average temperatures oscillated between 24° C and 27° C. The vegetation, initially marked by dense rainforest and vegetation cover similar to Taï National Park (536000 ha), has gradually been reduced in favor of huge plantations of perennial crops. Most of the soils in the region are ferralitic
Study was carried out in four localities of Nawa region. In each locality, four sampling sites consisted by each cocoa farm were identified. At each sampling site, four quadrats (30 m x 30 m) were installed. The plots of a locality have different characteristics from other localities. The plots ranged from full sun systems to shaded and intermediate systems. In Takoragui locality, we selected cocoa farms in full sun systems. In Petit Bouaké and Bobouho 1, cocoa farms are intermediate systems. The intermediate system chosen in Petit Bouaké is close to full sun system while Bobouho 1's system is close to shaded system. In Gnaboya locality, the plots are shaded system. Plots age varies from less than 5 years to 40 years. Cocoa farms are family farms and their sizes vary between them.

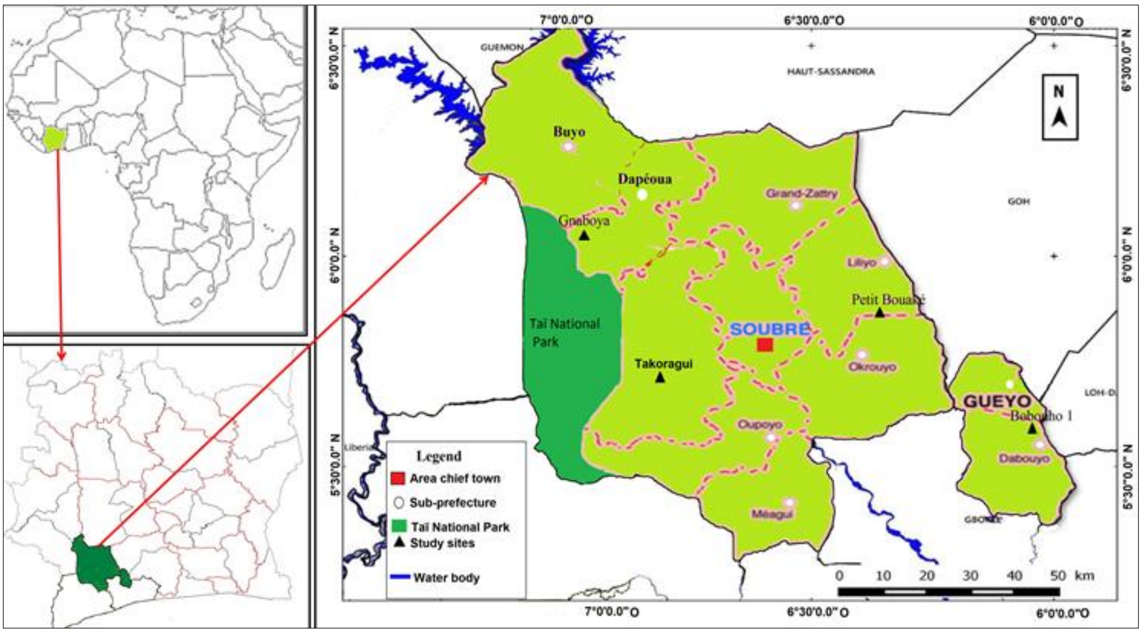


Fig 1: Location of study sites

Data Collection

Termites Sampling

The standardized termite transect method [15] was used to collect termites on the ground. This method, designed for the rapid assessment of termites in forest, has been modified and used in cocoa farms. Thus, four transects (25 m long and 2 m wide) were placed in 30 m x 30 m quadrats selected in each plot (Figure 2**)**. Each transect is subdivided into 5 sections of 5 m x 2 m (10 m²). The excavation was done in successive sections in the micro-habitats (twigs, dead leaves, fallen branches, etc.) on the soil surface at litter level. Termites search was done in successive sections in the micro-habitats (twigs, dead leaves, fallen branches, etc.) on the soil surface at litter level. Then random samplings of 12 clods of earth (monoliths) of 12 cm x 12 cm x 10 cm were taken in each section and were searched.

For the second approach, termites were collected from cocoa plants. For each sampling unit (quadrat), termites were collected from stems, cracks, galleries, nests and branches of cocoa trees up to a height of 2 m from the ground. The number of cocoa trees attacked by termites was determined. The presence of termite gallery or nest on a plant was considered as an attack of the plant. Termites collected were stored in labeled pillboxes containing 70% ethyl alcohol [16].

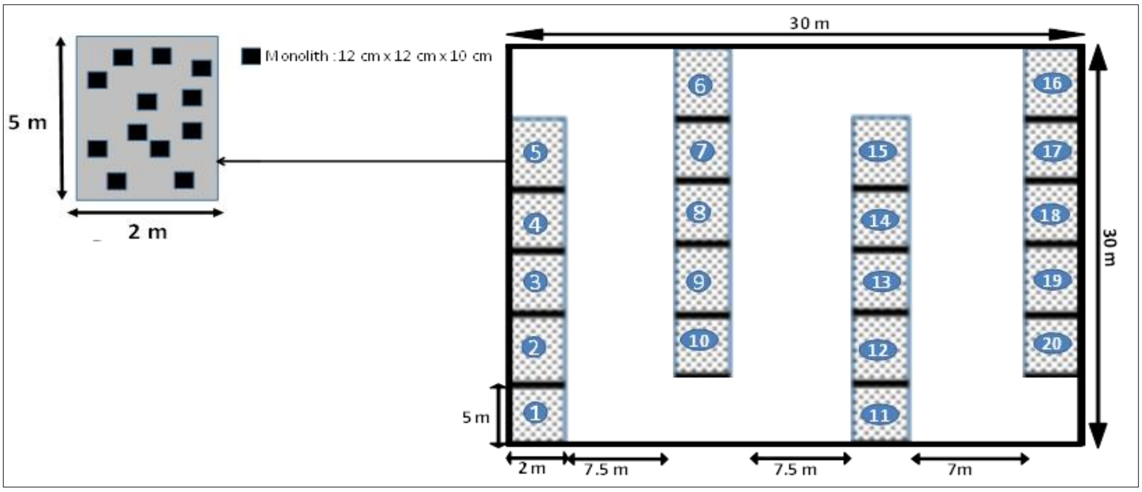


Fig 2: Termite sampling (adapted from [15])

Ants Sampling

Two methods were used for ants sampling. These are food bait method for the collection of litter ants and endogenous ants, and beating method for tree ants.

Food Bait Method

The bait method is a standardized method that has been used to sample ants from the soil (litter). We have placed baits at 10 sampling points in each quadrat with variables intervals of 10 m, 7.5 m or 5 m between baits to attract ants (Figure 3). The baits were pastes of a mixture of sugar, honey and tuna placed on a leaf on the ground, and the nearest cocoa tree was marked with a beacon tape to quickly locate the bait during collection rounds. Baits were observed every 15 minutes for one hour. For each species of ant feeding on the baits, 5 to 10 specimens were captured with tongs [17]. The samples were preserved in 90° alcohol and identification was made until species level.

Leaf Beating Method

This technique was applied following food bait method. This technique has been applied in addition to food bait method. We selected 10 cocoa trees in each quadrat (30 m x 30 m) to make collection. Using a Japanese umbrella and a stick, the foliage of the cocoa trees is beaten 5 times above the fabric. The ants fall on the fabric and are collected with the forceps. Direct sampling of ants from cocoa trees was also carried out when possible. The ants were collected and then placed in labeled pill boxes containing alcohol and bearing the code of plot, quadrat and number of the cocoa tree sampled.

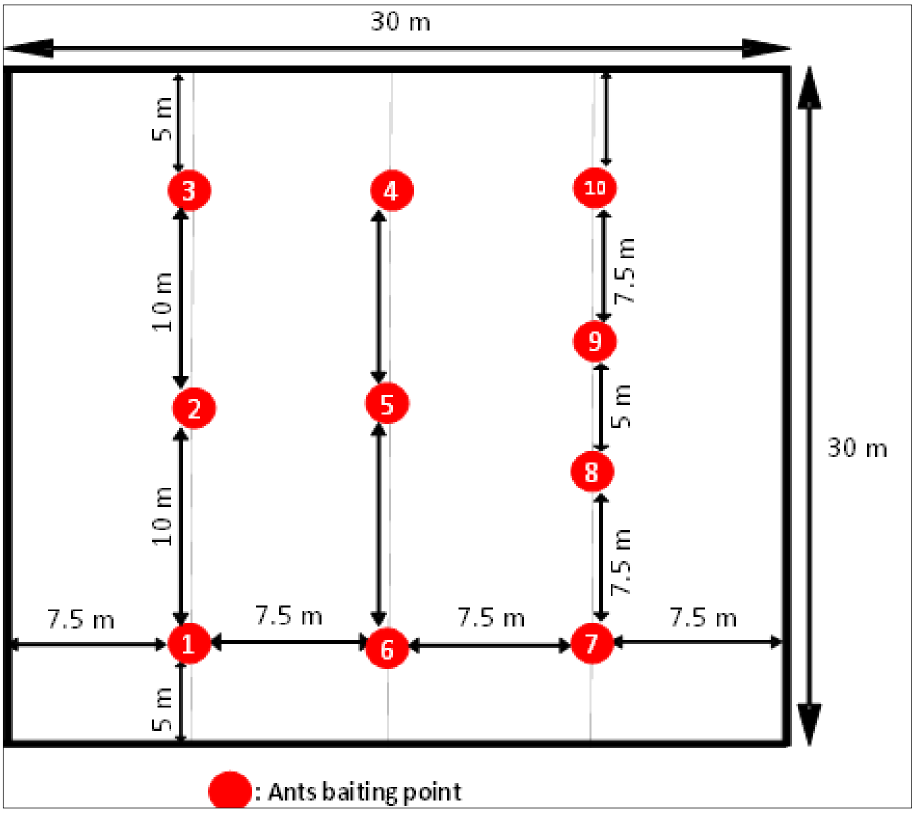


Fig 3: Ant sampling device

2. Data analysis

Variance analyzes (Anova) were performed with Statistica software (version 7.1) to compare the means of insect abundance in the different shade systems. Kruskal-Wallis test was used when data did not show normality or homogeneity. Mann-Whitney test was also performed. The level of significance p = 0.05 was retained. Correspondence and redundancy analyze carried out using CANOCO software (version 4.5) made it possible to determine the environmental parameters that influence species distribution of the fauna studied.

Results

1. Richness and diversity of termite fauna

The study has made it possible to obtain 29 species of termites belonging to 17 genera and three (3) families: Rhinotermitidae, Termitidae and Kalotermitidae. These cropping systems have very little variation in species richness. Indeed, specific richness is more important in intermediate system 2 (21 species) and in shaded system (18 species) (Table I). Full sun system and intermediate system 1 record each 17 species. Shannon index is relatively higher in intermediate system 2 (H'= 2.30) and shaded system (H' = 2.30). The plots in full sun system and intermediate system 1 have the lowest Shannon index values, with H' = 2.24 and H' = 2.15. Equitability index (E) is higher in the full sun system (0.79) and shaded system (0.79) showing homogeneity between species. In contrast, it is lower in the other two cropping systems.

Table 1: Diversity indices of different agroforestry systems

Indices	SSO	SI1	SI2	SO
Specific richness (S)	17	17	21	18
Shannon (H ')	2.24	2.15	2.30	2.30
Equitability (E)	0.79	0.76	0.76	0.79

SSO: Full sun system; SI1: intermediate system 1; SI2: intermediate system 2; SO: shaded system

2. Relative abundance of termites in different shade systems

The lowest relative abundance of termites was recorded in Intermediate System 1 (309 occurrences) (Table II). In contrast, the highest abundance was observed in the full sun system (456 occurrences). The intermediate system 2 and shaded system recorded 351 and 340 occurrences, respectively.

Fungus-growers abundance didn't vary significantly by cultivation system (ANOVA, p= 0.88). However, the highest abundances of this group were recorded in the intermediate system 2 (243 occurrences) and shaded system (230 occurrences). The abundance of other trophic groups didn't vary statistically between shade systems. The highest abundances of wood-feeders (270 occurrences) and soil-feeders (23 occurrences) are observed in the full sun system. The different trophic group's analysis (taken as a whole) shows that a significant difference is observed between the abundances (Figure 4). Fungus-growers are most abundant in the areas surveyed with 794 occurrences, or 54.53% of the total abundance of termites. They are followed by wood-feeders (629 occurrences or 43.2%). Soil-feeders (32 occurrences or 2.2%) and grass-feeders (1 occurrence) are the least abundant.

Table 2: Summary of occurrences number in trophic groups by cultivation system

Trophic Groups	SSO	SI1	SI2	SO	F	P	Total
Fungus-growers	163	158	243	230	0.225	0.88 NS	794
Soil-feeders	23	2	6	1	2.373	0.10 NS	32
grass-feeders	0	1	0	0	-	NS	1
wood-feeders	270	148	102	109	0.978	0.41 NS	629
Total	456	309	351	340			

SSO: Full sun system; SI1: intermediate system 1; SI2: intermediate system 2; SO: shaded system

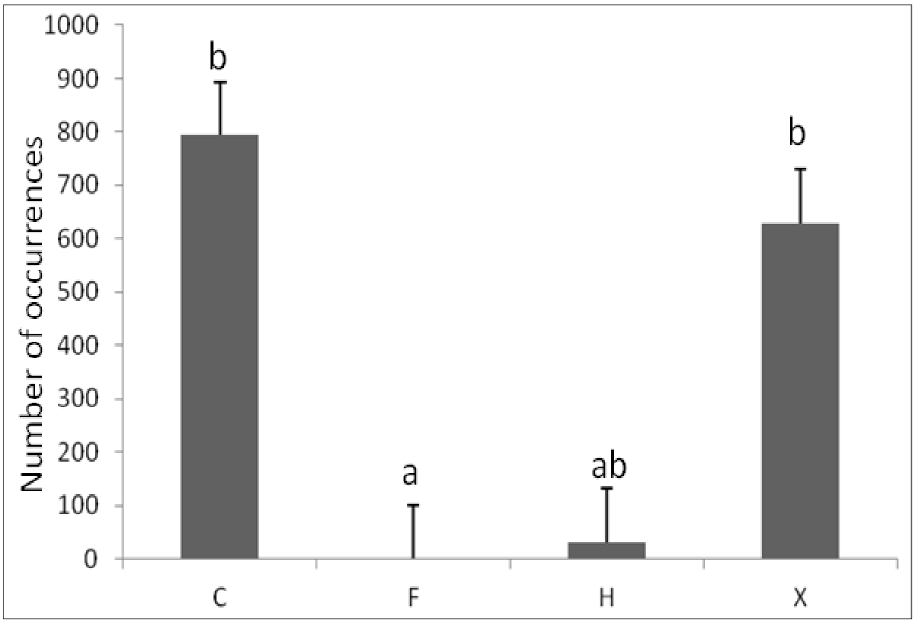


Fig 4: Relative abundance of termite's trophic groups.
Means followed by the same letter are not statistically different (Mann-Whitney test, P <0.05). C: Fungus-growers; F: grass-feeders; H: Soil-feeders; X: wood-feeders

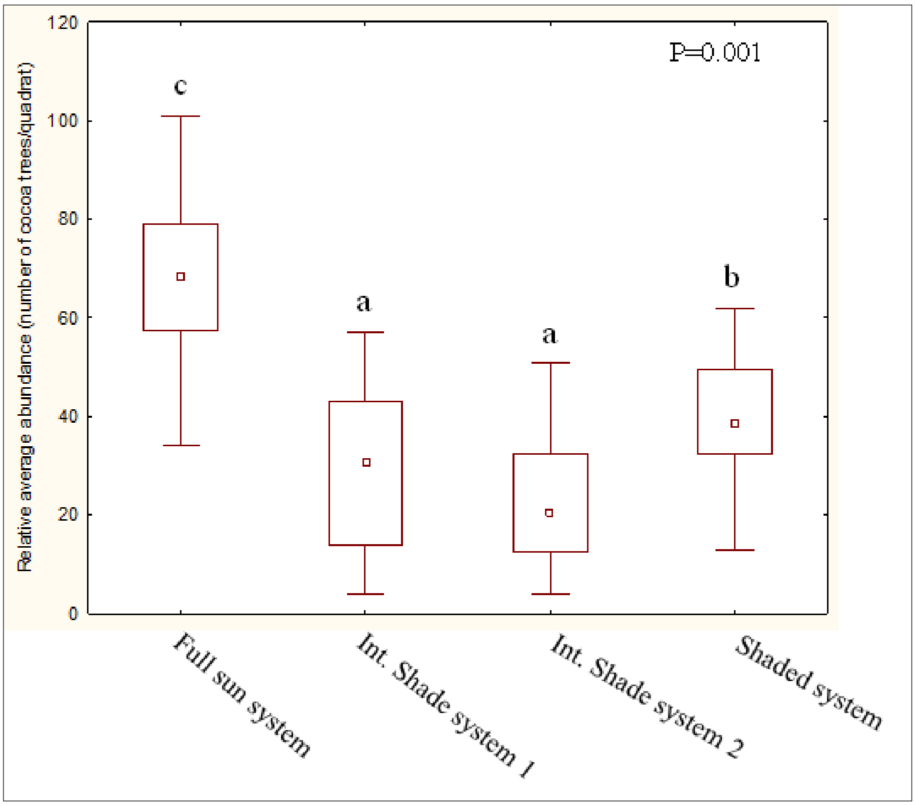
3. Termite attacks and damage in the different cocoa agroforestry systems

Quantitative analysis of termite attacks on cocoa trees reveals that out of a total of 6045 cocoa trees examined, 41.82% of the plants show termite attacks. The presence of activity or traces of termite were observed on all plots of the different shade systems. Termite attacks mainly affect the stems and branches of cocoa trees. Termite attacks are highest in the full sun system, while intermediate systems are the least attacked (Table III). In the intermediate management systems, the average termite attack rate is 29.1% and 27.87% for intermediate system 1 and intermediate system 2. In contrast, the average attack rate is 61.49% in full sun system. In shaded systems the attack rate is 44.32%.

Relative abundance study of cocoa trees attacked in each shade systems shows a significant variation in the relative abundance of attacks. (p = 0,001, test Kruskal-Wallis) (Figure 5). The average abundances of cocoa trees attacked vary greatly. Kruskal-Wallis test indicates that the relative abundance of attacks observed in the full sun system differs significantly from other shade systems. A significant difference was observed between the relative abundance of attacks in the shaded system and the other systems. However, no statistical difference was observed between the relative abundances of cocoa trees attacked in the two intermediate systems.

Table 3: Attack rate of cocoa trees in the different shade systems

Shade systems	Healthy cocoa trees (%)	Cocoa trees attacked (%)
Full sun system	38.51	61.49
Intermediate shade system 1	70.9	29.10
Intermediate shade system 2	72.13	27.87
Shaded system	55.68	44.32



Means followed by the same letter are not statistically different based on Kruskal-Wallis's test

Fig 5: Relative abundance of cocoa trees attacked

4. Diversity and abundance of ants according to different cocoa cultivation systems

Efficiency of harvest method

The efficiency of sampling method was tested by the ratio of species richness observed on species richness estimated. Specific richness observed corresponds at least 63% of expected in the different shade systems (Table IV). The number of species estimated is 28 and 31 species for full sun system and intermediate system 1. The highest number of species estimated was obtained in intermediate system 2 (50 species). The shaded system records the lowest value of species richness estimated (21 species). The shaded system has the fewest unique species (2 species) compared to other cultivation systems. Intermediate System 2 has the highest number of unique species with 12 species.

Diversity and specific composition of ants

Ants' specific diversity

A total, 63 ant species grouped into 41 genera and 07 subfamilies were collected from all cultivation systems (Table V). Intermediate System 2 is the richest cultivation system in ant species with 50 species. The shaded system is the least rich in ant species (21 species). Overall, average specific richness of ants varies significantly according the shade systems (ANOVA, $F = 14.17$; $p < 0.001$). Simpson's diversity index values are high in all shade systems. Equitability index values are also high, show a good distribution of relative abundances within species. However, the difference between equitability indices of the different agroforestry systems (from 0.52 to 0.66) suggests that distribution of relative abundances is not equitable between cultivation systems.

Table 4: Harvesting efficiency and diversity of ants according to shade system

	SSO	SI1	SI2	SO
Number of samples	320	320	320	320
Observed specific richness (Sobs)	28	31	50	21
Expected specific wealth (Jack 1)	42.06	44.13	80.06	31.31
Sampling coverage rate (%)	66.57	70.25	63.7	67.07
Number of unique species	3	4	12	2
Simpson (D)	0.74	0.8	0.84	0.65
Equitability indices	0.59	0.66	0.66	0.52

SSO: Full sun system; SI1: intermediate system 1; SI2: intermediate system 2; SO: shaded system

Table 5: Specific composition of ants in the different shade systems

Subfamilies	Tribes	Species	SSO	SI1	SI2	SO
Cerapachyinae						
	Cerapachyini	*Cerapachys sp.*	1	0	1	0
Dolichoderinae						
	Tapinomini	*Gloomy tapinoma*	0	0	1	0
		Tapinoma luteum	0	2	0	0
		Technomyrmex sp.	0	0	0	3
Dorylinae						
	Dorylini	*Dorylus nigricans*	0	0	1	0
Formicinae						
	Camponotini	*Camponotus maculatus*	5	7	1	0
		Camponotus olivieri	2	0	2	0
		Camponotus sp. 1	0	0	0	1
		Camponotus sp. 2	0	0	1	1
		Camponotus vividus	2	0	4	3
		Polyrachis militaris	10	4	0	4
		Polyrhachis sp. 1	0	1	1	0
		Polyrhachis sp.2	0	0	1	0
	Lasiini	*Paratrechina longicornis*	0	3	1	0
		Paratrechina sp. 1	0	0	1	1
		Nylanderia scintilla	0	0	5	0
		Nylanderia sp. 1	0	0	1	2
		Nylanderia sp. 2	0	0	1	0
	Oecophyllini	*Oecophylla longinoda*	154	107	137	145
	Plagiolepidini	*Anoplolepis sp.*	15	5	0	0
		Lepisiota megacephala	0	3	2	0
		Lepisiota sp.	1	0	5	0
		Lepsiota igregia	0	1	1	0
		Plagolepsis sp.	1	1	12	0
Myrmicinae						
	Crematogastrini	*Cardiocondyla sp.*	1	1	0	1
		Crematogaster sp.1	4	3	9	0
		Crematogaster sp.2	3	0	6	1
		Crematogaster sp.3	1	3	5	2
		Crematogaster sp.4	1	0	0	0
		Crematogaster sp.5	0	1	1	0
		Crematogaster sp.6	0	2	10	1
		Crematogaster striatula	0	2	5	0
		Dicroaspis sp.	0	0	2	0
	Pheidolini	*Pheidole sp. 1*	2	17	12	0
		Pheidole sp. 10	0	1	1	0
		Pheidole sp.11	1	0	0	0
		Pheidole sp.2	11	15	34	4
		Pheidole sp.3	0	2	0	0
		Pheidole sp.4	4	8	11	2
		Pheidole sp.5	0	2	1	0
		Pheidol sp.6	0	4	7	0
		Pheidole sp. 7	5	0	12	3
		Pheidole sp.8	1	0	1	0
		Pheidole sp.9	0	4	0	0
	Solenopsidini	*Monomorium sp.1*	0	0	1	0
		Monomorium sp.2	0	0	2	0
		Myrmicaria sp.	1	0	1	0
	Tetramoriini	*Tetramorium sp.1*	0	0	1	1
		Tetramorium sp.2	1	2	1	0
		Tetramorium sp.3	0	0	1	1
		Tetramorium aculeatum	0	0	1	0
Ponerinae						
	Ponerini	*Centromyrmex sp.*	1	2	1	0
		Odontomachus troglodytes	9	17	29	18
		Bothroponera sp.	4	0	0	0
		Hypoponera sp.	0	0	1	0
		Loboponera sp.	0	0	1	0
		Pachycondyla tarsata	0	0	1	5
		Paltothyreus sp.	27	1	0	9
		Paltothyreus tartsatus	63	52	62	66
		Phrynoponera sp.	0	1	1	0
		Mesoponera sp.	1	0	1	0
		Anochetus sp.	0	0	1	0
Pseudomyrmecinae						
	Pseudomyrmecini	*Tetraponera macquerysi*	0	1	0	0

SSO: Full sun system; SI1: intermediate system 1; SI2: intermediate system 2; SO: shaded system

5.

6. Relative abundances of ants in habitats

Differences in the structure of ant communities were observed by analyzing relative abundance of subfamilies (Figure 6). Out of 07 sub-families identified, three are more abundant in the different cultivation systems. A preponderance of Formicinae is observed. It is followed by ponerinae and Myrmicinae. The other four subfamilies (Dolichoderinae, Cerapachyinae, Dorylinae and Pseudomyrmecinae) are poorly represented, which indicates a dominance of terricultural ants. The relative abundance oMf Myrmicinae varies significantly according to shade system, contrary to other subfamilies. (Table VI). It is very abundant in the intermediate system 2, relatively abundant in the intermediate system 1, but very weakly found in the plots of the shaded system.

Out of all different shade systems and the 63-ant species identified, 04 species are dominant and have frequencies greater than 4%. These are the species *Pheidole sp.2* (4.99%), *Odontomachus troglodytes* (5.69%), *Paltothyreus tartsatus* (18.94%), *Oecophylla longinoda* (42.32%). However, shade does not appear to influence the abundance of these dominant species in different shade systems.

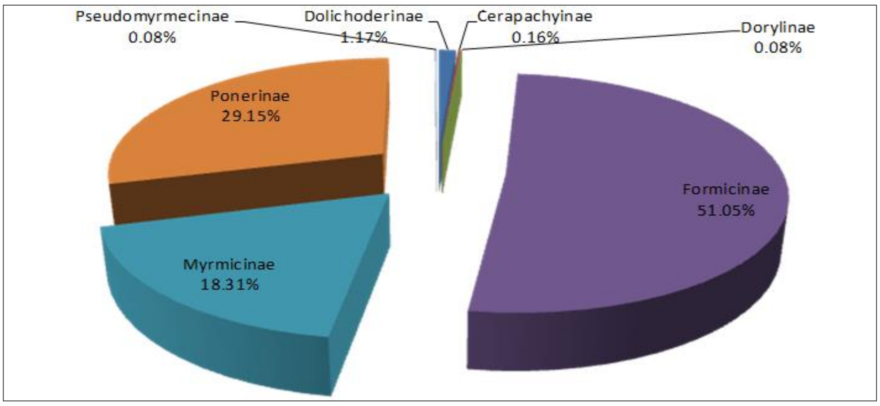


Fig 6: Proportion of sub-families identified in the different agroforestry systems

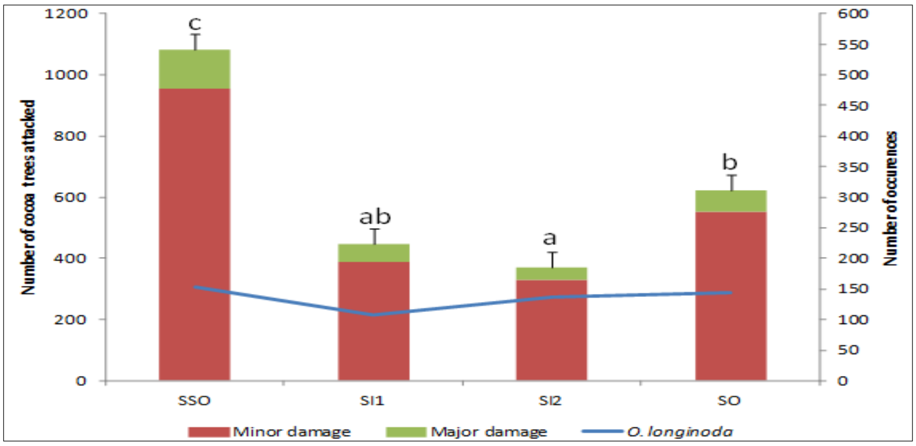
Table 6: Comparison of the relative abundance (occurrences) of ant subfamilies according to shade system

Subfamilies	SSO	SI1	SI2	SO	*F*	P
Cerapachyinae	1	0	1	0		NS
Dolichoderinae	1	4	5	5	0.796	0.508 NS
Dorylinae	0	0	1	0		NS
Formicinae	190	132	176	157	0.034	0.991 NS
Myrmicinae	35	65	121	14	4.366	0.006
Ponerinae	105	73	98	98	0.051	0.984 NS
Pseudomyrmecinae	0	1	0	0		NS

SSO: Full sun system; SI1: intermediate system 1; SI2: intermediate system 2; SO: shaded system; NS: No significant.

7. Relationship between Oecophyll ant's abundance and termite damage in the different cultivation systems

Overall, abundance of *O. longinoda* does not significantly correlate with the abundance of termite damage (Figure 7). A significant difference is observed in termite damage (Anova, F = 27.018; p < 0.00001). Indeed, while a significant number of termite damage is observed in the full sun system and shaded system, the occurrences number of *O. longinoda* same remained statistically in the different cultivation systems. No significant difference was observed between abundances of Oecophylls in the different cultivation systems (p> 0.05). The occurrences number of *O. longinoda* is higher in full sun system, but there is no significant difference between oecophylls abundances in the different cultivation systems, while there is a difference between the abundance of damage on cocoa trees. The *O. longinoda* abundances in the different agroforestry system do not appear to have a significant effect in reducing termite attacks.

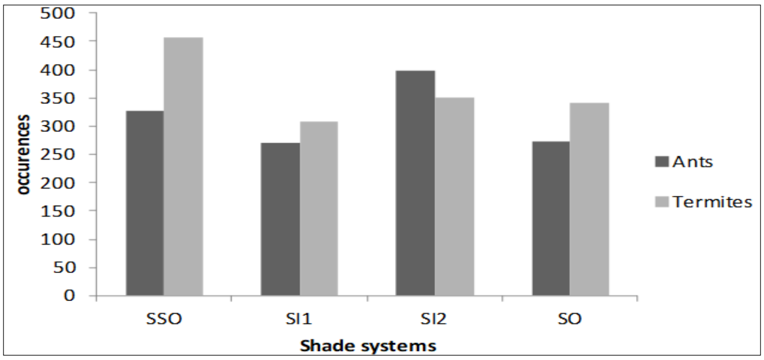


SSO: Full sun system; SI1: intermediate system 1; SI2: intermediate system 2; SO: shaded system

Fig 7: Variation of termite damage in relation to *O. longinoda*

8. Ants-termites interaction

The observation of relative abundance evolution of each insects group according to different agroforestry systems shows a distribution of termites evolves in the same direction as ants except the intermediate system 2 (Figure 8). In this system, ant's occurrences are higher than termite's occurrences. The relative abundance of ants is higher in this system compared to ant's abundance in other agroforestry systems. It is also in this intermediate system 2 that the lowest attack of termite is observed. Shade may not influence the relative abundance of ants. Ant's abundance could have an effect on termite's abundance and could reduce termite attacks.



SSO: Full sun system; SI1: intermediate system 1; SI2: intermediate system 2; SO: shaded system

Fig 8: Interaction evolution between ants and termites in different cultivation systems.

9. Influence of environmental parameters on termite installation

A canonical correspondence analysis was performed between environmental parameters and relative abundance of termite species (8 parameters x 29 species). The termite data coupling and environmental data shows that species distribution seems to be influenced by environmental parameters of different degrees (Table VII). The first two axes (F1 and F2) explain 52.7% of total variability (Figure 9). Factor axis 1 clearly separates silt and clay from other environmental parameters. Axis 2 differentiates clay and sand to other parameters (amounts of litter, detritus, grass and silt). In the upper part of axis 2, a strong link between silt and *M. parvus* is observed; between the amount of litter and the species *O. sp2, P. urgens* and *A. crucifer*. There is also a strong co-relation between amount of grass and *P. militaris*, *A. cavithorax*, *M. bellicosus* and *P. orthoceps* but also between the amount of detritus and *A. guineensis* specie. However, in the lower half, *M. subhyalinus* and *M. fuscotibialus* are positively correlated with clay. In this same part, *M. thoracalis, M. edentatus, C. intermedius* and *M. subhyalinus* are strongly associated with sand.

Table 7: Relationship between species and environmental variables

Axes	Axis 1	Axis 2	Axis 3	Axis 4	Total inertia
Eigen values	0.224	0.133	0.112	0.091	3,139
Species / environmental parameters correlations	0.729	0.727	0.674	0.683	
Cumulative Variance Values (%)	7.1	11.4	14.9	17.8	
	33.1	52.7	69.3	82.7	

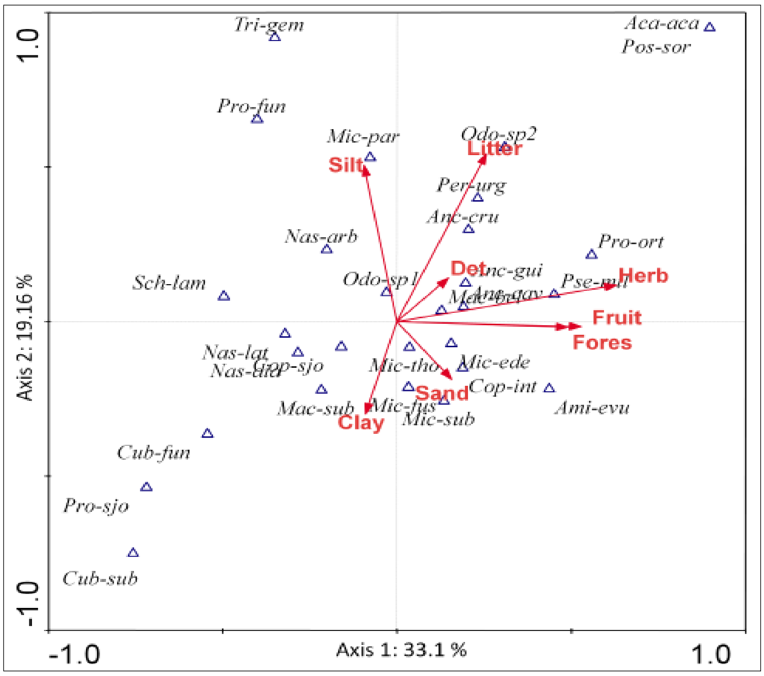


Fig 9: Canonical correspondence analysis of termite species and environmental variables

10. Influence of environment parameters on ants installation

Redundancy analysis was performed on basis of ant species abundance and environmental variables in order to determine environmental parameters that influence ant's distribution. The myrmecological and environmental data coupling shows that species distribution seems to be influenced by environmental parameters of different degrees (Table VIII). In the species distribution according to different biotopes characteristics, axes 1 and 2 express 75.9% of total variance (Figure 10). The rate of herbaceous cover, silt and the number of forest trees are positively correlated to the first axis. In contrast, the amount of litter, detritus, percentages of sand, clay and the number of fruit trees are negatively correlated to this same axis. In the positive part of axis 2, a strong correlation between the species *Pheidole* sp2, *Plagolepsis* sp, *Lepisiota megacephala* and fruit trees is observed. Amount of detritus and forest trees are respectively correlated with the species *Phrynoponera sp, Hypoponera sp, Odontomachus troglodytes* and with the species *Camponotus vividus, Nylanderia scintilla, Pheidole sp4.* In *the negative part of this axis, the species Anoplolepis sp, Camponotus maculatus, Cerapachys sp, Pachycondyla tarsata* and *Pheidole sp8* are correlated to sand.

Table 8: Relationships between species and environmental variables

Axes	Axis 1	Axis 2	Axis 3	Axis 4	Total inertia
Eigen values	0.066	0.022	0.010	0.010	1,000
Species / environmental parameters correlations	0.378	0.490	0.544	0.336	
Cumulative Variance Values (%)	6.6	8.8	9.8	10.8	
	56.8	75.9	84.8	93.2	

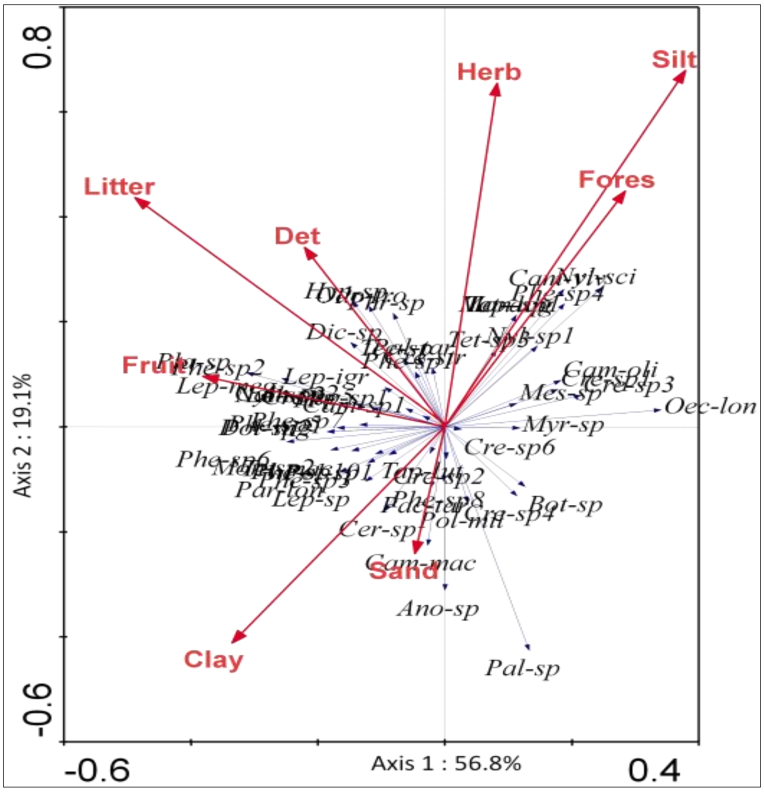


Figure 10: Ordination diagram of ants and environmental variables

Discussion

A total of 29 species of Termites distributed in 17 genera, 7 subfamilies and 3 families (Rhinotermitidae, Termitidae and Kalotermitidae) have been recorded. All termite species listed have been previously reported in Côte d'Ivoire. These results are below the number of species obtained by [8] and [18] who recorded respectively 34 and 36 species of termites in cocoa and mango orchards in Côte d'Ivoire. The difference in the number of species would result from termite's distribution that results in diversity and abundance that varies from one ecosystem to another depending on climate, soil type and vegetation [19]. The diversity and floristic composition of study area would therefore influence this specific difference. According to [20], the specific difference observed between different study areas is linked to soil nature and above all to floristic composition surrounding each areas. The slightly higher number of species in the intermediate system 2 (21 species) and shaded system (18 species) would therefore be related to floristic composition of these two cultivation systems. From a trophic level, the four group's presence reflects a good functional diversity of termitological fauna. The stand is dominated by fungi and wood borers in all management systems, reflecting an abundance of wood and litter food from the different areas. The stand is dominated by fungi and wood borers in all management systems, reflecting an abundance of wood and litter food from different areas.

Evaluation of termite attack rates showed that attacks were most common in full sun systems (61.49%), while intermediate systems were the least attacked. Termite attack rate varies depending on the plot and the shading system. Termite attacks rate varies between plot and shade system. This had been observed by cocoa farmers who felt that termite infestations were increased in parallel with increasing removal of shade trees [21]. The high rate of termite attack in full sun systems could be explained by vulnerability of this system to attack by insect pests. Plots in shaded systems are old plantations and this could have an effect on installation and termite attack. Areas and age of the plots influence termite attacks [8]. The incidence and intensity of termite attacks vary according to species, locality and soil conditions [22]. Termite attacks could therefore be linked to soil nature (red ferralitic soil in the study area) which favours the installation of termite mounds, source of plant infestations [23].

Sixty-three (63) ant's species grouped into 41 genera and 07 sub-families were collected from all cocoa management systems. The high sampling coverage rate (over 63% of myrmecofauna expected) attests that the methods used during this study would be suitable for the study of ant communities in the different shade systems. Average specific richness of ants varies significantly according to shade systems. It is richer in intermediate systems but decreases from full sun system to shaded system. The low ant richness in the full sun system would probably be due to original habitats destruction resulting in the elimination of native plants and their replacement by exotic plants causing partial changes in abiotic conditions [24]. Knowing those ants biodiversity varies according to plant species of a site, in such a modified environment (full sun system), the degree and type of disturbance of this habitat contributes to reduce diversity and specific richness of ants [25, 26]. In a modified area, species richness and composition are affected by habitat quality [27] [28]. At the level of shaded system, the low species richness could be attributed to this system has become like a reconstituted environment, but ants are little present in very closed forests because the quantity of radiant energy available at ground level represents a limiting factor [29, 30]. Moreover, it is established that initial state return of a forest following a modification by activities such as agriculture can have enormous effects on flora and fauna [31]. The shaded system is a complex agroforestry system typical of this description. Human activities could therefore contribute to modify the specific composition of ant population in this system. Differences in ant community structure were also established by analyzing the relative abundance of subfamilies. Three of the seven identified ant subfamilies are more abundant in the different cultivation systems: Formicinae, Ponerinae and Myrmicinae. Within each shade system, Formicinae are the most abundant. The relative abundance of Formicinae does not vary between shade systems. This dominant subfamily seems to be favored by disturbance and especially by the high abundance of *Oecophylla longinoda.* These results indicate a good adaptation of this species to different shade systems. The second most abundant subfamily is the Ponerinae. Their relative abundances do not vary between shade systems. Most species of Ponerinae subfamily are predators and the high diversity of prey in cocoa trees could explain their preference for these habitats. Ponerinae are also known to be susceptible to changes in microclimate and would be indicators of environmental type [32]. Myrmicinae subfamily is the last most abundant subfamily. Their relative abundance varies significantly according to shade system, unlike the other subfamilies. It is very abundant in the intermediate system 2, relatively abundant in full sun system and intermediate system 1, but very low in the shaded system. The variation observed in this subfamily indicates that the species in this subfamily respond differently to different shade systems. The high abundance of Myrmicinae in different shade systems could be related to their numerical importance within world fauna [32, 33]. Myrmicinae preponderance was also reported in a study of Formicidae at two stations in Algeria by [34]. In general, the significant variation in species richness and ant's abundance between different shade systems would suggest that typology and quality of these habitats may influence ant communities they harbor. Likewise, habitat changes can directly affect ant communities, their prey, and other animals with which they interact. Cultivation could lead a rapid destruction or reduction of certain soil communities [35].

The abundance of *Oecophylla longinoda* does not correlate with the abundance of termite damage. The abundance of *O. longinoda* was statistically identical in shade systems while the abundance of termite damage on cocoa trees is different. *O. longinoda* has a high abundance in the different shade systems but does not appear to have a significant effect in reducing termite attacks. *O. longinoda* is one of dominant species of Formicinae subfamily which has been collected extensively in different areas. Its abundance in these environments is due to its arboreal lifestyle and its omnivorous diet. As a result, these environments would offer it more availability of nesting sites and food sources, which could promote its distribution. *O. longinoda* presence has no effect on termite damage but it could influence attacks by other cocoa pests. Indeed, it has been shown that in West Africa *Oecophylla longinoda* is predatory on capsids [36]. Although in this study direct links between ecophylls abundance and termite damage were not observed, ants remain an interesting prospect in the biological control of termites [37]. Indeed, termite's abundance decreases with increase ant's abundance in the intermediate system 2, thus verifying the hypothesis of a relationship existence between these two groups of insects. Ant's abundance has an effect on termite's abundance and is therefore responsible for termite damage reduction in this cultivation system. This observation confirms the results of [38] showing that in certain agricultural ecosystems, ants control pest's population either by exerting a direct predation on them, or by producing chemicals that cause the decline of pest's population on host plants that are attacked. It has been reported that ants are predators of many crop pests [39]. For example, the black cocoa ant (*Dolichoderus thoracius*) eliminates mirids, cocoa pod tendrils and squirrel attacks in Southeast Asia [40]. Due to their numerical importance, ants play important roles in the environments they occupy [41]. Ants are very important predators of insects and other invertebrates [42, 43] it can help to limit the populations of insect pests such as the caterpillars of butterflies or hymenoptera during their outbreaks [44].

Correlation analysis between termite species and environmental variables reveals a reaction of certain species to certain environmental variables. Indeed, amount of litter, grass, detritus and the percentages of sand, clay and silt are environmental parameters that influence abundance of certain termite species. Thus, the relative abundances of *O. sp2*, *P. urgens* and *A. crucifer* are correlated with amount of litter. This link is explained by the first two species are mushroom growers and their food consists mainly of litter. In most cocoa farms, with abundant leaf loss these plots have rich litter and an abundance of decaying organic particles that are an important food source for these species. The species *P. militaris*, *A. cavithorax*, *M. bellicosus* and *P. orthoceps* are positively correlated with amount of grass. Ces espèces ont été davantage rencontrées dans le système intermédiaire 2 et le système ombragé. The high diversity of plants in these habitats, favoring a favorable microclimate, an abundant and diversified source of food has favored their proliferation. The relative abundances of *M. thoracalis, M. edentatus, C. intermedius* and *M. subhyalinus* are strongly associated to sand presence. In contrast, *M. parvus* specie is linked to presence silt. A positive correlation is observed between clay and *M. subhyalinus* and *M. fuscotibialus* species as well as *A. guineensis* specie and amount of detritus. These different links between termite species and these environmental parameters are generally due to the preference of these species for these environments which are for some degraded environments. The amount of food available in these habitats could also be linked to the presence of certain species that adapt to the new environment. The presence of a species in an environment is linked a reason or a phenomenon, some of which are not understood.

In myrmecofauna distribution, certain species are influenced by certain environmental parameters to various degrees. The existence of a correlation between *Pheidole sp2*, *Plagolepsis sp*, *Lepisiota megacephala* species and fruit trees is observed. The amounts of litter and forest trees are correlated respectively to *Phrynoponera sp, Hypoponera sp, Odontomachus troglodytes* and with *Camponotus vividus, Nylanderia scintilla, Pheidole sp4* species. The study sites are not natural environments and some are similar to disturbed environments, which would promote the proliferation of certain species such as *O. troglodytes.* According to [45], these are species that prefer open or disturbed habitats, hence their abundance in different environments. *Anoplolepis sp, Camponotus maculatus, Cerapachys sp, Pachycondyla tarsata* and *Pheidole sp8* species are also correlated to sand. Studies have shown that species such as *P. tarsata* have a wide distribution spectrum [46] and could therefore be found in different types of environments, although according to [24] its preference for one type of soil has not yet been verified.

Conclusion

Study carried out made it possible to assess termites and ants biodiversity in the different cultivation systems. Twenty nine (29) termite's species divided into 17 genera and 3 families were collected. All the termites collected are distributed in the four trophic groups. Mushroom and wood borers were the most abundant. The results obtained show that termite attack rate varies between cultivation systems. Attacks were highest in the full systems but low in intermediate systems. At myrmecofauna level, 63 ant's species divided into 41 genera and 07 subfamilies were identified. Among these different subfamilies, three are dominant. These are Formicinae, Ponerinae and Myrmicinae. The Myrmicinae subfamily is the only subfamily whose relative abundance varies significantly according to shade systems. Results show that oecophylls abundances in the different agroforestry systems have no significant effect in termite attacks reduction. Ants' abundance in the intermediate system 2 seems have an effect on termite's abundance and would impact on termite attacks. Correlation analysis between environmental variables and termite species and then ants showed correlations between some variables and some species of the fauna studied.

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