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## Effect of shade on the diversity of termites (Isoptera) in different cocoa agroforestry systems in the Nawa region (Côte d'Ivoire)

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**Abstract**

Termites are gradually being recognized as emerging pests and a major constraint to the sustainable production of cocoa in Côte d'Ivoire, the world's leading cocoa producer. In order to develop environmentally compatible management strategies against the pest species, it is important to identify the termite species in these systems and have a better understanding of their functional diversity. This study was conducted to evaluate the effect of shade management on the diversity of termites in different cocoa growing systems in the Nawa area, one of the main cocoa producing areas in Côte d'Ivoire. The study also evaluated the effect of shade cover on termite damage to cocoa. Sampling was done using a modified standardized transect method, where termites were collected in 25 m x 2 m transects, placed in 30 m x 30 m quadrats. Termites sampled were identified and grouped according to feeding habits. Twenty-nine (29) termite species, in 17 genera and 7 subfamilies under 3 families were sampled. These termite species are distributed among the four feeding groups. Fungus-growers and wood-feeders were the most diversified. The intermediate shade systems were the least attacked by termites compared to the full sun system and shaded system. Shade therefore, seems to influence termite biodiversity and damage in cocoa agroforestry systems. We recommend awareness-raising and assistance from cocoa farmers on shade management and the choice of an appropriate cropping system such as an intermediate shade system that would reduce termite attacks, produce long term and preserve biodiversity.

**Keywords:** Shade, cocoa, termite, agroforestry system

**1. Introduction**

The cocoa tree (*Theobroma cocoa L.*) is a sustainable plant native from Equatorial and South America. Its main production areas, in Africa extend from Côte d'Ivoire to Cameroun. Introduced towards 1888 in Côte d'Ivoire <sup>[1]</sup>, cocoa cultivation has known a speedy expansion at the expense of forester areas <sup>[2]</sup>. Cocoa represents one of the main cultures of export in the country and contributes to food security and poverty reduction of the country. Côte d'Ivoire is the cocoa leading producing country, with more than 40% of the world's cocoa. Unfortunately, this first place has cost much to its forest cover, from 16 million hectares at the beginning of the last century to approximately 2.5 million hectares nowadays <sup>[3]</sup>. The annual rate of deforestation was estimated at 3.04% between 1986 and 2000 and 2.66% between 2000 and 2015. During these periods, the forest cover loss was estimated at 2,756,412 hectares <sup>[4]</sup>. The main cause of forest clearing is extensive agriculture, using the slash and burn technique to generate challenging and new environmental constraints. These environmental constraints are accentuated by the climate change and the emergence of new types of pests and diseases in cocoa farms and agricultural systems. Among these pests, are termites. These pests were considered minor because of the negligible damage they could cause on cocoa trees. However, their number and importance in cocoa farms have increased drastically. These insects build galleries on the cocoa tree trunk and branches leading to tree death. A termite infestation and the destruction of cocoa trees are reported by farmers as major new constraints of cocoa production in Côte d'Ivoire, particularly in the southwest region of the country. The cocoa tree is traditionally known to be grown under a diversity of shade trees. However, with the development of a new cocoa variety known as Mercedes, cocoa is generally planted in Côte d'Ivoire with very little or no shade.

Over decades, this new form of the land-use system has resulted in the development and proliferation of emerging pests such as termites. We therefore hypothesize that termite outbreaks in cocoa farms could be associated with shade cover. We also support the scientific idea that proper shade management and land-use strategy will enhance local biodiversity and conservation biological control in agricultural systems<sup>[5]</sup>.

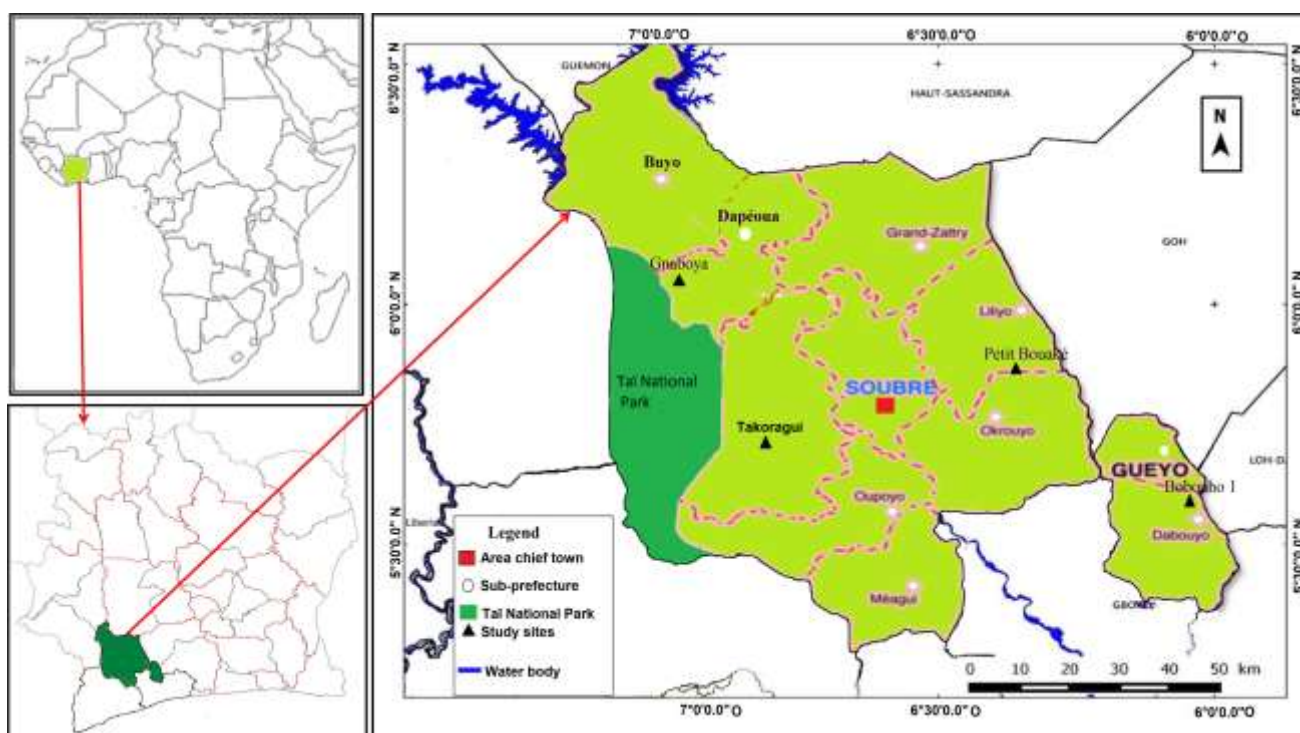
In the present study we evaluated the effect of shade management on the diversity of termite in different cocoa systems. We also looked at the effect of shade cover on termite damage to cocoa and provided recommendations on suitable shade management and choice of suitable cocoa agroforestry systems to balance production, natural biological control and biodiversity conservation.

## 2. Materials and methods

### 2.1. Study area

The study was conducted in the Nawa region of south-western

of Côte d'Ivoire (Figure1). We selected 16 cocoa plots that differed in the intensity of the shade. The plots were located in Takoragui (05° 45' 18" N, 06° 47' 30" W), where cocoa is grown under the full sun; Petit Bouaké (05° 56' 47" N, 06° 19' 46" W) and Bobouho 1 (05° 35' 33" N, 06° 01' 53" W), where the shade level is intermediate; and Gnaboya (06° 04' 31" N, 6° 54' 35" W), where cocoa is planted under heavily shaded systems. The Nawa region, with its capital Soubré is one of the largest areas of cocoa production in Côte d'Ivoire, and represents 20% of the national production of cocoa beans. This region is located in the Guinean forest zone and has a typical equatorial climate with a bimodal rainfall pattern of two rainy seasons and two dry seasons. The rainy seasons usually occur from April to June and from September to October, while the dry seasons are from November to March, and from July to August. Annual precipitation varies between 1000 mm and 1800 mm, and the average temperature is between 24 °C and 36 °C. The type of soil in this region is ferrallitic<sup>[6]</sup>.



**Fig 1:** Localization of the study area

### 2.2. Data Collection

All the faunistic and floristic data were collected in 30 m x 30 m quadrats. In each cocoa plot, we installed four (4) quadrats, and in each locality four (4) plots were selected. Collections were carried out in sixty-four (64) quadrats distributed in four localities. The plots were chosen according to specific characteristics, and ranged from full sun, to intermediate and shaded systems. In Takoragui locality, the plots selected were full sun systems, while in Petit Bouaké and Bobouho 1, intermediate shaded systems were selected. However, there is a difference between the intermediate systems of these two localities where that in Petit Bouaké is closed to complete sun system, while the one in Bobouho 1 is closed to a shaded system. The system in the last locality (Gnaboya) is a shaded system.

### 2.3. Floristic data collection

For the floristic data collection, all trees with a diameter at

breast height (DBH) greater than 10 cm were marked, numbered and measured individually within each of the 30 m x 30 m quadrat. So, for each tree, scientific and vernacular names were determined either in the field or in the laboratory of Jean Lorougnon Guédé University.

### 2.4. Termite sampling

Two approaches were adopted to evaluate the diversity and termite's activity in the cocoa farms. For the first approach, sampling was based on the standardized transect method which provides a representative sample of the taxonomic composition and composition of the functional groups of the local termite assemblage<sup>[7]</sup>. In this approach, each of the 30 m x 30 m quadrat was further divided into four transects of 25 m x 2 m (Figure 2). Each transect was subdivided into 5 sections of 5 m x 2 m. In each section, termites were sampled from leaf litter, and twelve soil monoliths (12 cm x 12 cm x 10 cm) were extracted, sieved and hand-searched. Dead wood within

each of the quadrates was also searched for termites' collection. Soldier and worker castes were collected and stored in 70% ethanol in tubes and labelled accordingly with the site, quadrat and section numbers. For the second approach, the sampling was done on cocoa plants (young, mature and old cocoa trees) in each of the 30 m x 30 m quadrat. On each cocoa tree, termites were collected on galleries, nests, trunk and branches at a height of up to 2 m from the soil. The number of cocoa trees attacked by termites was also counted. The presence of termite galleries and nests on a cocoa plant was considered an attack by termites. All cocoa trees in the sampling area were examined to determine

the proportion of trees with termite damage. This served to evaluate the damages caused by termite on cocoa. A cocoa tree is said to be attacked when it carries galleries with or without termites. So cocoa trees have been classified into three categories: healthy cocoa trees, cocoa trees with superficial damage (type I damage) and cocoa trees with internal damages (major damage) which can lead to the death of the cocoa tree (type II damage). All termite specimens in all the sampling sections were collected and transported to laboratory for identification. The termite species identified were then classified into four feeding groups: fungus-growers, wood-feeders, grass-feeders and soil-feeders.

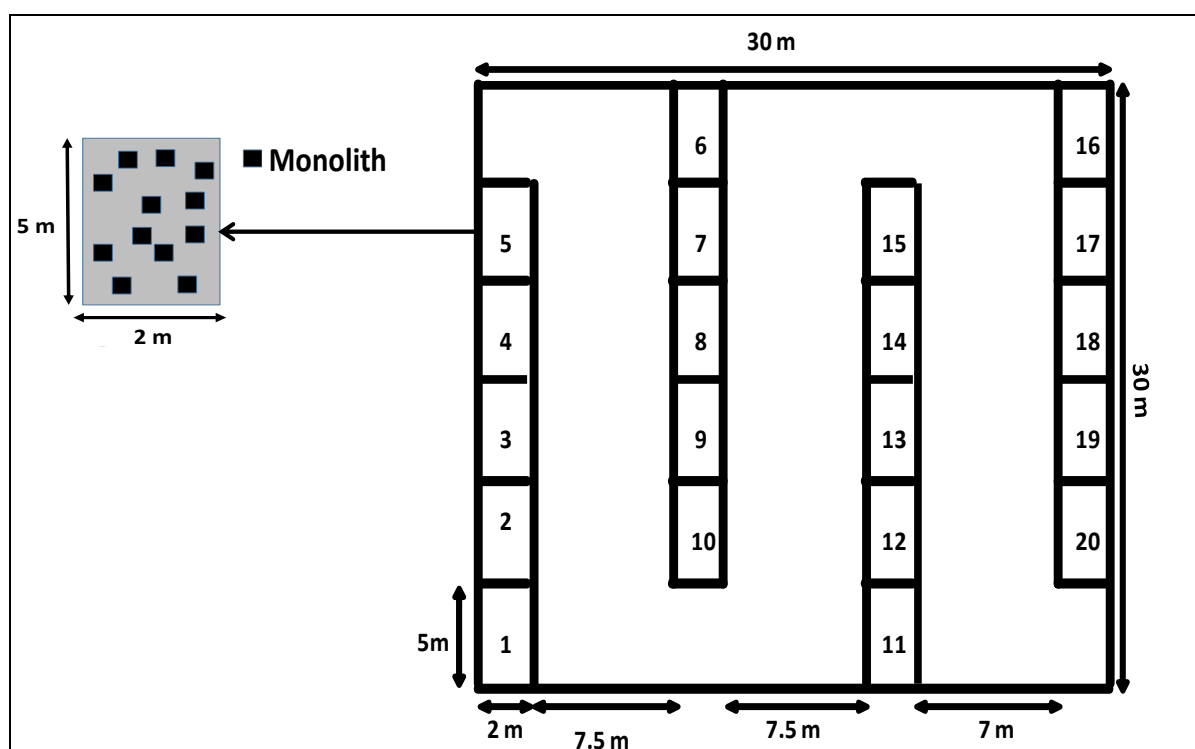


Fig 2: Termite sampling device (adapted from Jones & Eggleton, 2000)

## 2.5. Termite identification

Termite specimens were sorted and grouped into morpho-species. The identification was based on morphological characters on caste soldiers or workers for groups of termites lacking the soldier castes. Several keys such as [8-19] have been used for termite identification.

## 2.6. Data analysis

Termites are social insects and the occurrence of a single individual indicates the presence of a whole colony nearby, we used the occurrence (presence or absence data) instead of absolute number of individuals. To see how strong our estimates of species richness were, we constructed species accumulation curves after randomizing 500 times the sample in order to ensure the statistical representation of the target community [20]. We then calculated some alpha diversity index namely, Species richness (S), Shannon–Wiener index, Pielou index of equitability J for each cultivation system with Past software. The differences in species composition and abundance of termites and shade trees in agroforestry systems were analyzed using ANOVA performed using Statistica 7.1 software. When significant differences between means were noted at  $P < 5\%$ , we performed a Tukey post-hoc's test to compare means between cultivation systems. We used the Mann-Whitney's U pairwise test for pairwise comparison

between the forest trees and fruit trees. A factorial analysis of correspondence was realised with XLSTAT software to establish the relationship between the type of termite damage and the level of shade.

## 3. Results

### 3.1. Richness and composition of shade trees

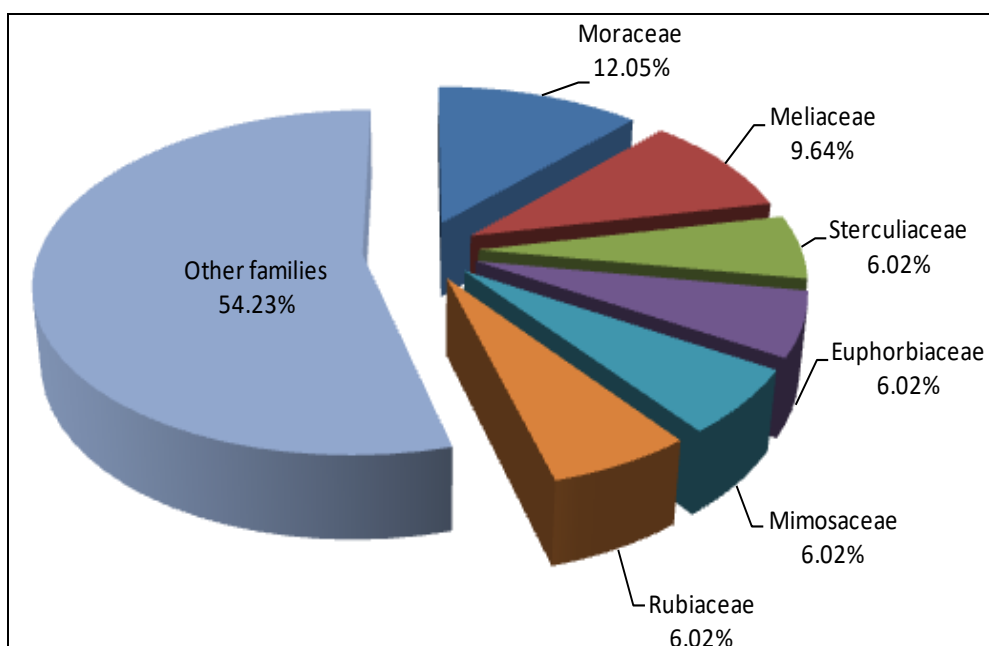
We identified 83 shade tree species in 62 genera and 32 families in the different cocoa plots (Table 1). The most dominant families were Moraceae (10 species; or 12.05%), Meliaceae (8 species; or 9.64%), Euphorbiaceae, the Mimosaceae, Sterculiaceae and the Rubiaceae with 5 species each, or 6.02% (Figure 3). Other families were less than 5%. The number of shade trees in the shaded system (52 species), were more than those in the intermediate shaded system 2 (40 species). The same trend was observed for the genera and family richness. The species abundance varied significantly between different agroforestry systems (Anova,  $F = 5.675$ ;  $p = 0.0008$ ) (Figure 4). More forest trees were recorded in the different shade systems, except in the full sun systems where the number of forest tree species were equal to that of fruit tree species. Among the different shade systems, the highest rates of forest tree species with 81.15% and 61.54% respectively were recorded in the two intermediate systems. There was also a significant difference between the forest and

fruit tree species in different cocoa farming systems ( $p = 0.0003$ , Mann-whitney test). The most common forest trees were *Albizia adianthifolia* (Mimosaceae), *Ceiba pentandra* (Bombacaceae), *Ficus exasperate* (Moraceae) *Funtumia elastica* (Apocynaceae) *Hevea brasiliensis* (Euphorbiaceae),

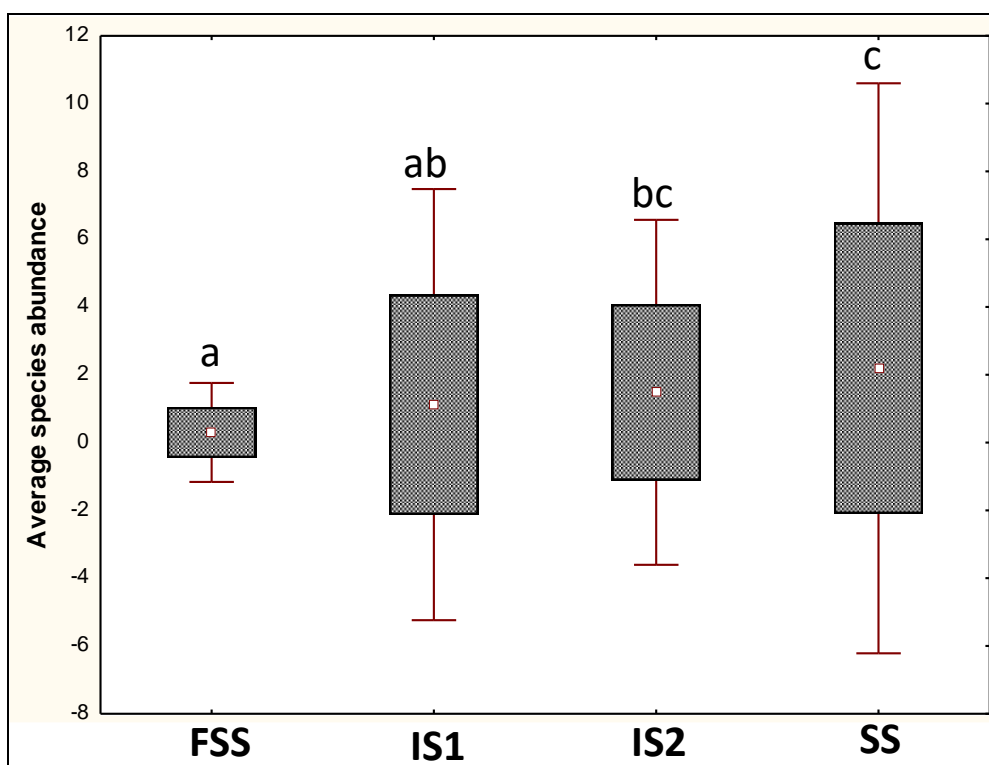
*Spathodea campanulata* (Bignoniaceae), *Spondias mombin* (Anacardiaceae) and *Terminalia superba* (Combretaceae). We have also listed important non-timber species such as *Cocos nucifera* (Arecaceae) and *Elaeis guineensis* (Arecaceae).

**Table 1:** Diversity of timber trees in different shade systems

Shade system	Species Richness	Number of genera	Number of families	Fruit trees (%)	Forest trees (%)
Full sun system	15	13	11	50	50
Intermediate system 1	21	20	15	38.46	61.54
Intermediate system 2	40	33	22	18.85	81.15
Shaded system	52	47	28	40.22	59.78
Total	83	62	32	-	-



**Fig 3:** Most abundant families of timber trees in the different agroforestry systems



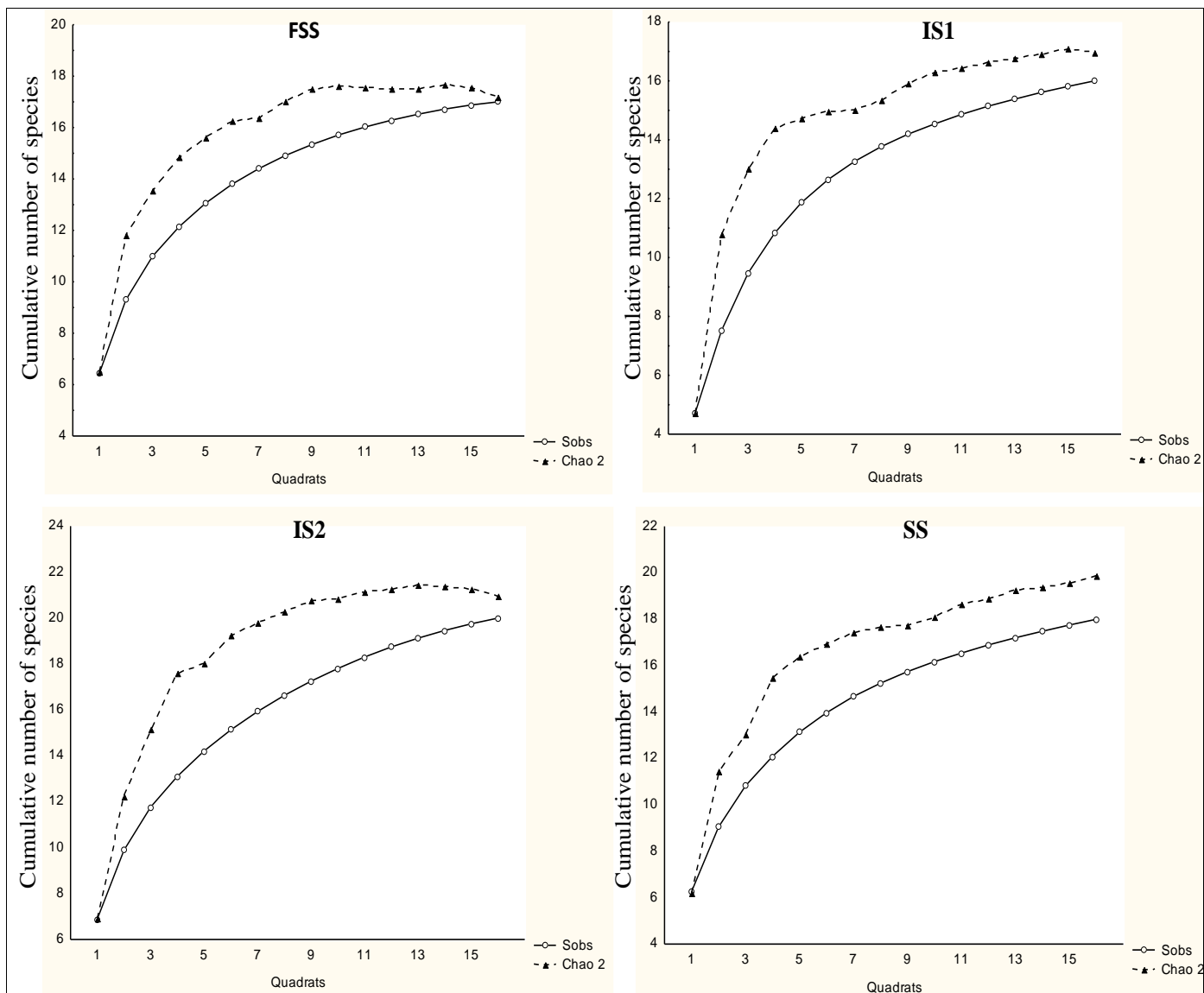
**Fig 4:** Average abundance of trees species. FSS: Full sun system; IS1: intermediate system 1; IS2: intermediate system 2; SS: Shaded system. Means followed by the same letter are not significantly different at 0.05 threshold value based on Tukey test.

## 2.2. Termite's fauna

### Sampling efficiency

The representativeness of a sample is closely related to the efficiency of the sampling method used. Consequently, the evaluation of this efficiency addresses one of the major concerns of community ecology. A rapprochement is observed between the accumulation curves obtained from the

Chao 2 estimator and those of the observed specific richness (Figure 5). This shows a good estimate of the specific richness of termites in the different area. Furthermore, an asymptotic trend in the curves is observed indicating that the numbers of termite species would no longer change significantly even if additional transects had been sampled.



**Fig 5:** Sample-based accumulation curves of observed and estimated species richness in agroforestry systems. FSS: Full sun system; IS1: intermediate system 1; IS2: intermediate system 2; SS: Shaded system.

### Species richness, diversity and distribution of termite's fauna

A total of 29 termite species belonging to 17 genera and 3 families were recorded in the four localities (Table 2). In all the localities, the family Rhinotermitidae comprising 2 subfamilies (Coptotermitinae and Rhinotermitinae) was dominant in terms of richness. This was followed by the family Termitidae comprising 4 subfamilies: Macrotermitinae, Termitinae, Cubitermitinae and Nasutitermitinae. The least dominant family was family Kalotermitidae comprising of only one sub-family (Kalotermitinae). *Coptotermes intermedius*, *Coptotermes sjostedti*, *Ancistrotermes cavithorax*, *Ancistrotermes guineensis*, *Macrotermes bellicosus*, *Microtermes subhyalinus*, *Nasutitermes arborum* and *Nasutitermes latifrons* were sampled in all the localities, while species such

as *Schedorhinotermes lamanianus*, *Acanthotermes acanthotharax*, *Odontotermes sp2*, *Pseudacanthotermes militaris*, *Pericapritermes urgens*, *Trinervitermes geminatus* and *Postelectrotermes sordwanae* were sampled only in one locality.

For the feeding groups, eleven (11) termite species sampled were the fungus-growing termites belonging to the Termitidae family in the subfamily Macrotermitinae. The wood-feeders included the Rhinotermitidae (subfamily Rhinotermitinae and Coptotermitinae), Termitidae (subfamily Termitinae and Nasutitermitinae), and Kalotermitidae (subfamily Kalotermitinae). Also, 11 wood-feeding species were sampled in all the localities. However, the grass-feeders consisted of a single species, belonging to the Termitidae family and Nasutitermitinae subfamily. Six (6) of the termite species sampled were soil-feeding termites belonging to the

Termitidae family. These six species are divided in two subfamilies: Termitinae and Cubitermitinae.

The Shannon index was relatively higher in the intermediate shade system 2 ( $H'=2.30$ ) and shaded system ( $H'=2.30$ ) while The Plots in Takoragui and Petit Bouaké localities with full

sun and intermediate systems recorded the lowest values of Shannon index ( $H'= 2.24$  and  $H' = 2.15$ , respectively) (Table 3). The Pielou index of equitability J values were higher in the full sun system (0.79) and shaded system (0.79), than the two others localities.

**Table 2:** Distribution of termite species in different shade systems

Families	Sub-Families	Species	FSS	IS1	IS2	SS	FG	
Rhinotermitidae (Light, 1921)	Coptotermitinae (Holmgren, 1910)	<i>Coptotermes intermedius</i>	*	*	*	*	X	
		<i>Coptotermes sjostedti</i>	*	*	*	*	X	
	Rhinotermitinae	<i>Schedorhinotermes lamanianus</i>			*		X	
Termitidae	Macrotermitinae (Kemner, 1934)	<i>Acanthotermes acanthothorax</i>			*		C	
		<i>Ancistrotermes cavithorax</i>	*	*	*	*	C	
		<i>Ancistrotermes crucifer</i>	*	*	*	*	C	
		<i>Ancistrotermes guineensis</i>	*	*	*	*	C	
		<i>Macrotermes bellicosus</i>	*	*	*	*	C	
		<i>Macrotermes subhyalinus</i>	*		*	*	C	
		<i>Microtermes subhyalinus</i>	*	*	*	*	C	
		<i>Microtermes thoracalis</i>	*	*	*	*	C	
		<i>Odontotermes sp1</i>	*	*	*	*	C	
		<i>Odontotermes sp2</i>		*			C	
		<i>Pseudacanthotermes militaris</i>					*	C
		Termitinae	<i>Amitermes evuncifer</i>		*	*	*	X
			<i>Microcerotermes edentatus</i>					*
	<i>Microcerotermes fuscotibialis</i>		*	*	*	*	X	
	<i>Microcerotermes parvus</i>			*	*	*	X	
	<i>Pericapritermes urgens</i>				*		H	
	Cubitermitinae	<i>Cubitermes fungifaber</i>	*		*		H	
		<i>Cubitermes subcrenulatus</i>	*				H	
		<i>Procubitermes fungifaber</i>		*			H	
		<i>Procubitermes sjostedti</i>	*				H	
		<i>Promirotermes orthocephus</i>			*	*	H	
	Nasutitermitinae	<i>Nasutitermes arborum</i>	*	*	*	*	X	
		<i>Nasutitermes diabolus</i>	*			*	X	
<i>Nasutitermes latifrons</i>		*	*	*	*	X		
<i>Trinervitermes geminatus</i>			*			F		
Kalotermitidae (Banks, 1919)	Kalotermitinae (Emerson, 1919)	<i>Postelectrotermes sordwanae</i>			*		X	
Total	7	29	17	17	21	18		

\*: presence of the specie, C: Fungus-growers, F: Grass-feeders, H: Soil-feeders, X: Wood-feeders and FG: Feeding groups  
FSS: Full sun system; IS1: intermediate system 1; IS2: intermediate system 2; SS: Shaded system.

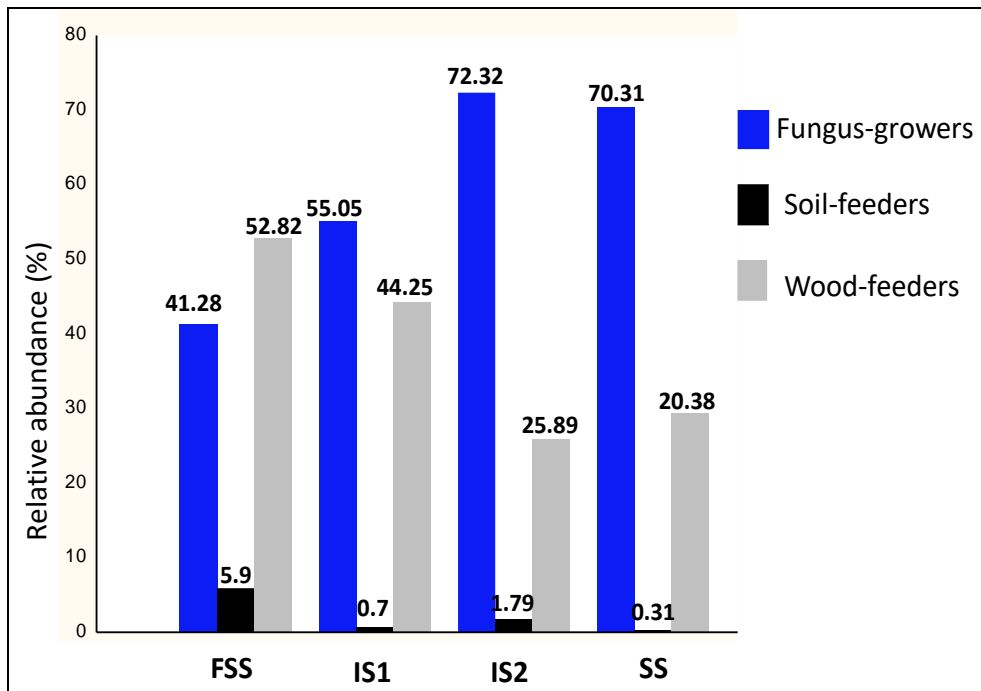
**Table 3:** Diversity of termite in cocoa agroforestry systems

Diversity indexes	Full sun system	Intermediate system 1	Intermediate system 2	Shade system
Species richness (S)	17	17	21	18
Shannon ( $H'$ )	2.24	2.15	2.30	2.30
Equitability -J	0.79	0.76	0.76	0.79

#### Abundance of feeding groups of litter termites

The termites collected from the soil were divided into three trophic groups. These are fungus-growers, wood-feeders and soil-feeders. No grass-feeder species was collected from the soil. The fungus-growers and wood-feeders were dominant in all the shade systems (Figure 6). In the full sun system, wood-feeders (52.82%) had the highest relative abundance, followed by fungus-growers (41.28%). On other, in the

intermediate and shaded systems, the fungus-growers were dominant with proportions going up to more 72% in the second intermediate system. We recorded the lowest numbers of wood-feeders in the second intermediate system. The soil-feeders were the least abundant trophic group in all the shade systems but with a higher number sampled in the full sun system.



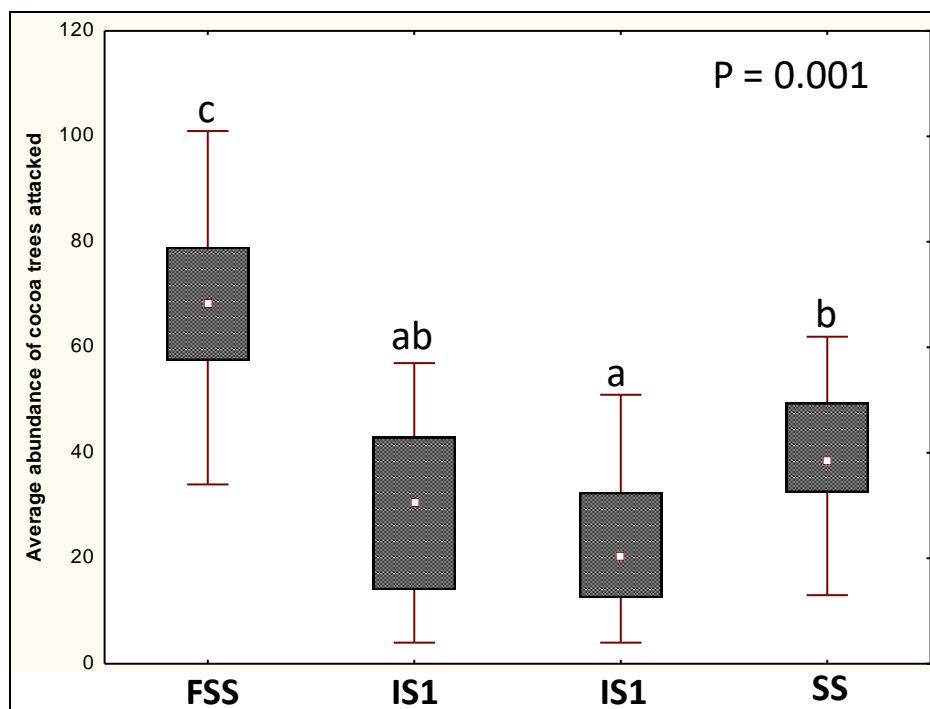
**Fig 6:** Relative abundance of termites feeding groups. FSS: Full sun system; IS1: intermediate system 1; IS2: intermediate system 2; SS: Shaded system

**Attacks and damage of termite pests in cocoa plantations**

The study of average relative abundance of cocoa trees attacked in the four shade systems shows a significant variation in the relative abundance of attacks (Anova,  $p = 0.001$ ) (Figure 7). The average relative abundance of cocoa trees attacked was higher in full sun system while the intermediate systems recorded the lowest relative abundance. A significant difference was observed between the relative abundance obtained in shaded system and the other systems. However, no difference was observed between the relative abundances of cocoa trees attacked in the two intermediate systems.

The quantitative analysis of termite attacks on cocoa trees

revealed that out of a total of 6045 cocoa plants examined, 41.82% presented termite attacks. In the intermediate systems, the average attack rates are 29.1% (Intermediate system 1) and 27.87% (Intermediate system 2). In the full sun system (Takoragui), the average rate of infestation was 61.49%. Termite infestations in this locality were more comparing to others localities. Moreover, the two categories of infestation were higher in the full sun system compared to the other shade systems (Table 4). From the analysis of quantitative results, types I damage were higher than type II damage in all the localities. There is a significant difference between the types of damage in each shade system.



**Fig 7:** Average abundance of cocoa trees attacked (cocoa trees / quadrat). FSS: Full sun system; IS1: intermediate system 1; IS2: intermediate system 2;

SS: Shaded system. Means followed by the same letter are not significantly different at 0.05 threshold value based on Tukey test.

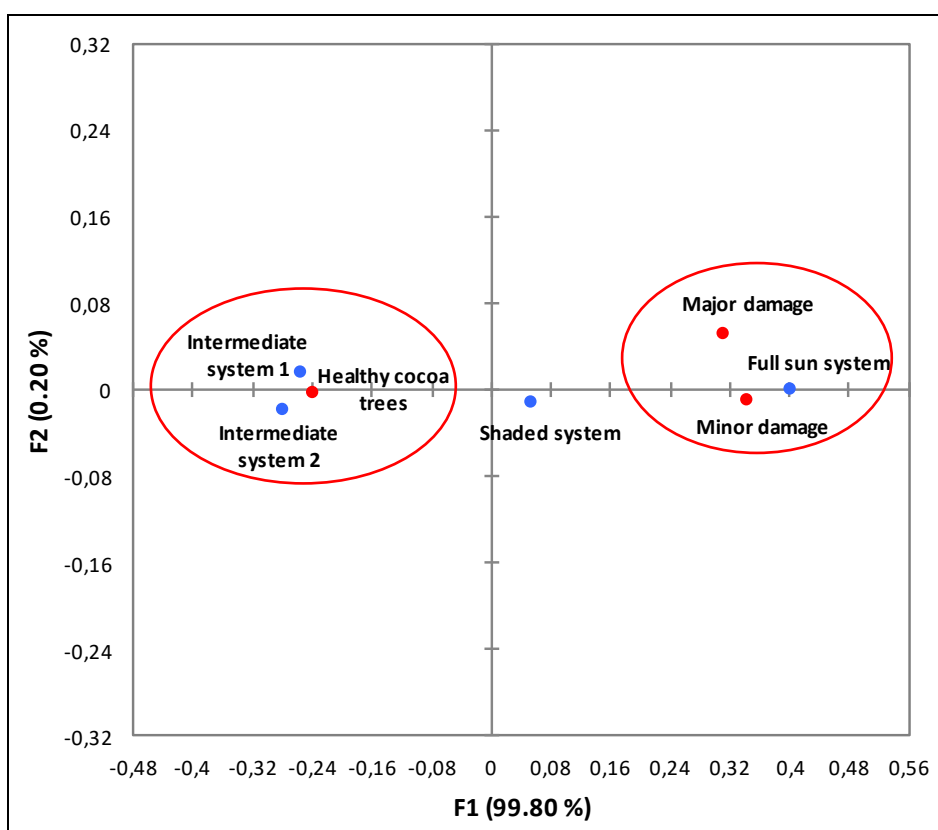
**Table 4:** Attack of cocoa trees according to damage types

Shade systems	Mean			P value
	Healthy cocoa trees	Minor damage	Major damage	
Full sun system	42.44±15.81	59.75±18.95	8.0±3.16	<0.0001
Intermediate system 1	68.38±22.83	24.19±14.43	3.88±3.1	<0.0001
Intermediate system 2	60.00±18.5	20.56±12.33	2.62±1.5	<0.0001
Shaded system	49.0±26.22	34.5±12.52	4.5±1.59	<0.0001

### Relationship between shade level and termite damage

The correspondence analysis based on termite attacks abundance and the type of damage shows the relationships between shade level and termites damage. The axes (F1 and F2) extract 100% of the total inertia, expressing all of information on distribution of the variables studied (Figure 8). The eigenvalue of axis 1 is very high (99.8%) indicating a good diagonalization of data and a significant relationship between the variables studied. Axis 1 opposes the two intermediate systems with the shaded and full sun systems. It also opposes, on the same side, healthy cocoa trees and the two types of damage (minor damage and major damage). Axis

2 highlights the opposition between the first and second intermediate system. It also opposes the two types of damage. The classification resulting from the correspondences analysis allows having two large groups. The first group reveals a strong correlation between the intermediate systems and the number of healthy cocoa trees. In the second group, the correlation is high between the full sun system with fewer shade trees and the two types of damage recorded on cocoa trees. The shade level (number of shade trees) appears to have an effect on the types of termite damage and the number of cocoa trees that suffered termite damage.



**Fig 8:** Factorial map showing the relationship between shade level and damage types

## 3. Discussion

### 3.1. Floristic richness

We identified 83 tree species belonging to 32 families. The Moraceae and Meliaceae families were the most represented in all the cocoa agroforests with 10 and 8 species respectively. This study shows a large difference in species richness and composition in the four cocoa agroforestry systems. Regarding plant species richness, there was an increase in the number of plant species from full sun systems to shaded systems. The proportion of forest trees was greater than that of fruits trees in shaded systems and intermediate systems. The difference could be as a result of in plantations already in production, structures in charge to supervise cocoa farmers in

these areas provide generally forest trees as shade trees. Some forests trees species found in the plantations in the study area such as *Albizia adianthifolia*, *Ceiba pentandra*, *Ficus exasperata*, *Funtumia elastica*, *Hevea brasiliensis*, *Spathodea campanulata*, *Spondias mombin* and *Terminalia superba* were identified in agroforestry systems of other regions of Côte d'Ivoire [21-23]. The conservation and introduction of forests trees in cocoa plantations could be linked to recognition by the new Ivorian forest code adopted in 2014 from the ownership of tree to the land owner. This could encourage the latter to allow these forest trees to proliferate or to be introduced into plantations, with the aim that in addition to the environmental services they provide to the plantation,



these trees could be used by producers without any constraints.

### 3.2. Diversity and distribution of termite fauna

Twenty nine (29) termite species belonging to 17 genera, 7 subfamilies and 3 families (Rhinotermitidae, Termitidae and Kalotermitidae) were identified. All termite species we sampled in this study have previously been reported in Côte d'Ivoire. Our results are similar to that of Ndiaye (1998) who collected 29 termites' species from fruit tree orchards in Senegal using orchard tree collection method. Studies carried out in Côte d'Ivoire by Tano (1993), Tra Bi (2013) and Coulibaly (2014) identified respectively 42, 34 and 36 termite species, respectively. This difference can be explained by the fact that Tano's sampling was conducted in a savanna region (Boro-Borotou) identified as one of the richest termite savannas compared to other African savannas. However, in general, species diversity is lower in most anthropized areas. This agrees with the work of Samb *et al.* (2011) who observed a decrease in species diversity in areas frequented by humans. These differences could also result from the fact that, termite's distribution translates into diversity and abundance that vary from one ecosystem to another depending on climate, soil type and vegetation <sup>[7]</sup>. Diversity and floristic composition of the plant species in our study area would therefore influence this specific difference. According to Anani Kotoklo *et al.* (2008), specific difference observed between different study areas is related to nature of soil and especially the floristic composition that surrounds each environment. The slightly higher number of species at intermediate system 2 (21 species) and shaded system (18 species) is therefore related to floristic composition of these two cropping systems.

For the feeding levels, the presence of 4 groups reflects a good functional diversity of the termitological fauna. The stand is dominated by fungus-growers and wood-feeders in all management systems, reflecting an abundance of wood food and litter from different environments. Indeed, fungus-growers harvest their food from dead leaves, dead wood and dried grass. Lignivorous feed on live, dead, dry or decaying wood. This result is consistent to the work of Tra Bi *et al.* (2010) explaining the dominance of fungus-growers by their adaptation favored by symbiotic relationship they have with the Termitomyces fungus which facilitates wood degradation. The existence of a correlation between full sun system and wood-feeders group, would be an indicator of the high rate of termite damage. The soil-feeders abundance in the full sun system compared to the other systems could be linked to the evolution of the physico-chemical structure in the full sun system which favored installation of this group of termite in this medium more degraded.

### 3.3. Attacks and damage of termite's pests in cocoa plantations

According to our results, infestations by termites are mostly type I. These high rates of type I attacks are due to the attack mode of different termite species encountered. Most termites build veneers on the trunks of plants. These veneers serve as protection to attack the plant <sup>[30]</sup>. A rate of attack due to termites is variable according to plots and shade systems. In systems without shade, the attack rate and damage caused by termites are higher compared to other management systems. This could be explained by several reasons: first, the vulnerability of the system without shade against the attacks

of insect pests. Cocoa trees age also has an impact on the termite attack. These results are in agreement with those of Tra Bi *et al.* (2013) showed that the middle and age of plots influence termite attacks. Termite attacks may be related to the soil nature (ferralitic red soil) that would favor the installation of termite mounds, sources of plants infestation <sup>[30]</sup>.

Intermediate systems are the least attacked by termites. This weak attack of termites in intermediate systems could be explained by the composition and complexity of these systems. Several factors including shade would influence termite's installation in plots. These intermediate management systems could therefore help reduce termite attacks, given that massive deforestation and climatic disturbances in recent years have led to termites, formerly considered as minor pests, gaining momentum.

### 3.4. Relationship between shade trees and termite damage

We observed a strong correlation between the full sun system and termite damage on cocoa trees. Termite damage on cocoa trees was higher in systems with fewer shade trees. The level of shade would influence the types of termite damage and the number of cocoa trees suffered termite damage. We suspect that these attacks on cocoa trees were due to the lack of trees in these plots. It is likely that with the presence of shade trees, termites attack them and reduce the number of attacks on cacao trees. Field observations seem to prove that termite infestation affects a large number of shade trees regardless of the cropping system. Although <sup>[31]</sup> believe that in shaded plots, the density of trees associated with cocoa can negatively influence the success rate of cocoa trees by causing mortality, shade management could reduce pest attacks and thus improve yield <sup>[32]</sup>. Clough *et al.* (2011) showed that moderate shading, high labour input per unit area and an effective pest and disease management approach based on manual and cultural control are essential to increase yields while maintaining production in the long term.

Although aware of the damage caused by termites, farmers are rather concerned about the ravages of the swollen shoot. We recommend awareness raising and assistance from cocoa farmers on shade management and the choice of an appropriate cropping system that would reduce termite attacks, produce long term and preserve biodiversity.

### Conclusion

Some insects are considered as major pests due to importance of damage to cocoa trees. Conversely, others are considered as minor pests because the losses the insects cause are negligible. However, because of the massive deforestation and climate change that have occurred in recent years, termites, previously considered as minor pests, are gradually becoming major pests in cocoa agroforests. In this work, we studied diversity of plant species, termite fauna and their damage in plots of different cocoa growing systems. This study shows that that shade influences termite species richness and damage in cocoa farms. We also noted that intermediate systems are least attacked by termites. Agroforestry systems, in addition to cocoa production, generate financial benefits from fruit or forest trees, these intermediate systems can serve as a compromise between long-term production, biodiversity conservation and producer incomes. However, implementation of these systems requires their adoption by producers and support of structures in charge of cocoa sector.

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