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Diversity and functional structure in ant community in a forest savannah transitional zone in Obala (Centre Region of Cameroon)

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ABSTRACT We study ant community in Obala (Cameroon), a forest-savannah ecotone to determine diversity and functional structure. Ants were sampled using pitfall, bait and hand-collecting in four habitats. Ant community was characterized using genera and species richness per subfamily, species richness and Pielou index for diversity, Venn diagrams for the distribution of species richness, multinomial model and Individual value to determine habitat specialization, and Multiple Correspondence Analysis to identify functional structure. We identified 104 ant species belonging to 34 genera and six subfamilies; 90, 31, 35 and 17 ant species were collected respectively in cocoa farms, food crops plantations, teak forests and savannahs. Myrmicinae, Ponerinae and Formicinae were the richest subfamilies at genera and species levels. Cocoa farms were richer and more diverse (S = 90; E = 0.68) than other habitats. Eight species were shared amongst the four habitats and the high number of generalist species occurred between cocoa farms and teak forests. Indicator species were mainly ground-dwelling ant species, confirming the high level of environmental threat in Obala. Four functional structures were identified: non-dominant ground foraging species with low ability for space control; tree foraging species with low ability for food control found in cocoa farm; subdominant species that exert medium level of food and space control; and ubiquist numerically dominant ant species with high aptitude for food and space control. In a functional structure involving ant species that plays the same or complementary roles in the ecosystem functioning and determine network of species assemblages.

KEY WORDS Habitat specialization; diversity; functional structure; Obala.

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INTRODUCTION

Habitat structure and human activities are known to be the main factors influencing species diversity and distribution in terrestrial ecosystems. In farmlands experiencing various agronomic practices, soils arthropods were numerically dominated by insects, ants being the most abundant group (Eni et al., 2014). So, ant appear as the most abundant taxa found in natural ecosystems and agroecosystems, and they provide ecosystem services through a wide range of diverse and complex biotic interactions. Their role in the biocontrol of pests is well documented for coffee berry borer

(Morris et al., 2018), and *Sahlbergella singularis* Hagl. (Van Mele & Cuc, 200); most of them were positively associated with hemipterans that cause damage to cultivated plants (Aléné et al., 2016). Ant community structure in agroforestry systems rely on a complex relationship established between ground-dwelling and arboreal ant species. It results in a tridimensional mosaic pattern in which arboreal ant community composition is sometimes mostly influenced by the ground-dwelling ant species, depending on the habitat structure and the trees composition (Tadu et al., 2022).

Several factors may explain changes in ant diversity and structure in natural and anthropic ecosystems including insecticide treatment (Tadu et al., 2013), agricultural expansion and conversion of natural habitat to agricultural system (Eisawi et al., 2022), and behavioral dominance which depends on whether dominant species are native or non-native (Arnan et al., 2018). However, some agricultural practices like crops diversity in plantain-based agrosystems do not affect numerical diversity for some ant taxa (Dassou et al., 2017) and seasonal variation have a low influence on ant abundance and diversity (Dassou et al., 2017; Tchoudjin et al., 2020a).

Despite several studies conducted in the last ten years on ant diversity in Cameroon (Tadu et al., 2014; Messop-Youbi et al., 2018; Tchoudjin et al., 2020b, Tadu et al., 2021), many localities remain unexplored and the impact of local land use systems on ant diversity and distribution is still unknown. More, the functional structure in ant communities and its influence on networks of species assemblage in a context of increasing anthropogenic disturbance and habitat losses need to be clarified.

In Obala, arboreal ant communities in cocoa agroforestry systems were investigated (Tadu et al., 2014) but the study was not extended to the ground-dwelling ant communities and different land use systems available in the locality. So, regarding the landscape of the area, cocoa farms, food crop plantations, planted or natural teak forests are the most represented. Through these land use systems, we investigated their influence on diversity, habitat specialization and functional structure and the resulted network of species assemblage in ant communities.

MATERIAL AND METHODS

Study area

The study locality was Obala Subdivision, in the Lekié Division, in the Centre Region of Cameroon. The study was conducted from July to October 2021 in three villages, Nkol-Mendouga (4°02'N - 11°29'E) in the south, Mekas in the centre (4°09'N - 11°33'E) and Minkama in the north-east (4°11'N - 11°32E) (Fig. 1).

From a phytogeographic point of view, Obala is situated in the forest-savannah ecotone. It is a transition zone between the Sudanese savannah and the semi-deciduous forest (Letouzey, 1985). The landscape is a mosaic of vegetation formations dominated by cocoa-based agroforests and food crops plantations. Savannahs are progressively disappearing as a result of the expansion of food crops plantations, cocoa agroforestry system and planted or natural reforestation by teak trees. The soils are ferrallitic, red or ochre color. The climate is equatorial type of transition with an average rainfall about 1500 mm and an average temperature of 25 °C per year. This climate is divided into 4 seasons: a major dry season (November to March), a minor rainy season (March to June), a minor dry season (July to August), and a major rainy season (August to November) (Suchel 1988). Due to global climate change, the climate of Obala was disturbed, rainy and dry season period vary from one year to another and affect meteorological prevision and agricultural calendar. Cocoa is the main cash crop in the locality followed by fruits like mangoes, oranges, mandarins, citrus and bush butter. People of Obala produce an important part of the fresh food that is available and consumed in the capital city of Yaoundé.

Description of sampling plots

A total of 13 plots were sampled: seven cocoa farms, three food crop fields, two patches of teak forest and one patch of savannah. In Nkol-Mendouga, sampling was conducted in three cocoa plantations and three food crop fields; two cocoa plantations and one savannah patch were sampled in Mekas while two cocoa plantations and two patches of teak forests were sampled in Minkama. The coordinates of the sampling plots are summarized in Table 1.

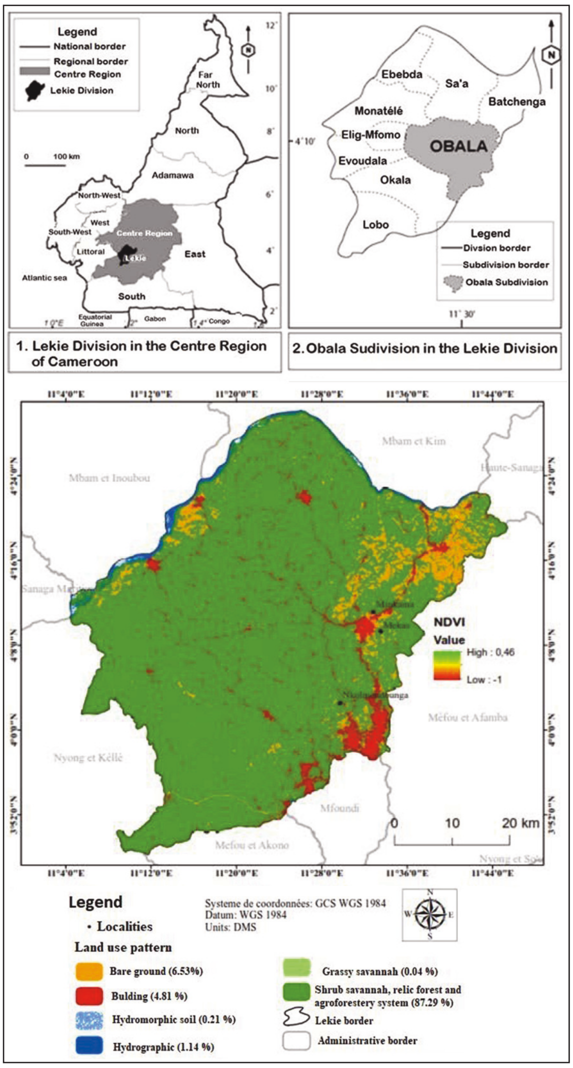


Figure 1. Location of the study area (Obala, Cameroon).

Cocoa plantations are generally old (more than 50 years on average). However, most of them are still exploited. Old and unproductive trees are frequently replaced by the younger ones from different varieties. The Amelonado variety introduced by Germans is dominant in all the plots and it is associated with different hybrid varieties resulting from SODECAO's selection programs. The farms are regularly pruned, cleared and treated with pesticides and fungicides to control pests and diseases. The most used pesticides were Cofresh 100ec and Parastar 100ec while the main fungicides were Sonamil 720 wp, Apromil 72 wp, and Nordox 75 wg. To improve yields production, fertilizers (NPK 15.15.30) were used by some farmers. Cocoa trees are grown in association with fruit trees such as bush butter (*Dacryodes edulis* Lam.), mango (*Mangifera indica* L.), orange (*Citrus sinensis* L. Osbeck), mandarin (*Citrus retivulata* Blanco), clementine (*Citrus clementina* hort.ex Tanaka), herbaceous plants such as banana and plantain (*Musa* spp.) and forest trees that provide shade for the cocoa trees (*Theobroma cacao* L.). The most common food crops cultivated are cassava (*Manihot esculenta* Crantz), cocoyam (*Xanthosoma sagittifolium* Schott) and plantain (*Musa paradisiaca* L.). Cassava is generally grown in a monoculture system; however, a few stem of maize (*Zea mays* L.) are planted when the cassava is still very young. A few palm oil trees (*Elaeis guineensis* Jacq.) can also found.

Teak forests (*Tectona grandis* L.F.) found in Minkama, were monospecific farms in which the trees are less regularly arranged. They are exploited for the production of wood. However, the teak forests extends throughout the locality with very small patches resulting from natural colonization. Savannah is the most threatened habitat in the locality because of the extension of agricultural activities and natural colonization by teak trees.

Ant sampling

The study was conducted in four types of habitats: cocoa farms, crops plantations, teak forests and savannahs. In each locality, we delimited plots of 30x30 m (900 m^2), using a 50 m long decameter. Each sampling plot was delimited at the center of the habitat to reduce edge effects. Ants were collected on the ground and on the trees in the cocoa farm and teak forests. In food crop fields and savannahs, they were collected only on the ground. The minimal interval between two sampling plots in each site was around 500 m.

Ants were sampled on all the trees present in the delimited section using pitfall traps (9 cm in diameter and 12 cm of depth) fixed on trees at 1.5 m above the ground with an adhesive band combined with hand-collecting helping with a mouth aspirator and forceps when necessary. On the ground, four non-contiguous transects of 30 m distant of 10 m each other were delimited in each plot of 30x30 m² (Tadu et al., 2021). We alternatively applied three captures methods: pitfalls (9 cm in diameter and 12 cm of depth), quadrats (collect litter in a square of 1x1 m), and baits (mixture of sardine and honey)

Sites	Plots	Coordinates		Plant composition
		X	Y	
Nkol-Mendouga	Cacao farm 1	4.04515	11.49270	Cacoa, forest and fruit trees, banana
	Cacao farm 2	4.04312	11.49182	Cacoa, forest and fruit trees, banana
	Cacao farm 3	4.04220	11.49466	Cacoa, forest and fruit trees, banana
	Food crops 1	4.04815	11.48535	Cassava, plantain, cocoyam
	Food crops 2	4.04692	11.48587	Cassava, plantain, cocoyam
	Food crops 3	4.04498	11.48888	Cassava, plantain, cocoyam
Mekas	Cacao farm 4	4.15556	11.55946	Cacoa, forest and fruit trees, banana
	Cacao farm 5	4.15448	11.55946	Cacoa, forest and fruit trees, banana
	Savannah	4.16093	11.55848	grass and shrub
Minkama	Cacao farm 6	4.11124	11.32534	Cacoa, forest and fruit trees, banana
	Cacao farm 7	4.11122	11.32485	Cacoa, forest and fruit trees, banana
	Teak forest 1	4.18231	11.54545	Only teak trees
	Teak forest 2	4.18372	11.54630	Teak and forest trees

Table 1. Coordinates of the sampled plots in Obala (Cameroon).

for ant sampling. Ten pitfall traps three meters apart from each other were disposed on the first transect, in a second transect we collected the litter in five quadrats of 1 m^2 separated by six meters (also repeat in the last transect). In a third transect, 10 baits regularly disposed at three meters intervals were deposited. Pitfalls were removed after 72 hours, baits five minutes later and litter collected in the quadrat was sorted for one hour and ants were captured using a mouth aspirator and forceps. Combining these three methods increases the species inventory and maximizes sampling success (Delabie et al., 2021). In the laboratory, ants were sorted and stored in labelled vials containing 70% alcohol. They were identified based on the dichotomic keys of Fisher & Bolton (2016) at genera levels, and Taylor (2010) at species level when possible. Voucher specimens were deposited in the laboratory of Zoology of the University of Yaoundé 1.

Data analysis

Ant diversity in different land use systems in Obala

Data from cocoa farm, food crops and teak forests were pooled together before the analysis. We computed and compared genera and species richness per subfamily in each type of habitat. Ant diversity in each community was evaluated based on species richness (S) and the Pielou index (E) computed using the Vegan package (Oksanen et al., 2011). We chose species richness and Pielou index to characterize diversity, because they are more intuitive and simpler for interpretation. The assumption is that, high species richness and high Pielou index in a particular land use system compared to another one suggest a higher diversity. Sorensen index (d), was used to determine similarity between ant communities. The analysis was done with the Vegan package (Oksanen et al., 2011) for R software (version 3.2.2). We tested the main effect of type of habitat on the variation of species richness, and equitability between ant communities with the Kruskal-Wallis test associated with the Wilcoxon pairwise test when necessary. For pairwise comparisons, the p-value was adjusted with a sequential Bonferroni procedure. The results were appreciated at 5% confidence level.

Species richness distribution between land use systems

We studied species richness distribution between land use systems using Venn diagrams that showed the number and the relative percentage of exclusive and shared species between land use systems. The analysis was done using ggvenn package for R (Yang 2023).

Habitat specialization an indicator species in ant community

We investigated the relation between ant species and land use systems using multinomial model (CLAM method) proposed by Chazdon et al. (2011) and indicator value of Dufrêne & Legendre (1997). For Chazdon et al. (2011), the multinomial model was more sensitive than indicator value analysis or abundance-based phi coefficient indices in statistically detecting habitat specialists and generalists as well. CLAM method allows us to groups' species from land use system A and B based on their frequency into four categories: (1) generalist species, (2) group A specialist species, (3) group B specialist species, and (4) species that are too rare to be classified with confidence. A generalist or ubiquist species is one that can thrive under a wide range of environmental conditions and can make use of a wide variety of resources; in contrast, a specialist species can only thrive under a narrow range of environmental conditions, with a limited diet (Towsend et al., 2003). According to CLAM method, a species is considered as specialist when at least two-third of individuals are found in a singular habitat.

We used indicator value proposed by Dufrêne & Legendre (1997) to find indicator species for each type of habitat. Indicator value "$d_{i,c}$" used in both specificity $a_{i,c}$ and fidelity $f_{i,c}$ for each species for a type of habitat and was computed as a product of the relative frequency and relative average abundance in cluster. It is given by the following relation:

$$d_{i,c} = a_{i,c} \text{ x } f_{i,c}$$

where:

$$a_{i,c} = \frac{\sum_{j\varepsilon c} p_{i,j}/n_c}{\sum_{k=1}^{K}((\sum_{j\varepsilon k} x_{i,j})/n_k} \text{ and } f_{i,c} = \frac{\sum_{j\varepsilon c} p_{i,j}}{n_c}$$

$p_{i,j}$ is the presence/absence (1/0) of species i in sample j; $x_{i,j}$: abundance of species i in sample j; n_c: number of sample in a cluster c; for cluster c in set k. The analysis was done with labdsv package (Roberts, 2016) for R software (version 3.2.2) and the result was appreciated at 5% confidence interval.

Ant distribution between land use systems

We evaluated the abundance of different ant species in each type of habitat and the continuation of the analysis concerned only the species with a cumulative appearance per sample in the whole habitat superior or equal to 5%. We tested the main effect of the land use system on the variation of abundance of frequent ant species with Kruskal-Wallis test associated with the Wilcoxon pairwise comparisons test when necessary. For pairwise, the p-value was adjusted with a sequential Bonferroni procedure. The analysis was done with R software (version 4.3.2) and the results were appreciated at 5% confidence level.

Functional group and network of species assemblage in ant community

We considered the functional structure at a local scale as a dynamic system in which the species assemblage models ~~depends~~ depend on the habitat structure where the ant species was found, surrounding habitat and behavioral traits intrinsic to each ant species. We consider in our analyses: (1) habitat affinity based on the presence or absence of ant species in a particular type of habitat: ant species collected at least in two types of habitats were considered as ubiquist, when the species occured only in one type of habitat we considered it as specific to this habitat; (2) for foraging strata, when ant species occured only on the ground or on the trees we assigned them to be either ground or trees foraging ant species, and ground-trees foraging ant species when the workers were collected both on the ground and the trees; (3) for food control: the abundances of workers collected on the bait were categorized in three intervals of abundance:]0-10],]10-100[and ≥ 100 represented respectively low, medium and high ability to control food resources. We used a similar scale to evaluate (4) the foraging activity for each ant species based on their cumulative abundance from the three sampling techniques; so, low, moderate and high foraging activity corresponded respectively to ant species with abundance between]0-10],]10-100[and ≥ 100 were define; and (5) numerical dominance corresponding to non-dominant, subdominant and dominant ant species respectively for]0-10],]10-100[and ≥ 100 workers abundance in the four sampling land use systems sampled. A matrix containing the five selected variables was analyzed using Multi Correspondence Analysis (MCA). A functional structure was then assigned and the main network assemblage was checked within the different groups. Multi Correspondence Analysis were done using package FactoMineR (Lê et al., 2008) for R software.

RESULTS

Ant diversification with land use structure

All the sampling methods implemented allowed us to collect a total of 1287 samples: 598 samples in Nkol-Medouga (418 samples on the trees and 180 samples on the ground), 247 samples in Mekas (157 samples on the trees and 90 on the ground), 442 samples in Minkama (322 on the trees and 120 on the ground). A total of 104 ant species belonging to 34 genera and six subfamilies were collected in the four types of habitats in Obala, including cocoa farms, food crops plantations, teak forests and savannah. We found 90, 31, 35 and 17 ant species respectively in the cocoa farms, food crops plantations, teak forests and savannahs. At the genera level, Myrmicinae, Ponerinae and Formicinae with respectively 11 (32.35%), 10 (29.41%) and 8 (23.53%) genera were the most diverse subfamilies. A similar trend was observed at species level where Myrmicinae, Formicinae and Ponerinae were represented by 47 (45.19%), 31 (29.81%) and 15 (14.42%) species, respectively. Considering all the land use systems, cocoa fams were the most diverse at generic and specific levels. So, we found 10 (32.26%), 9 (29.03%) and 8 (25.81%) genera belonged to Myrmicinae, Ponerinae and Formicinae subfamilies, respectively; at species level 41 (45.56%), 29 (32.22%) and 12 (13.33%) species collected belong to Myrmicinae, Formicinae and Ponerinae subfamilies, respectively (Table 2).

Species richness and the Pielou index showed that, ant community was most diverse in cocoa farm (S = 90; E = 0.68) followed by teak forest (S = 35; E = 0.73). Food crop (S = 31, E = 0.43) and savannah (S = 17; E = 0.62) were the least diverse land use system. The average species richness (χ^2 = 45.73; df = 3; p< 0.0001) and Pielou index (χ^2 = 9.12; df = 3; p = 0.03) varied significantly with the land use system. Pairwise comparison showed that the average species richness did not vary significantly between food crops and savannah (p = 0.06), and between cocoa farm and teak forest (p = 0.13). Other types of habitats showed a significant difference in the average species richness. Pielou index varied significantly only between food crops and teak forest (p = 0.03), other systems showed non-significant difference (p> 0.05).

Species richness distribution and implication for ant community composition

The Venn diagram (Fig. 2) shows that among the 104 ant species collected, 48 (46.2%), 7 (6.7%) and

Subfamilies	Land use systems								Total	
	Cocoa farm		Food crops		Teak forest		Savannah			
	Genus	Species	Genus	Species	Genus	Species	Genus	Species	Genus	Species
Dolichoderinae	2(6.45)	5(5.56)	1(5.56)	1(3.23)	2(13.33)	2(5.71)	1(8.33)	1(5.88)	2(5.88)	7(6.73)
Dorylinae	1(3.23)	1(1.11)	1(5.56)	1(3.23)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	2(5.88)	2(1.92)
Formicinae	8(25.81)	29(32.22)	4(22.22)	8(25.81)	3(20.0)	8(22.86)	3(25.0)	5(29.41)	8(23.53)	31(29.81)
Myrmicinae	10(32.26)	41(45.56)	6(33.33)	11(35.48)	6(40.0)	19(54.29)	4(33.33)	7(41.18)	11(32.35)	47(45.19)
Ponerinae	9(29.03)	12(13.33)	5(27.78)	9(29.03)	4(26.67)	6(17.14)	3(25.0)	3(17.65)	10(29.41)	15(14.42)
Pseudomyrmicinae	1(3.23)	2(2.22)	1(5.56)	1(3.23)	0(0.0)	0(0.0)	1(8.33)	1(5.88)	1(2.94)	2(1.92)
Total	31	90	18	31	15	35	12	17	34	104

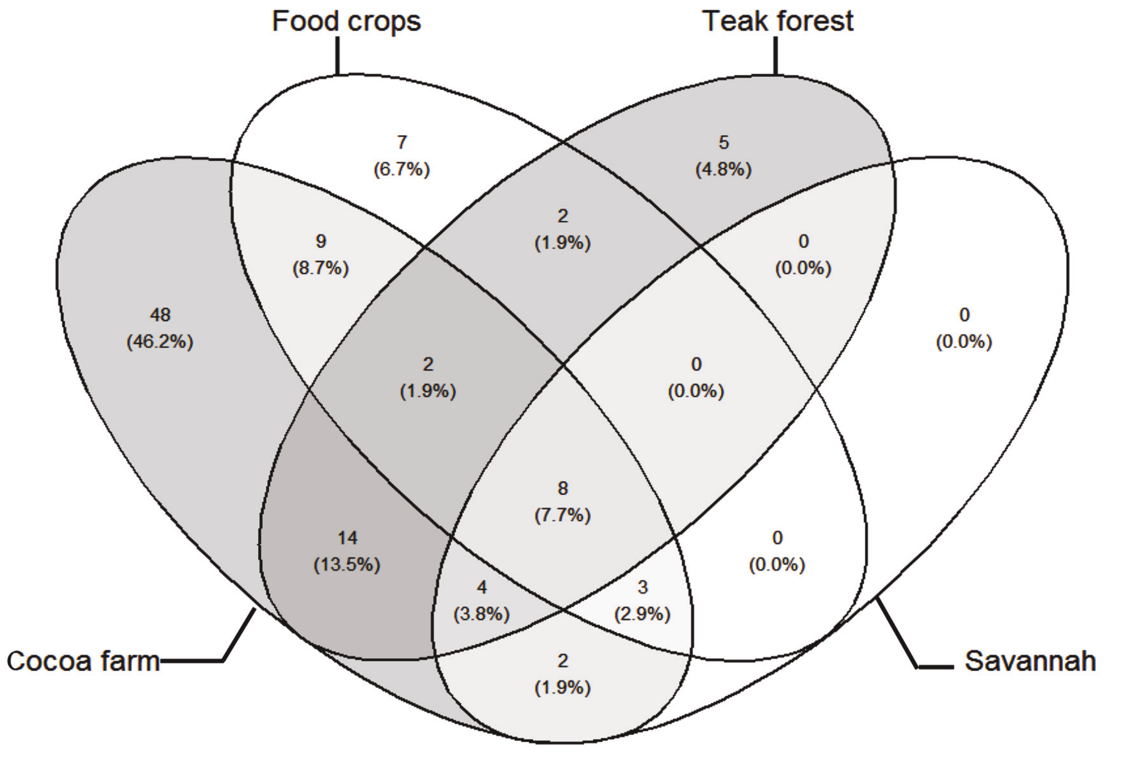
Table 2. Variation of genera and species richness between different land use systems in Obala (Cameroon).

5 (4.8%) ant species were specific to cocoa farm, food crops and teak forests, respectively; no ant species was specific to the savannah. Food crops and savannah, food crops and teak forests and teak forests and savannah do not share exclusive species. The number of common species shared by the four types of habitats is low and represent just 8% of the total species richness (Fig. 2).

Sorensen index showed that all the sampled land use systems in Obala were globally similar in regard to their species composition. In fact, Sorensen index was higher than superior to 50% between all the pairs of land use systems. Nevertheless, cocoa farm and savannah (68.0%) appeared more similar, followed by cocoa farm and food crops, and food crops and teak forest with 64.0% of similarity, respectively. Teak forest and savannah were the least similar type of habitats (Table 3).

Habitat specialization in ant community

The highest species richness was observed between cocoa farms and food crops with 99 ant species, followed by cocoa farms and teak forests with 97 ant species; food crops and savannahs with 37 ant species was the least rich. Clam method showed that, the highest number of generalist species was found between cocoa farms and teak forests and were represented by 11 (11.30%) species and the lowest between food crops and teak forests in one hand and food crops and savannahs on the other hand with three species each. In cocoa farms a specialist



	Cocoa farms			
Cocoa farms	1	Food crops		
Food crops	0.64	1	Teak forest	
Teak forest	0.55	0.64	1	Savannah
Savannah	0.68	0.54	0.54	1

Figure 2. Venn diagrams showing the number of exclusive and share ant species between the four types of habitats in Obala (Cameroon).

Statut	Land use systems					
	Co-Fc	Co-Tf	Co-Sa	Fcr-Tf	Fc-Sa	Tf-Sa
Generalist	4(4.0 %)	11(11.30%)	4(4.40%)	3(5.60%)	3(8.10%)	5(12.50%)
Specialist true	17(17.20 %)	10(10.30%)	14(15.60%)	5(9.30%)	2(5.40%)	6(15.0%)
Specialist false	8(8.10 %)	7(7.20%)	5(5.60%)	9(16.70%)	4(10.80%)	3(7.50%)
Too rare	70(70.70 %)	69(71.10%)	67(74.40%)	37(68.50%)	28(75.70%)	26(65.0%)
Species richness	99	97	90	54	37	40

Table 3. Matrix of similarity showing the species composition between ants' communities in different land use systems in Obala (Cameroon). Relative proportion genus and species richness are given into a bracket. Co: Cocoa farm, Fc: Food crops plantations, Tf: Teak forest and Sa: Savannah. Relative species richness was given into a bracket, species richness in a table is represent by ant species found in the both land use systems. Specialist true and Specialist false represent the number of specialist species in the first and second land use system in the the same order like in a table.

Ant species	Land use systems				Total	χ^2 (Kruskal-Wallis)
	Co	Fc	Tf	Sa		
Atopomyrmex mocquerysi André,1889	1743(16.47%)	0(0.00%)	0(0.00%)	0(0.00%)	1743(12.84%)	χ^2= 9.27*
Camponotus (Tanaemyrmex) congolensis Emery,1899	52(0.49%)^{a}	748(65.61%)^{bc}	122(11.39%)^{bde}	288(34.66%)^{bcf}	1210(8.91%)	χ^2= 327.7***
Camponotus (Tanaemyrmex) maculatus Fabricius,1782	1027(9.70%)^{a}	114(10.0%)^{bc}	55(5.37%)^{acd}	70(8.42%)^{acd}	1266(9.32%)	χ^2= 26.84***
Crematogaster (Atopogyne) africana Mayr,1895	725(6.85%)	0(0.00%)	82(8.00%)	0(0.00%)	807(5.94%)	χ^2= 17.89***
Dorylus (Anomma) nigricans Illiger,1802	940(8.88%)	0(0.00%)	0(0.00%)	0(0.00%)	940(6.92%)	χ^2= 3.0 ns
Oecophylla longinoda Latreille,1802	713(6.74%)	0(0.00%)	0(0.00%)	0(0.00%)	713(5.25%)	χ^2= 13.35**
Tetramorium aculeatum Mayr,1866	925(8.74%)	0(0.00%)	4(0.39%)	3(0.36%)	932(6.86%)	χ^2= 31.83***
Other ant species	4459(42.13%)	278(24.39%)	762(74.34%)	470(56,56%)	5969(43.95%)	
Total	10584(100.0%)	1140(100.0%)	1025(100.0%)	831(100.0%)	13580(100.0%)	

Table 4. Clamtest analysis showing species richness distribution and the habitat specialization of ant species in different land use systems in Obala (Cameroon). Co: Cocoa farm, Fc: Food crops plantations, Tf: Teak forest and Sa: Savannah. df=3; *: p= 0.05, **: p< 0.001 and ***: p<0.0001 for significant p-value at 5% level, ns for non-significant p-value, different letters translate the significant difference between the group, relative abundance are into the bracket.

species were represented respectively by 17 (17.20%), 14 (15.60%) and 10 (10.30%) species when comparing to food crops, savannahs and teak forests, respectively. The number of too rare species represented more than 60% of the species richness collected in pairs of land use systems (Table 4). Individual values showed that *Anoplolepis tenella* (Indval = 0.05; p = 0.02), *Mesoponera ambigua* (Indval = 0.03; p = 0.02), *Pheidole megacephala* (Indval = 0.03; p = 0.02) and *Pheidole rohani* (Indval = 0.02; p = 0.04) were the indicator species found in cocoa farms. In food crops *Camponotus maculatus* (Indval = 0.23; p = 0.03) and *Myrmicaria opaciventris* (Indval = 0.20; p = 0.01) were the indicator species. *Odontomachus troglodytes* (Indval = 0.08; p = 0.02) was the indicator species of teak forests. No indicator species was found in savannahs.

Ant species distribution between land use systems

Seven ant species were numerically dominant with a cumulative relative abundance in all types of habitats combined ≥ 5%. *Atopomyrmex mocquerysi* with 12.48 % of workers collected was the most abundant ant species, followed by *Camponotus maculatus* (9.32%); *Tetramorium aculeatum* and *Oecophylla longinoda* represented respectively 6.86% and 5.25% of the total workers collected. In regard of the influence of type of habitats on ant distribution, *A. mocquerysi* was collected only in cocoa farm and represented 16.47% of the workers while *Camponotus congolensis* was dominant in food crops (65.61%), teak forests (11.39%) and savannahs (34.66%). Exception to *D. nigricans*, Kruskal-Wallis showed a significant influence of type of habitats on the distribution of the all the numerically dominant ant species of the community (Table 5).

Functional structure and network of species assemblage

Four functional structures in which nine network of ant species assemblages was found in the four types of habitats: (1) functional structure of non-dominant ground foraging ant species with low ability for space control ([0–10] workers that forage on the ground), found in teak forests and food crops plantations. Four network of species assemblage were identified in this functional structure composed by ant species like *Bothroponera soror, Pheidole tenuinodis, Tetramorium sericeiventre, Camponotus foreli, Camponotus weerka, Anochetus africanus, Technomyrmex* sp., *Polyrhachis* sp. (FS 1, Fig. 3); (2) functional structure of tree foraging species with low aptitude for food control ([0–10] workers collected on a baits) found in cocoa farm. Two networks of species assemblages were identified in this functional structure composed mainly by *Camponotus acvapimensis*, *Cataulacus kohli*, *Crematoagster clariventris*, *Polyrhachis monista, Polyrhachis laboriosa, Polyrhachis militaris, Tetraponera ophtalmica* (FS 2, Fig. 3); (3) the functional structure of subdominant ant species able to exert a medium level for food ([10–100] worker) and space control ([10–100]) regroups two networks of species assemblages composed by *Cataulacus guineensis, Pheidole megacephala*, *Pheidole speculifera, Polyrhachis schistacea, Tetraponera anthracina* (FS 3, Fig. 3) and (4) the

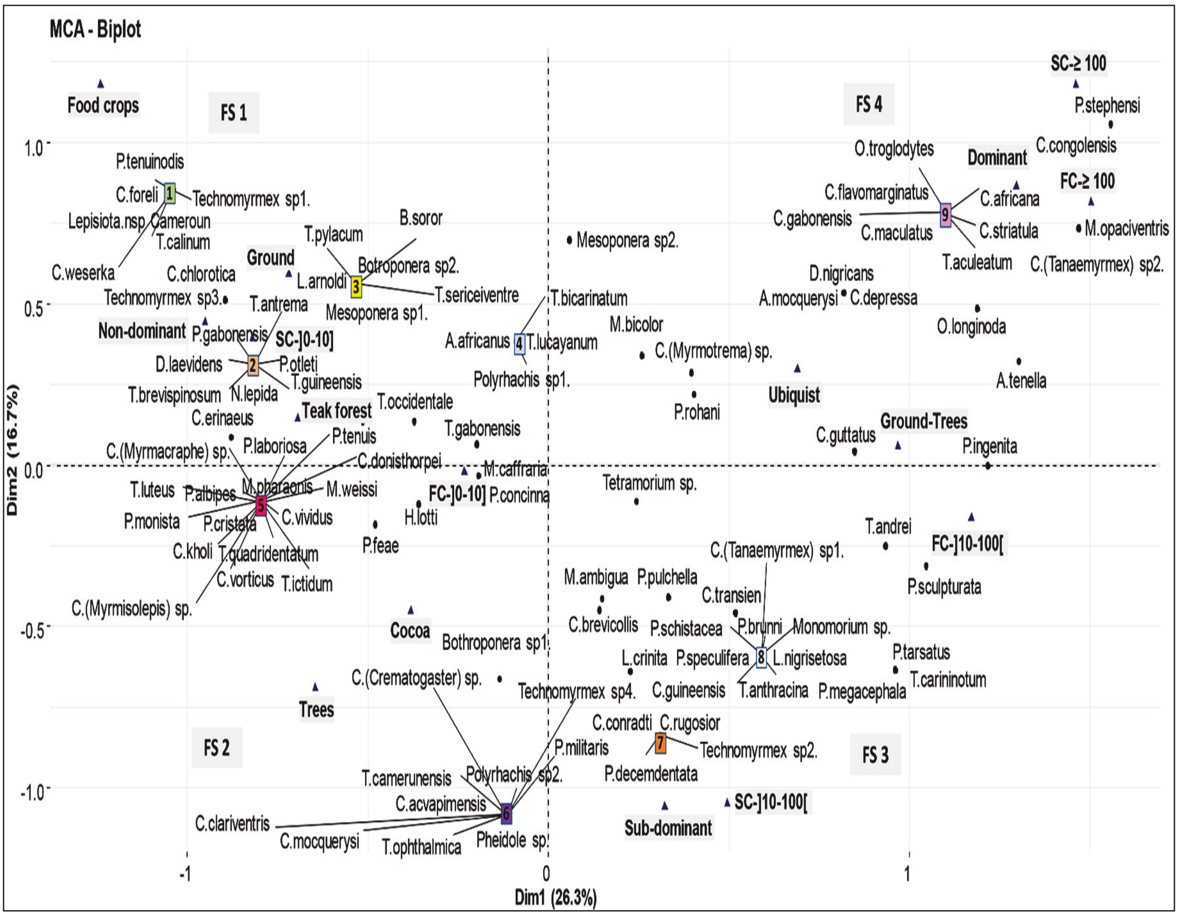


Figure 3. Functional structure in ant community in Obala (Cameroon). FS represent functional structure, the main ant assemblage in each functional structure was highlight with different color and number; FC: Food Control; SC: Space Control.

functional structure of numerically dominant ant species, generally found in at least two habitats (ubiquist) that forage both on the tree and the ground, and able to monopolize high number of worker around food and forage with more than 100 workers (FS 4, Fig. 3). Network of ant assemblages in this group is composed by the main ecologically dominant ant species like *Tetramorium aculeatum, Oecophylla longinoda, Myrmicaria opaciventris, Crematoagster striatula, Crematoagster gabonensis* and *Crematoagster africana* (Fig. 3).

DISCUSSION

We collected 104 ant species belonging to 34 genera and six subfamilies on the ground and on the trees in cocoa farms, teak forests, savannahs and food crops plantations in Obala. Tadu et al. (2014) found 61 ant species belonging to 22 genera and six subfamilies on cocoa and associated trees in the same area. In Mfou, 144 ant species belonging to 39 genera and six subfamilies were collected on the ground and on the trees in cocoa farms, secondary forests and palm grooves (Tadu et al., 2021). Our result reveals that cocoa farms with 90 species was the richest agroecosystem in Obala. Regarding their location, Obala and Mfou are situated along a south north latitudinal gradient in the Centre Region and present a high contrast in vegetation structure and anthropogenic disturbance. Despite the high proximity of Mfou with Yaoundé city, human made ecosystems like cocoa farms were less disturbed than the ones found in Obala. In fact, in Mfou cocoa farming was abandoned by population in favor of the new jobs provided by the urbanization (Tadu et al., 2021), while in Obala cocoa farming and other agricultural activities were still intense. Insecticides and fungicides were frequently used to protect crops against insect pests and fungi; chemical fertilizers were also used by some farmers to improve cocoa production. Landscapes of Obala were highly disturbed than those in Mfou, mainly due to human management. At a local scale in Obala, the decline of the natural forest ecosystems and their substitution by cocoa agroforestry systems, make cocoa farms a unique ecosystem close to the forest by their structure and diversification of trees composition. In Obala, associated trees in cocoa farms were mainly dominated by fruits trees intentionally introduced in the farms to provide shade for cocoa trees and additional incomes for farmers (Babin et al., 2010). In regard to species richness distribution among the four land use systems, the number of specialized ant species in cocoa farm is high compared to other land use systems, and the number of shared species between the four land use systems was very low. So, cocoa farms provide a wide range of micro habitats for several ant species to forage and nest, confirming the idea that cocoa farms are the best alternative ecosystems for preserving biodiversity (Merijn et al., 2007). Also, the low number of shared species between the four types of habitats is related to the difference in habitat heterogeneity and the intensity of human disturbance. A similar result was found in Minko'o where Tchoudjin et al. (2020b) showed that ant diversity and composition vary between different types of habitats subject to different managements; in this locality, less disturbed forests, young and old cocoa farms were richer than other types of habitats. Distribution of species richness in relation to habitat specialization showed that no specialized ant species was found in savannah. This may result from the reforestation process of savannah by teak forests and creation of cocoa farms that induce progressively the migration of savannah ant species which colonize and fit one's surrounding the new constraints imposed by the human made ecosystems. *Anoplolepis tenella*, *Mesoponera ambigua*, *Pheidole megacephala* and *Pheidole rohani* were the indicator species of cocoa agroecosystems, *Camponotus maculatus* and *M. opaciventris* were the indicator species in food crops, *Odontomachus troglodytes* was indicator species of teak forests while no indicator species was found in savannah. The identity of indicator species varies with types of habitats in relation with human disturbance and edge effect due the surrounding vegetation around the farms. In all the types of habitats, indicator species were ground-dwelling ant species sometimes with arboreal behavior; their presence reinforces the high level of environmental threatening in Obala. Our results showed that savannah is different to the other type of habitats. This suggests that savannah is the most threatened ecosystem in the area and needs to be protected. In fact, the expansion of human made ecosystems progressively substitute the savannah and contribute to their decline.

The numerically dominant ant species in Obala were the same as in other studies in different re-

Subfamily - Genus - Species	**Type of habitat**				
	Cocoa farm	**Food crops**	**Teak forest**	**Savannah**	**Total**
DOLICHODERINAE	277	2	37	23	339
Tapinoma	19	0	33	23	75
Tapinoma carininotum Weber, 1943	19	0	33	23	75
Technomyrmex	258	2	4	0	264
Technomyrmex andrei Emery, 1899	190	0	0	0	190
Technomyrmex camerunensis Emery, 1899	16	0	0	0	16
Technomyrmex sp. 1	0	2	0	0	2
Technomyrmex sp. 2	37	0	0	0	37
Technomyrmex sp. 3	0	0	4	0	4
Technomyrmex sp. 4	15	0	0	0	15
DORYLINAE	940	1	0	0	941
Lionoponera	0	1	0	0	1
Lionoponera foreli Santchi, 1914	0	1	0	0	1
Dorylus	940	0	0	0	940
Dorylus (Anomma) nigricans Illiger, 1802	940	0	0	0	940
FORMICINAE	3354	901	620	375	5250
Anoplolepis	151	3	0	5	159
Anoplolepis tenella Santchi, 1911	151	3	0	5	159
Camponotus	2359	865	577	358	4159
Camponotus (Myrmosericus) flavomarginatus Mayr,1862	83	0	220	0	303
Camponotus (Myrmacraphe) conradti Mayr, 1861	39	0	0	0	39
Camponotus (Myrmacraphe) sp.	10	0	0	0	10
Camponotus (Myrmisolepis) sp.	4	0	0	0	4
Camponotus (Myrmopelta) vividus Smith, 1858	8	0	0	0	8
Camponotus (Myrmotrema) sp.	549	0	0	0	549
Camponotus (Tanaemyrmex) acvapimensis Mayr, 1862	61	0	0	0	61
Camponotus (Tanaemyrmex) brevicollis Stitz, 1916	12	0	0	0	12
Camponotus (Tanaemyrmex) congolensis Emery, 1899	52	748	122	288	1210
Camponotus (Tanaemyrmex) donisthorpei Emery, 1920	1	0	0	0	1
Camponotus (Tanaemyrmex) guttatus Emery, 1899	32	3	0	0	35
Camponotus (Tanaemyrmex) maculatus Fabricius, 1782	1027	114	55	70	1266
Camponotus (Tanaemyrmex) sp. 1	14	0	4	0	18
Camponotus (Tanaemyrmex) sp. 2	467	0	176	0	643
Lepisiota	10	5	39	12	66
Lepisiota arnoldi Santchi, 1937	1	3	0	3	7
Lepisiota crinita Mary, 1895	0	0	28	0	28
Lepisiota nigrisetosa Santchi, 1935	9	0	11	9	29
Lepisiota n. sp.	0	2	0	0	2
Nylanderia	2	0	0	0	2
Nylanderia lepida Lapolla et al., 2011	2	0	0	0	2
Oecophylla	713	0	0	0	713
Oecophylla longinoda Latreille, 1802	713	0	0	0	713
Paraparatrechina	2	0	0	0	2
Paraparatrechina albipes Emery, 1899	2	0	0	0	2

Plagiolepis	21	0	4	0	25
Plagiolepis brunni Mayr, 1904	21	0	4	0	25
Polyrhachis	96	28	0	0	124
Polyrhachis decemdentata André, 1889	33	0	0	0	33
Polyrhachis laboriosa F. Smith, 1858	7	0	0	0	7
Polyrhachis militaris Fabricius, 1782	17	0	0	0	17
Polyrhachis monista Santschi, 1910	1	0	0	0	1
Polyrhachis otleti Forel, 1916	1	0	0	0	1
Polyrhachis schistacea Gerstäcker, 1859	19	27	0	0	46
Polyrhachis sp. 1	1	1	0	0	2
Polyrhachis sp. 2	17	0	0	0	17
MYRMICINAE	5642	135	334	411	6522
Atopomyrmex	1743	0	0	0	1743
Atopomyrmex mocquerysi André, 1889	1743	0	0	0	1743
Cardiocondyla	0	1	0	0	1
Cardiocondyla weserka Bolton, 1982	0	1	0	0	1
Cataulacus	70	0	17	0	87
Cataulacus erinaceus Stitz, 1910	0	0	9	0	9
Cataulacus guineensis F. Smith, 1853	43	0	8	0	51
Cataulacus kohli Mayr, 1895	4	0	0	0	4
Cataulacus mocquerysi André, 1889	16	0	0	0	16
Cataulacus vorticus Bolton, 1974	7	0	0	0	7
Crematogaster	1594	10	143	5	1752
Crematogaster (Topogyne) africana Mayr, 1895	725	0	82	0	807
Crematogaster (Topogyne) clariventris Mayr, 1895	92	0	0	0	92
Crematogaster (Topogyne) depressa Latreille, 1802	133	0	0	0	133
Crematogaster (Crematogaster) sp.	28	0	0	0	28
Crematogaster (Crematogaster) transien Forel, 1913	50	0	0	1	51
Crematogaster (Sphaeorocrema) striatula Emery, 1899	231	0	6	0	237
Crematogaster (Sphaerocrema) chlorotica Emery, 1899	0	0	2	0	2
Crematogaster (Sphaerocrema) gabonensis Emery, 1899	314	10	53	4	381
Crematogaster (Sphaerocrema) rugosior Santchi, 1910	21	0	0	0	21
Dicroaspis	1	0	0	0	1
Dicroaspis laevidens Santschi, 1919	1	0	0	0	1
Mellissotarsus	1	0	0	0	1
Melissotarsus weissi Santchi, 1910	1	0	0	0	1
Monomorium	15	60	8	207	290
Monomorium bicolor Emery, 1877	3	60	2	207	272
Monomorium pharaonis Linnaeus, 1758	7	0	0	0	7
Monomorium sp.	5	0	6	0	11
Myrmicaria	613	16	1	0	630
Myrmicaria opaciventris Emery, 1893	613	16	1	0	630
Pheidole	645	43	151	196	1035
Pheidole concinna Santchi, 1910	0	0	49	0	49
Pheidole prelli ingenita Santschi,1928	136	0	9	0	145
Pheidole megacephala Fabricius, 1793	39	28	0	0	67

Pheidole pulchella Santchi, 1910	84	0	0	0	84
Pheidole rohani Santschi, 1925	9	12	2	0	23
Pheidole sculpturata Mayr, 1866	7	2	67	158	234
Pheidole sp.	11	0	0	0	11
Pheidole speculifera Emery, 1877	28	0	0	2	30
Pheidole stephensi Taylor, 2004	331	0	24	36	391
Pheidole tenuinodis Mayr, 1901	0	1	0	0	1
Terataner	1	0	0	0	1
Terataner luteus Emery, 1899	1	0	0	0	1
Tetramorium	959	5	14	3	981
Tetramorium aculeatum Mayr, 1866	925	0	4	3	932
Tetramorium antrema Bolton, 1976	1	0	0	0	1
Tetramorium bicarinatum Nylander, 1846	1	0	2	0	3
Tetramorium brevispinosum Stitz, 1910	1	0	0	0	1
Tetramorium calinum Bolton, 1980	0	1	0	0	1
Tetramorium gabonensis André, 1829	5	0	0	0	5
Tetramorium guineense Bernard, 1953	5	0	0	0	5
Tetramorium ictidum Bolton, 1980	1	0	0	0	1
Tetramorium lucayanum Wheeler, 1905	2	0	1	0	3
Tetramorium occidentale Santchi, 1916	1	0	1	0	2
Tetramorium pylacum Bolton, 1980	2	0	6	0	8
Tetramorium quadridentatum Stitz, 1910	7	0	0	0	7
Tetramorium sericeiventre Emery, 1895	1	1	0	0	2
Tetramorium sp.	7	3	0	0	10
PONERINAE	275	99	34	21	429
Anochetus	2	0	2	0	4
Anochetus africanus Mayr, 1865	2	0	2	0	4
Botroponera	18	2	0	0	20
Bothroponera soror Emery, 1899	3	1	0	0	4
Bothroponera sp. 1	14	0	0	0	14
Bothroponera sp. 2	1	1	0	0	2
Hypoponera	0	13	0	0	13
Hypoponera dulci Forel, 1907	0	13	0	0	13
Mesoponera	17	35	11	3	66
Mesoponera ambigua André, 1890	16	14	8	3	41
Mesoponera caffraria F. Smith, 1858	0	12	2	0	14
Mesoponera sp. 1	1	3	0	0	4
Mesoponera sp. 2	0	6	1	0	7
Odontomachus	206	3	8	1	218
Odontomachus troglodytes Santschi, 1914	206	3	8	1	218
Paltothyreus	20	46	13	17	96
Paltothyreus tarsatus Fabricius,1798	20	46	13	17	96
Paltythyrea	9	0	0	0	9
Platythyrea tenuis Emery, 1899	9	0	0	0	9
Phrynoponera	1	0	0	0	1
Phrynoponera gabonensis André, 1892	1	0	0	0	1

Plectroctena	1	0	0	0	1
Plectroctena cristata Emery, 1899	1	0	0	0	1
Psalidomyrmex	1	0	0	0	1
Psalidomyrmex feae Menozzi, 1922	1	0	0	0	1
PSEUDOMYRMICINAE	96	2	0	1	99
Tetraponera	96	2	0	1	99
Tetraponera anthracina Santschi, 1910	21	2	0	1	24
Tetraponera ophthalmica Emery, 1912	75	0	0	0	75
TOTAL	10584	1140	1025	831	13580

Table 5. Variation of the abundance of the main ant species between the land use systems in Obala (Cameroon).

gions in Cameroon and elsewhere in Africa. The following ant species *Atopomyrmex mocquerysi*, *Camponotus maculatus Tetramorium aculeatum* and *Oecophylla longinoda* were the most common ant species found in cocoa farms (Taylor & Adedoyin, 1978; Tadu et al., 2014; Tchoudjin et al., 2020b). Among these dominant ant species, *T. aculeatum* and *O. longinoda* provide ecosystem services in agricultural milieu (Thurman et al., 2019). Despite the positive relationship established with some Hemipteran pest like *Toxoptera aurantii* in cocoa farms, it is well established that these species excluded spatially *Shalbergella singularis* (Beilhe et al., 2018), the main cocoa pest in West and Central Africa in their territory. In a market-gardening based agroecosystem, *Pheidole megacephala, Myrmicaria opaciventris, Camponotus flavomarginatus,* and *Tapinoma* sp. were frequently and positively associated to hemipterans species like *Macrosiphum euphorbiae, Aphis fabae, Aphis gossypii* and *Alacortum solani* causing damage to cultivated solanum varieties and *Capsicum annum* (Aléné et al., 2019).

Four functional structures in which nine network ant assemblages were identified: (1) non-dominant ground foraging ant species with low ability for space control; (2) tree foraging ant species with a low aptitude for food control, found in cocoa farms; (3) subdominant species able to control food and space at medium level; (4) ubiquitous, numerically dominant ant species with high aptitude for food and space control. In a functional structure, involved ant species may play the same or complementary roles in how the ecosystem works, despite the low affinity between some of them, which determines network associations. In regard of ant species composition in functional structure, *T. auleatum* and *O. longinoda* belonged to the same functional structure but did not have the same network of ant assemblages. This result suggests a negative association (Majer, 1972; Tadu et al., 2019) that results in the spatial exclusion between them. The difference observed in the nesting behavior may contribute to determine network of association between some ant species. It is the case for *C. gabonensis*, *C. striatula* and *C. africana* three dominant arboreal ant species that belonged to the same network of association with *T. aculeatum*. These species nests on associated trees where they build their nests for *C. africana* or opportunistically in a cavity of trees for *C. gabonensis* and *C. striatula*. This nesting behavior reduces interspecific competition between these species and favors the establishment of positive network of association.

CONCLUSIONS

Ant fauna was rich and diverse in Obala as in other localities prospected in the Centre and South Regions of Cameroon. Cocoa farms had the highest species richness compared to food crops plantation, teak forest and savannah. *Atopomyrmex mocquerysi*, *Camponotus maculatus Tetramorium aculeatum* and *Oecophylla longinoda* were the main numerically dominant ant species found in the locality. Functional structures and network of species assemblages form the base of ant community structure in which involved ant species play the same or complementary roles in how ecosystem works. The savannah ecosystem was progressively replaced by the expansion of human made wooded ecosystems which progressively drive the savannah ant species and constrain them to adapt to the new environmental conditions. Savannah is the most threatened type of habitat in the area and needs to be protected to preserve its natural diversity.

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