Journal of Entomology and Zoology Studies 2018; 6(6): 177-186

Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2018; 6(6): 177-186

Received: 22-09-2018
Accepted: 24-10-2018

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Effects of ecotone on ant diversity and assemblage pattern in cocoa agroforestry system in the Centre Region of Cameroon

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Abstract
Ant communities are affected by anthropogenic disturbance related to conversion of forest into agroforestry systems. The effect of this disturbance on arboreal ant diversity is poorly documented in the African agroforestry systems in general and in Cameroon in particular. In the Centre region of Cameroon, the study was done in Bokito, Ngomedzap and Nkolbisson along a latitudinal gradient ranging from evergreen forest to savanna through the ecotone. Visual sampling technique were used and sixty one ant species from twenty two Genera were identified. The most speciose Families were Myrmicinae and Formicinae, with twenty species each. *Tetramorium aculeatum* was the most frequent species followed by *Oecophylla longinoda*. The forest habitat harboured the highest diversity compared with savanna and ecotone. Ant species richness between these landscapes showed a strong evidence of variation in the diversity and occurrence although a generalized binomial linear model showed a low influence of habitat type on ant community.

Keywords: agroforestry system, ant, Bokito, Ngomedzap, Nkolbisson

1. Introduction
Anthropogenic disturbances, mainly related to agriculture, is commonly considered among major causes of biodiversity loss, at both global and regional scales in tropical regions worldwide [1, 2]. Since human-affected lands cover much of the tropical ecosystems, it may be argued that preserving biological diversity in managed agroforestry systems may allow conservation of various native species [3]. Managed ecosystems such as cocoa based farmlands are classified into three categories according to shade management strategy [3]: (1) Rustic cocoa agrosystem in which cocoa trees are planted beneath alleged thinned primary or old secondary forest; (2) planted shade systems, that widely vary from traditional polycultural systems that associate multiple species of planted shade trees with occasional remnant forest trees to monocultural, specialized shade, where the shade is dominated by one or few planted tree species or genus and (3) zero shade cacao farmlands. Shade coffee and cocoa agroforestry systems have been recognised as potential refuges for forest species and support high levels of biological diversity [3-5] and can play an important role in conservation strategies in fragmented landscape by providing habitat for plant and resources for animal and by maintaining connectivity between forest patches [6, 7].
Ants are dominant animal groups of various ecosystems in terms of biomass, diversity and role in ecosystem structure and functions [8, 9] where they act as preys, predators, scavengers, seed dispersers, pollinators etc., and are highly sensitive to environmental disturbance as they are closely related to microclimate conditions [10]; thus, may be used for biodiversity and environmental monitoring studies [9, 11, 12].
Due to the increase of habitat and biodiversity loss in humid tropics, there is an urgent need for ecological studies to identify factors influencing species distribution in order to plan suitable conservation strategies [13, 14]. In Tropical Africa, few studies have been conducted on the influence of field crop management on arthropods diversity and community structure. Therefore, the potential role of cocoa agroforestry systems in the conservation of biodiversity in disturbed landscapes shown elsewhere is poorly documented in Africa. In the Centre Region of Cameroon, the most extended cocoa production basin of the country, cocoa is grown in a wide expand of landscape along a latitudinal gradient, ranging from the evergreen tropical

humid rain forest in the Southern part to dry savanna with patches of human made forest in the North [15]. Cocoa is often grown as a multispecies planted shade agroforest [16-18]. These plantations are set from evergreen forest plots in the Southern part of the basin, more or less old secondary vegetation in the ecotone or in semi deciduous forest patches in the northern parts. Following anthropogenic disturbances, recolonization processes in ant communities may be highly influenced by border effect [19, 20]. The effect of vegetation changes on ant diversity in the Congo basin is poorly documented. Only few studies have been published on arboreal ant diversity in cocoa agroforest in relation to farm management and agricultural practices in Cameroon [17, 20, 21]. The ecotone area, around Yaoundé, anthropogenic disturbances related to farmland leads to bushy vegetation dominated by shrubs and small sized trees that surround Cocoa agroystems. The present study aimed to assess ant diversity and community structure along the South-North latitudinal gradient in the Centre region with the emphasis on the impact of these vegetation in the ecotone. We hypothesized that in ecotone landscapes, bushy vegetation derived from forest disturbance may affect the ant community differently from savanna dominated landscapes.

Discussion focussed mainly on the characterization of the ant community in these three landscapes in relation with anthropogenic disturbance and landscape variation, with particular reference to dominated savanna of Obala [20] and bushy area of Yaoundé.

2. Materials and methods

2.1 Study area

The data was collected in 3 smallholder cocoa farms, selected in the Centre region of Cameroon (Figure 1). These localities were selected based on progressive South-North variation in rainfall, temperature and vegetation characteristics: Ngomedzap (03°16’10’’N, 11°13’21’’E, Altitude 700 m); Nkolbisson in Yaoundé (03°51’13’’N, 11°25’20’’E, Altitude 756 m) and Bokito (04°34’29’’N, 11°10’45’’E, Altitude 450 m). The selected farm had not received insecticide treatment within the past two years; sampling were conducted during dry season. The climate is Sub-equatorial with a bimodal rainfall regime [20].

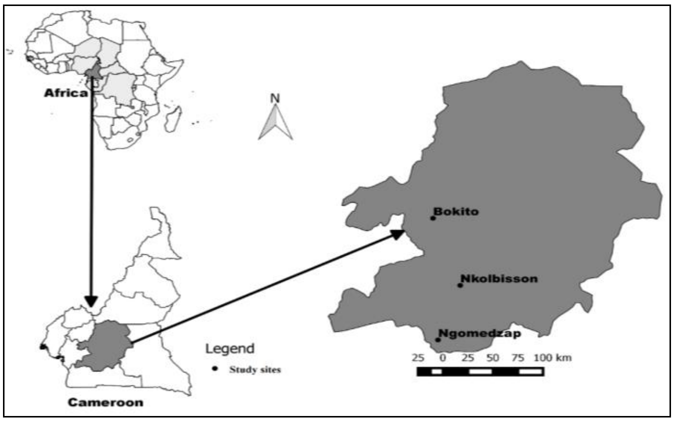

Fig 1: Map of the study sites in the centre region of Cameroon. Reference system Transversal Mercator projection; spheroid of Clarke (1981).

2.2 Habitat structure in the three study sites

The cocoa farm studied at Ngomedzap was established in evergreen forest partially logged. In the farm, the vegetation is dominated by forest trees mainly *Terminalia superba* (Engl. and Diel), *Ficus mucuso* (Welw. Ex Ficalho) and *Ficus exasperata* (Vahl). Around the farm we have mostly evergreen forest relatively well conserved and few human habitations. The 1529 cocoa trees sampled covered an area of 30 962 m^2.

Nkolbisson, located in the northern outskirt of Yaoundé have a landscape characterized by strongly degraded semi-deciduous forest corresponding to an accentuated disturbance to long term agricultural activity in a relatively humid area. Except cultivated plants and regrowth, natural forest vegetation has practically disappeared and vegetation type is usually called ruderal. Cocoa agrosystems studied is surrounded by a highly degraded semi-deciduous forest and food crop plots. The northern side of the cocoa farm gives way to a swamp dominated *Alchornea cordifolia* (Schumach), *Pennisetum purpureum* (Schumach). On an area of 20621 m^2, there were 1364 cacao trees sample.

Bokito, located in the north western part of the study area is covered by bushy savannah vegetation with patches of gallery-forests and human-made agroforests [17]. In the selected plot, shade is composed of fruit trees and remnants of forest trees conserved during farm creation. Around the study farm the vegetation is dominated by savanna and food crop plantations. This cocoa farm was regularly weeded and comprised of 995 trees on 20149 m^2.

2.3 Data collection

Field studies were carried out from January to April 2008 during dry season. Three traditional cocoa plantations were selected for the survey of ant diversity. Visual observations followed by hand captures using forceps and aspirator were used for ants sampling during the daytime from 7.00 am to 5.00 pm. We carried out a survey on all the cocoa trees in the selected farm. Ants were searched on leaves, trunks, branches and the canopy as far as accessible. We collected ants on 995, 1364, 1529 trees respectively at Bokito, Nkolbisson and Ngomedzap. Ants collected were fixed in 70 % ethanol and in haemolysis tubes provided with a unique identification code for proper sample identification.

2.4 Ant identification

In the laboratory, all ants were sorted and identified to genus [8, 22, 23] and when possible to the species level using dichotomous key of Taylor (2010)[24]. Voucher specimens are deposited in laboratory of Zoology of the University of Yaoundé I. When identification to species was not possible, sample were designated a morphospecies code.

2.5 Data analyses

2.5.1 Measuring ant species richness and sampling success

To estimate ant species richness and measure sampling success, occurrence rather than abundance was used in order to reduce influence within species colony-size variation [25-28]. Species richness in the habitats types was estimated using Chao2, a non-parametric estimator included in the EstimateS software version 8.2 [29]. Sampling success was evaluated by dividing the value of species richness observed by the value of expected species expressed in percentage:

$$CS = \frac{SRO}{ES} x100$$

Where

SRO is the species richness observed and ES the expected species obtained by Chao 2 estimator. An incidence-based rarefaction curve was plotted to visualise the summation of species richness with increasing number of sampled trees.

2.5.2 Influence of habitat types on ant diversity
Ants community were characterized in each habitat by the species richness, and species diversity indexes such as Shannon-Wiener diversity and Evenness indices using the Vegan package [30] for R (version 3.4.1, 2017). In order to evaluate the impact of habitat on ant diversity, the mean value of ant species per tree of these parameters were then compared between sites using the Kruskal-Wallis test, with associated Wilcoxon test for pairwise comparisons corrected with sequential Bonferoni procedure for P-values adjustment. Analysis was done using R software (version 3.4.1; 2017) and the result was appraised at 5 % confidence interval.

2.5.3 Differences in ant species composition among habitats types
To classify and evaluate level of similarity in ant species composition between studied farms, a cluster analysis was conducted using Jaccard distance based on an unweighted pair group method on a presence/absence data matrix using ade4 package [31] for R (version 3.4.1; 2017).

2.5.4 Influence of habitat on ant occurrence between the habitats
The habitat type effect on the variation of occurrence on species whose relative occurrence in range frequency diagram was in between 10 % and 100 % and assessed using the Chi square test by the GLM procedure for binomial data. A pairwise Wilcoxon test associated with Bonferroni correction for p-value adjustment was used hereafter to search for variation source between habitats. This analysis was done in R software (version 3.4.1; 2017)

2.5.5 Ant distribution models between habitats types
The impact of habitat type on ant community structure was appreciated by computing and plotting the species relative occurrence per site, using rank incidence diagram. The rank incidence diagram also known as dominance-diversity curves for each community was fitted to a mathematical model of species occurrence (Null, Pre-emption, Lognormal, Zipf and Mandelbrot) which reflect ecological assumptions about resource sharing models. The models generated were appraised on the basis of the Bayesian information criterion (BIC) and Akaike's (AIC). The penalty in BIC in k=log(s) where S is a number of species whereas AIC uses k = 2. Based on AIC value, the best-fitted model is the one that has the lowest value compared to one another. Analysis were done with Vegan package [30] for R (version 3.4.1; 2017).

2.5.6 Ant assemblage pattern
Ant assemblage pattern was studied using correspondence analysis (CA). In order to assess the study sites in terms of ant species which were present, the plots were compared using CA of the correlation matrix derived from ant presence /absence data (figure 5). In the present analysis, only species with occurrence ranging from 1 % to 100 % according to Whittaker plot was taken into account. This ordination method provides an indication of the degree of relatedness of study sites in terms of species which were most present within them. The correspondence analysis (CA) was done using vegan package [30] for R (version 3.4.1; 2017).

3. Results
3.1 Measuring ant species richness
The sampling success evaluated on the base of the Chao2 non-parametric estimator ranged between 88.46 % (Ngomedzap) and 89.32 % (Bokito).

Table 1: Estimation of ant diversity based on estimated chao2 value / observed value. Shannon diversity index and evenness.

Parameters	Study Sites			χ^2
	Bokito	Nkolbisson	Ngomedzap	
Number of trees sampled	995	1364	1529	
Chao 2	45.90 (89.32)	38.17 (89.08)	52 (88.46)	
Species Richness (S)	41 (1.35±0.02)^a	34 (1.49±0.03)^b	46 (1.60±0.03)^c	χ^2= 27.24; df= 2; P<0,0001
Shannon Index (H')	2.48 (0.27±0.01)^a	1.77 (0.32±0.01)^b	2.85 (0.36±0.01)^b	χ^2= 15.12; df= 2; P<0,0001
Evenness	0.67 (0.74±0.01)^a	0.50 (0.91±0.007)^b	0.74 (0.78±0.01)^a	χ^2= 82.38; df= 2; P<0,0001

χ^2: Kruskal Wallis test, Study sites with different letters are statistically significant according to pairwise comparisons.
Values in bracket represent Mean± SEM. Sampling unit =Tree

Randomized (50 runs) species rarefaction curves were also plotted for each cocoa farm to summarise the completeness of the sampling success (Figure 2). The curves of the three cocoa farms shows an increase of expected species with capture effort and similar slope and species saturation plateau is observed.

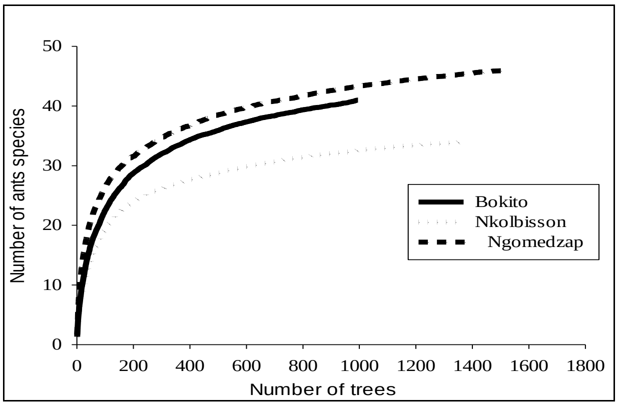

Fig 2: Randomized (50 runs) species accumulation curves of the ant communities of three cocoa farms based on sample size (number of trees).

3.2 Ant diversity

The species richness varied from 34 (Nkobisson) to 41 (Bokito) and 46 (Ngomedzap) and the smallest mean species richness per tree (1.35±0.02) was recorded at Bokito, the highest at Ngomedzap (1.60±0.03). Mean species richness per tree vary significantly (χ^2= 27.24, df= 2, P< 0.0001) between sites. Pairwise comparison showed significant difference between mean species richness per tree (P< 0.05) in all combination (Table 1). The ant community was more diverse (Shannon mean) at Ngomedzap (H'= 2.85 (0.36 ± 0.01); E= 0.74 (0.78 ± 0.01)) than at Bokito (H'= 2.48 (0.27±0.01); E= 0.67(0.74 ± 0.01) and Nkolbisson (H'= 1.77 (0.32 ± 0.01); E = 0.50 (0.91 ± 0.007)), with significant differences for both Shannon-Wiener (H') mean per tree (χ^2 = 15.12; df= 2; P< 0.0001) and Evenness mean per tree (χ^2= 82.38, df= 2, P< 0.0001). Pairwise comparisons revealed significant differences among site combination, with the exception of Nkolbisson and Ngomedzap for Shannon mean index (P> 0.05) and Bokito and Ngomedzap for Evenness mean index (P> 0.05) (Table 1).

3.3 Overlap and complementary in ant species between habitat

The agglomerative hierarchical classification revealed a high ecological dissimilarity between study sites. The dissimilarity value is between 0.60 and 0.80 thus close to 1 indicating a low similarity between study sites. Therefore, Ngomedzap and Nkolbisson formed a cluster which differentiates them from Bokito (figure 3). Ngomedzap and Nkolbisson share more common species (31) whereas Bokito/Nkolbisson and Bokito/Ngomedzap have few species in common, 22 and 27 ant species, respectively; however, 21 ant species were common to those three study sites.

Fig 3: Cluster analysis based on Jaccard dissimilarity with unweighted-pair group method showing dissimilarity in species occurrence between habitats types.

3.4 Ant community structure among habitats types

Rang frequency diagram may be divided into three unequal parts (figure 4). The first part, including most frequent species in terms of occurrence (more or equal to 10% of the relative occurrence), with no more than eight species *Camponotus acvapimensis*, *Oecophylla longinoda*, *Crematogaster clariventris*, *Crematogaster gabonensis*, *Tapinoma sp.1*, *Tetramorium aculeatum*, *Crematogaster striatula* and *Pheidole megacephala* for all sites. The second part comprising less occurring ant species (1 to less than 10%) included fewer than 17 species at each site. The third part comprised rare species with occurrences below 1% (Appendix 1).

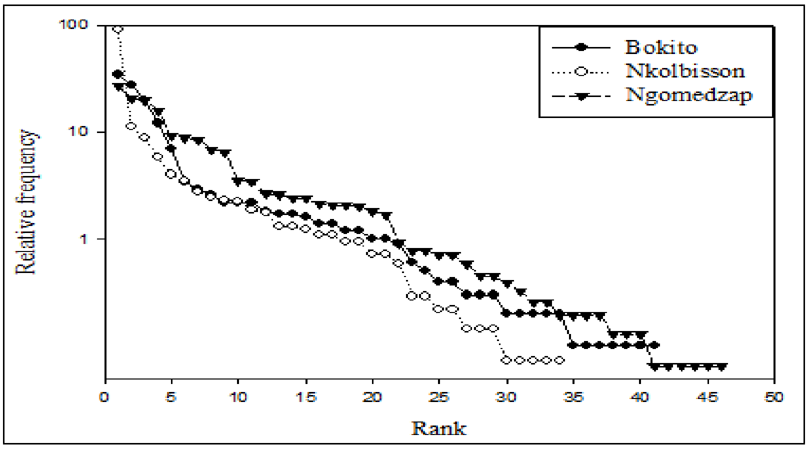

Fig 4: Species rank occurrence distribution plot for the three habitats types

The adjustment of rang frequency curve with theoretical model showed that ant distribution fits Mandelbrot, Pre-emption and Zipf distribution models respectively at Bokito (AIC = 241.910), Nkolbison (AIC = 362.48) and Ngomedzap (AIC = 319.28) (Table 2).

Table 2: Fitted ant occurrence distribution model of ant communities with theoretical models

				Sites					
Models		**Bokito**			**Nkolbisson**			**Ngomedzap**	
	Deviance	**AIC**	**BIC**	**Deviance**	**AIC**	**BIC**	**Deviance**	**AIC**	**BIC**
Brokenstick	889.751	1053.664	1053.664	2824.23	2970.73	2970.73	883.37	1090.88	1090.88
Pre-emption	290.050	455.964	457.677	1518.19	1666.69	1668.21	109.78	319.28	321.11
Lognormal	134.312	302.225	305.652	312.01	462.51	465.56	228.21	439.72	443.38
Zipf	198.996	366.910	370.337	211.98	362.48	365.54	559.91	771.41	775.07
Mandelbrot	71.997	241.910	247.051	211.98	364.48	369.06	109.77	323.28	328.76

BIC: Bayesian information criterion; AIC: Akaike's; the best fitted models are in bold

3.5 Variation of ant occurrence between habitat types

At Bokito the most occurring species, *Cr. gabonensis* was encountered on 34.57 % of sampled trees, followed by *C. acvapimensis*, *Oe. longinoda* and *Cr. clariventris* collected respectively 27.34 %, 19.80 % and 12.16 % cocoa trees. At Nkolbisson, the most frequent was *T. aculeatum* 90.32 %. Followed by *Tapinoma* sp.1 and *Camponotus vividus*. At Ngomedzap, the most predominant species was *Ph. megacephala* (26.95 %), followed by *Cr. striatula* (20.73 %) and *Oe. longinoda* (19, 82 %) (Table 3).

Table 3: Variation of occurrence of the most frequent ant species (relative frequency > 1%)

Species		Study Sites		chisq (Glmproc)
	Bokito	Nkolbisson	Ngomedzap	
Tapinoma sp.1	0 (0.00)a	152 (11.14)b	141 (9.22)b	χ^2= 184.22; d.f.=2; P<10^{-3}***
Camponotus acvapimensis (Mayr,1862)	272 (27.34)a	34 (2.49)b	54 (3.53)b	χ^2= 425.48; d.f.=2; P<10^{-3}***
Camponotus sp.5	10 (1.01)a	2 (0.15)b	32 (2.09)a	χ^2= 29.40; d.f.=2; P<10^{-3}***
Camponotus vividus (F.Smith,1858)	17 (1.71)a	122 (8.94)b	131 (8.57)b	χ^2= 71.68; d.f.=2; P<0,0001***
Oecophylla longinoda (Latreille,1802)	197 (19.80)a	18 (1.32)b	303 (19.82)c	χ^2= 334.26; d.f.=2; P<10^{-3}***
Polyrhachis decemdentata	29 (2.91)a	55 (4.03)a	53 (3.47)a	χ^2= 2.20; d.f.=2; P=0.331 NS
Polyrhachis militaris (Fabricius,1782)	5 (0.50)a	4 (0.29)a	40 (2.62)b	χ^2= 38.04; d.f.=2; P<10^{-3}***
Atopomyrmex mocquerysi (Andre,1889)	3 (0.30)a	24 (1.76)b	12 (0.78)a	χ^2= 14.00 ; d.f.=2; P<10^{-3}***
Cataulacus guineensis (Stitz,1853)	12 (1.21)a	79 (5.79)b	136 (8.89)c	χ^2= 76.45; d.f.=2; P<10^{-3}***
Cataulacus sp.1	18 (1.81)a	15 (1.10)a	26 (1.70)a	χ^2=2.62 ; d.f.=2; P=0.286 NS
Crematogaster clariventris (Mayr,1895)	121 (12.16)a	3 (0.22)b	244 (15.96)b	χ^2= 311.8; d.f.=2; P<10^{-3}***
Crematogaster gabonensis (Emery,1892)	344 (34.57)a	31 (2.27)b	100 (6.54)a	χ^2= 569.04; d.f.=2; P<10^{-3}***
Crematogaster striatula (Emery,1892)	34 (3.42)a	48 (3.52)a	317 (20.73)b	χ^2= 297.93; d.f.=2; P<10^{-3}***
Myrmicaria opaciventris (Emery,1893)	0 (0.00)a	8 (0.59)b	106 (6.93)c	χ^2= 160.88; d.f.=2; P<10^{-3}***
Pheidole megacephala (Fabricius,1793)	70 (7.04)a	18 (1.32)b	412 (26.95)c	χ^2= 503.73; d.f.=2; P<10^{-3}***
Tetramorium aculeatum (Mayr,1866)	22 (2.21)a	1232 (90.32)b	41 (2.68)a	χ^2= 3486.1; d.f.=2; P<10^{-3}***
Anochetus sp.1	22 (2.21)a	17 (1.25)a	3 (0.20)b	χ^2= 26.62; d.f.=2; P<10^{-3}***
Odontomachus troglodytes	14 (1.41)a	1 (0.07)b	1 (0.07)b	χ^2= 27.43; d.f.=2; P<10^{-3}***
Tetraponera tessmanni (Stitz,1910)	0 (0.00)a	32 (2.35)b	37 (2.42)b	χ^2= 4.48; d.f.=2; P<10^{-3}***

Numbers are the occurrence of ant species per tree and values in bracket are their relative occurrences; $\chi 2$: chi squared for binomial data (Glm proc); sites with different letters are statistically different according to pairwise comparison; ***: highly significant value at 5% confidence interval and NS: Non-significant.

The habitat structure influences the presence/absence (χ^2=65.93; df= 2; P< 10^{-3}) for most of the species. For each species which relative occurrence where higher than 1%, habitat types influence significantly their occurrence (Table 3). The habitat structure influence was significant (P<0.05) for all three study sites when using the pairwise Wilcoxon for *O. longinoda*, *Ca. guineensis*, *Myrmicaria opaciventris* and *Ph. megacephala*. Species whose presence /absence were not influence by the habitat structure in and around the study sites are *Polyrachis decemdentata* and *Cataulacus* sp.1 (Table 3).

3.6 Ant assemblage pattern

Among the 61 ant species sampled, 19 species occurred in the three study sites (cumulative relative frequency ≥ 1%) (Appendix 1). The correspondence analysis shows that those species are occurring differently in these three cocoa farms (figure 5). From the first axis, it appears that *T. aculeatum* is the most common species at Nkolbisson while *O. troglodytes*, *Cr. gabonensis* and C. *acvapimensis* were frequent at Bokito and *Tapinoma* sp.1, Anochetus sp.1, *Ca. guineensis*, *C. vividus*, *Cr. clariventris*, *Cr. striatula*, *M. opaciventris*, *Oe. longinoda*, *Ph. megacephala*, *Po. militaris*, *At. mocquerisy*, *P. decemdentata* and *Te. tessmanni* seem strongly associated with Ngomedzap cocoa farm.

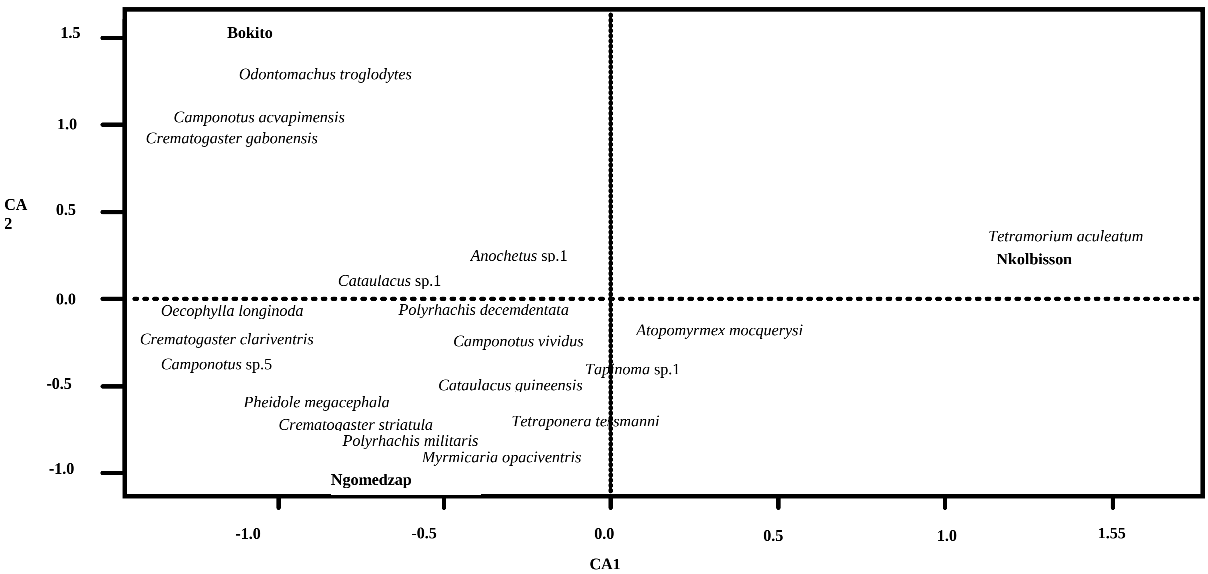

Fig 5: Correspondence analysis showing the relatedness of species numerically dominant present in three cocoa farms

4. Discussion

4.1 Evaluation of sampling effort

Theoretical species richness was evaluated using the Chao2 nonparametric estimator. For each site, both estimated sampling effort and rarefaction curve shows that the sampling effort provides a good estimate of species richness. The species richness is the most direct measurement of species diversity of a community [26]. The results show that there is a gradual decline of species diversity from forest with the highest species number to the species depleted zone of transition between savanna and forest. Conventionally, the minimal sample size accepted for optimal sampling is 20 [13]. For all three study sites, a slightly real asymptote plateau was reached for all habitat types. This stage corresponds to state in which the species richness changes little despite an increase in the sample size. According to Agosti *et al*., [13] the curve for a thoroughly sampled fauna will reach a plateau, with few or no species being added with additional sampling.

4.2 Influence of habitat type on ant diversity

Ant communities were unequally diversified and our results are consistent with those of Room (1971) who collected by hand catching 67 ant species in Ghanaian cocoa farms. Majer [32] obtained 44 ant species on a Ghanaian cocoa farm. Similar results were obtained by Taylor [33] who identified respectively 56 ant species on Nigerian cocoa farms. Tadu *et al*. [20] collected 66 ant species in 21 selected plots of 100 cocoa trees in the Centre region of Cameroon. Emphasizing on the ecotone landscape ant diversity, 34 ants species were collected in the ecotone of Nkolbisson whereas 61 ants species were obtained at Obala [20]. It is though far below the 96, 97 and 161 ant species recorded respectively in forest canopy of Mbalmayo forest [34], in a managed timber plantation still at Mbalmayo forest Reserve, Centre region of Cameroon [2] and in the forest canopy of an old primary forest, primary swamp and secondary forest of Budongo forest reserve in Uganda [14].

The study site of Ngomedzap located in forest yielded the highest species richness and diversity compared to Bokito in savanna and Nkolbisson in the transitional zone between savanna and forest. On the base of Tadu *et al*. [20] result, the ecotone of Obala harbours more ant species than other study sites and were the most diversified according to Shannon Wiener indices. We assume that in favour of the relatively stable environment at Ngomedzap farm dominated by forest trees and surrounding environment covered by relatively well conserved evergreen forest most habitat such as nesting sites was available for many species compare to the Nkolbisson and Bokito where the surrounding environment of the farm was highly disturbed by human activities. This may contribute to mitigate interspecific competition between dominant species and favour the cohabitation between them. Moreover, in relation with anthropogenic disturbance, Ngomedzap farms were less disturbed than another site. This particularity may also contribute to explain high species richness and diversity.

Dominance impoverishment rule states that low diversity ant communities are often numerically and behaviourally dominated by a single specie [8] which is the case of Nkolbisson cocoa farm were *T. aculeatum;* count among the most frequent dominant African arboreal ant species typically present in tree crop plantation, along the forests edges and is relatively well represented in secondary forests [14, 35]; It is characterised by large, polydomous colonies that built nest by bounding host tree leaves with rough carton. These characteristics coupled with aggressiveness towards other species would also explain its numerical dominance in the cocoa farm of Nkolbisson. In the ecotone of Obala, *T. aculeatum* were the most occurring species followed by *Oe. longinoda* and *Cr. gabonensis* which are known as numerically dominants canopy ants. The canopy structure in relation with shade also affect the spatial distribution of ant in cocoa farm. In fact, it's well established that *T. aculeatum* colonies were found dominant in the shade farm while *Oe. longinoda* were found dominant in the lighted farm [18]. The difference among sites in species richness and diversity may be explained by variations observed in vegetation structure [36]. At a local scale, species interaction, resources availability and habitat conditions should be the prominent processes determining species richness [36].

Similarly, variation in habitat conditions will affect species distribution and interactions [37]. Vegetation change can enhance the habitat for an ant at the expense of another ant. For instance, *C. acvapimensis,* is largely a savanna species but wherever grassy clearing occurs in the forest this species is almost certain to be found [38]. Microclimate and nesting sites are often the direct, proximate mechanism driving relationship between ants and vegetation structure [39]. Nest site preferences are the factors after space, most affecting ant distribution and hence mosaic composition at any particular point [38]. In the Centre region of Cameroon, there were great variations in vegetation structure at a macro-geographic scale, with evergreen forest at Ngomedzap, bushy-savanna with patches of gallery forests at Bokito to highly degraded evergreen semi-deciduous forest at Nkolbisson. Ngomedzap offered a great diversity of habitats favourable to the establishment of diverse ant species. This may explain the high species richness and alpha diversity recorded. The most frequent human-caused disturbance at these sites are related to weeding and mechanical destruction of arboreal ants-nests during pruning activity. In the Centre region, farm management, manually done by farmers, includes weeding, pruning and thinning of part of the understory in order to introduce young cocoa plants [7, 20]. These practices may have contributed to destabilize arboreal ant communities. General farm sanitation which involved the removal of old cocoa pods and dead wood tend to reduce population of certain species such as *Cr. striatula* and *Pheidole* sp [38].

4.3 Overlap and complementarity between habitat types

Ant community composition at Bokito, Ngomedzap and Nkolbisson were not similar to each other but ant community composition of Ngomedzap are similar to Nkolbisson and were less similar to Bokito community composition. This result is in agreement with those obtained by Tadu *et al*. [20] which demonstrate that community composition of Ngomedzap and Obala are more similar than that of Bokito. These differences may be due to the age of farm trees and the canopy cover within each cocoa because on the base of the age cocoa farm, Ngomedzap harbours more old trees and was having a dense canopy cover than Bokito and Nkolbisson. As a result, according to Schulz & Wagner [14], younger trees and low canopy cover harbour fewer species than do older trees and dense canopy cover. Observed difference in ant community composition between those three vegetation types could be attributed either by the difference in nest sites availability, temperature and microhabitat structure and resource capture by ants in cocoa plantation. Many habitat variables potentially influence ants but the most important appear to be related to vegetation structure [32]. All ants are influenced to some degree by habitat variables, but according to Greenslade's model, these variables have a particular important influence on the abundance on dominant species [11]. Also, geographic distance could increase dissimilarity between communities under study. Several studies have suggested a potential relationship between local ant assemblages and habitat characteristics. At Bokito, the landscape is dominated by bushy-savanna, the implantation of cocoa farms is done in domesticated forest patches. On many farms in our study areas, cocoa trees were cultivated in a planted shade system made mainly of domesticated fruit trees. Ant species colonizing these farms may have drifted from nearby savanna dominating the pockets forests landscape. On the other hand, Nkolbisson landscape presented large pockets of highly degraded semi-deciduous forest with high human disturbance while Ngomedzap was dominated by evergreen forest with less human disturbance. Also, at Nkolbisson, the ant community were mainly dominated by *T. aculeatum* which alone represents 60.54% of the entire community which is not the case in Bokito and Ngomedzap. The numerical dominance of this species may have had a negative impact on the occurrence of other ant species on this site. In fact, *T. aculeatum*, being a strongly territorial-species its presence will reduce the availability of niches for other dominant species. Only non-territorial ant species such as *Tapinoma* sp.1 was able to confound in this space by dispersing small numbers of individuals on a very large number of trees and do not appear to be threatened by *T. aculeatum*. That's why *Tapinoma* sp.1 has such a high occurrence in the cocoa farm of Nkolbisson. A general observation was done by Room [40] who stated that there are always a few species present in the ant fauna of tropical tree crop canopy which dominate all the others in terms of density of foraging individuals. The activity patterns of subordinate species are influenced by competition of dominant species favored in certain microclimates [39].

4.4 Ant community structure and functioning
According to Whittaker plots, ant communities at Ngomedzap, Nkolbisson and Bokito showed different structural patterns. From a functional point of view and based on resource sharing in the ant communities, structure patterns fitted with species occurrence model reveals distinct functional structure between study sites. Bokito, Nkolbisson and Ngomedzap ant community best fitted respectively a Mandelbrot, Pre-emption and Zipf model, numerically dominated by *Cr. gabonensis*, *C. acvapimensis* and *O. longinoda* at Bokito; by *T. aculeatum* and *Tapinoma* sp.1 at Nkolbisson; and *Ph. megacephala*, *Cr. striatula* and *O. longinoda* at Ngomedzap. These results varied from those of Tadu *et al*. [20] where Bokito and Obala ant communities best fitted log-normal model and Bokito, the Mandelbrot model. On this point of view, the ecotone zone of Obala followed different model from Nkolbisson's and the most occurring species were *Oe. longinoda*, *Cr. gabonensis* and *T. aculeatum*. In the cocoa farm of Nkolbisson, there were big trees suitable for ant nests and mirids holds on trees favor the expansion of *C. vividus* after the regression of the territory of *T. aculeatum* in areas where most trees were dry. On those dry trees, colonies of *C. vividus* were nesting in hollows of dead branches due to high nesting sites of *T. aculeatum*. These ants cited above occurred on more than 100 trees and are known to be numerically dominant species in tropical rainforest. These numerical dominant ant species have been defined in literature as those species which predominate numerically, which tend to have mutually exclusive distribution patterns, tend to occupy large and continuous expanses of forest or tree crop canopy [41] are able to develop intra as well as interspecific territoriality [42]. As a result of their territoriality, they are distributed in a three-dimensional mosaic pattern in the forest canopy [43]. Occurrence distribution patterns are established to describe the structure and functioning of a community which has reached a certain equilibrium and the pathways to reach; mechanism by which the community organization progresses; following what process; what type of interrelations and on what constraints. If the community structure observed is that provided by such pattern, then the community studied has been formed according to this distribution model [44]. The Mandelbrot model observed at Bokito suggests that none of the species exert control over trees. In fact, the ant community was dominated by *C. acvpimensis* dominant savanna species with populous colony size and less aggressive toward other species. In cocoa farm, this ant species spatial distribution is under pure nugget effect and thus explains random distribution [18]. At Nkolbisson, the ant community is distributed under a zipf model which describes strong inequality between species occurrence. While in the ecotone of Obala [20], the ant community followed lognormal model, describing strong interspecific competition for tree monopolization between dominants ant species. The ant community of Nkolbisson is simple and a strong competition for trees monopolization only allows the coexistence of a limited number of species of which only a very small number is largely dominant. In fact, the ant community at Nkolbisson is structured by *T. aculeatum*, a very populous and aggressive ant species that dominates most bushy vegetation in the ecotone areas. At Ngomedzap, the pre-emption distribution model explained the fact that species having an average rank are very abundant and only a few species dominate. In this cocoa farm, *Ph. megacephala* a tramp species which thanks to its strong aggressiveness would keep away other species of the communities and control many trees [38].

4.5 Ant assemblage patterns
Ant assemblages are often structured by interspecific competition [37, 45]. In the present study, plants species through resources provided, may directly affect nesting ant communities. Food resources include extrafloral nectaries, honeydew and preys [46]; whereas nesting sites are located in both dead and living trees. The availability and quality of nesting sites, food resources seem to be an important factor determining ant distribution [9, 47]. *C. acvapimensis* known as a savanna species was strongly associated with Bokito located in a savanna zone. *Oe. longinoda* which is strongly associated with Ngomedzap evergreen forest [20]is known as a common ant in plantations has been recorded as the fifth most common species in the Mbalmayo forest reserve in Cameroon[2].

5. Conclusion
Ant species richness, community composition and structure in cocoa agroforestry systems is much diversified. Diversity and ant distribution vary from one study site to another in relation to vegetation type and anthropogenic disturbances influencing ant assemblages. The presence or absence of ants were influenced by habitat structure in these three landscapes. In the southern Cameroonian area, the cocoa farm of

Ngomedzap is less disturbed humanly and is similar to Nkolbisson ant community composition and characterized by the introduction of cocoa farms in pockets of forests. Between Ngomedzap and Bokito, the transitional zone shows a decline in species richness and a high occurrence of ant's species. Although Ngomedzap and Nkolbisson are quite similar in ant community composition they were different on a functional point of view having distinct ant assemblage patterns which explain their structure on the basis of unshared species between two study areas. Is there a mosaic of ants in our cocoa plantations? If so, how are the ecological dominants affecting the spatial distribution of non-dominant species? The answer to this question will allow us to better understand the notion of ant community structure and interspecific relationships in these different landscapes.

6. Acknowledgments

This work would have been impossible without the support of cocoa farmers of Bokito, Nkolbisson and Ngomedzap

7. References

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Appendix 1: Diversity of ant species collected in cocoa farms in the Centre region of Cameroon.

Subfamilies	Species		Study Sites		Total
		Bokito	Nkolbisson	Ngomedzap	
Dolichoderinae	*Axinidris bidens* (Shattuck,1991)	17 (1.71)	0 (0.00)	0 (0.00)	17 (0.44)
	Tapinoma sp.1	0 (0.00)	152 (11.14)	141 (9.22)	293 (7.54)*
	Tapinoma sp.2	0 (0.00)	4 (0.29)	33 (2.16)	37 (0.95)
	Tapinoma sp.3	0 (0.00)	0 (0.00)	31 (2.03)	31 (0.80)
	Tapinoma sp.4	0 (0.00)	0 (0.00)	4 (0.26)	4 (0.10)
	Tapinoma sp.5	0 (0.00)	0 (0.00)	1 (0.07)	1 (0.03)
	Tapinoma sp.6	12 (1.21)	0 (0.00)	0 (0.00)	12 (0.31
	Technomyrmex sp.1	14 (1.41)	0 (0.00)	0 (0.00)	14 (0.36)
Dorylinae	*Dorylus* sp.1	1 (0.10)	2 (0.15)	0 (0.00)	3 (0.08)
Formicinae	*Anoplolepis tenella* (Santchi,1911)	0 (0.00)	0 (0.00)	32 (2.09)	32 (0.82)
	Camponotus acvapimensis (Mayr, 1862)	272 (27.34)	34 (2.49)	54 (3.53)	360 (9.26)*
	Camponotus brutus (Forel, 1886)	22 (2.21)	1 (0.07)	1 (0.07)	24 (0.62)
	Camponotus sp.1	0 (0.00)	10 (0.73)	28 (1.83)	38 (0.98)
	Camponotus sp.2	0 (0.00)	10 (0.73)	3 (0.20)	13 (0.33)
	Camponotus sp.3	0 (0.00)	1(0.07)	0 (0.00)	1 (0.03)
	Camponotus sp.4	2 (0.20)	0 (0.00)	12 (0.78)	14 (0.36)
	Camponotus sp.5	10 (1.01)	2 (0.15)	32 (2.09)	44 (1.13)*
	Camponotus vividus (F.Smith, 1858)	17 (1.71)	122 (8.94)	131 (8.57)	270 (6.94)*
	Lepisiota sp.1	2 (0.20)	1 (0.07)	9 (0.59)	12 (0.31)
	Oecophylla longinoda (Latreille, 1802)	197 (19.80)	18 (1.32)	303 (19.82)	518 (13.32)*
	Paratrechina longicornis (Latreille, 1802)	1 (0.10)	0 (0.00)	0 (0.00)	1 (0.03)
	Polyrhachis decemdentata (Andre, 1889)	29 (2.91)	55 (4.03)	53 (3.47)	137 (3.52)*
	Polyrhachis laboriosa (Smith, 1858)	16 (1.61)	13 (0.95)	7 (0.46)	36 (0.93)
	Polyrhachis militaris (Fabricius, 1782)	5 (0.50)	4 (0.29)	40 (2.62)	49 (1.26)*
	Polyrhachis sp.1	0 (0.00)	2 (0.15)	2 (0.13)	4 (0.10)
	Polyrhachis sp.2	0 (0.00)	0 (0.00)	5 (0.33)	5 (0.13)
	Polyrhachis sp.3	0 (0.00)	0 (0.00)	1 (0.07)	1 (0.03)
	Polyrhachis sp.4	4 (0.40)	0 (0.00)	0 (0.00)	4 (0.10)
	Polyrhachis weissi (Santschi, 1910)	2 (0.20)	0 (0.00)	0 (0.00)	2 (0.05)
Myrmicinae	*Atopomyrmex mocquerysi* (Andre, 1889)	3 (0.30)	24 (1.76)	12 (0.78)	39 (1.00)*
	Cataulacus guineensis (Smith, 1853)	12 (1.21)	79 (5.79)	136 (8.89)	227 (5.84)*
	Cataulacus sp.1	18 (1.81)	15 (1.10)	26 (1.70)	59 (1.52)*
	Cataulacus sp.2	3 (0.30)	0 (0.00)	4 (0.26)	7 (0.18)

	Cataulacus sp.3	0 (0.00)	38 (2.79)	0 (0.00)	38 (0.98)
	Crematogaster clariventris (Mayr,1895)	121 (12.16)	3 (0.22)	244 (15.96)	368 (9.47)*
	Crematogaster gabonensis (Emery, 1899)	344 (34.57)	31 (2.27)	100 (6.54)	475 (12.22)*
	Crematogaster sp.1	1 (0.10)	26 (1.91)	11 (0.72)	38 (0.98)
	Crematogaster sp.2	10 (1.01)	0 (0.00)	1 (0.07)	11 (0.28)
	Crematogaster striatula (Emery, 1892)	34 (3.42)	48 (3.52)	317 (20.73)	399 (10.26)*
	Monomorium sp.1	1 (0.10)	0 (0.00)	0 (0.00)	1 (0.03)
	Myrmicaria opaciventris (Emery, 1893)	0 (0.00)	8 (0.59)	106 (6.93)	114 (2.93)*
	Pheidole megacephala (Fabricius, 1793)	70 (7.04)	18 (1.32)	412 (26.95)	500 (12.86)*
	Pheidole sp.1	0 (0.00)	0 (0.00)	37 (2.42)	37 (0.95)
	Pheidole sp.2	6 (0.60)	0 (0.00)	14 (0.92)	20 (0.51)
	Pheidole sp.3	0 (0.00)	0 (0.00)	1 (0.07)	1 (0.03)
	Tetramorium aculeatum (Mayr, 1866)	22 (2.21)	1232 (90.32)	41 (2.68)	1295 (33.31)*
	Tetramorium sp.1	1 (0.10)	0 (0.00)	3 (0.20)	4 (0.10)
	Tetramorium sp.2	3 (0.30)	0 (0.00)	0 (0.00)	3 (0.08)
	Tetramorium sp.3	1 (0.10)	0 (0.00)	0 (0.00)	1 (0.03)
Ponerinae	*Anochetus africanus* (Mayr,1865)	0 (0.00)	1 (0.07)	7 (0.46)	8 (0.21)
	Anochetus sp.1	22 (2.21)	17 (1.25)	3 (0.20)	42 (1.08)*
	Odontomachus troglodytes (Santschi, 1914)	14 (1.41)	1 (0.07)	1 (0.07)	16 (0.41)
	Pachycondyla soror (Emery, 1899)	0 (0.00)	0 (0.00)	11 (0.72)	11 (0.28)
	Pachycondyla tarsata (Fabricius, 1798)	2 (0.20)	3 (0.22)	2 (0.13)	7 (0.18)
	Platythyrea conradti (Emery, 1899)	1 (0.10)	0 (0.00)	2 (0.13)	3 (0.08)
	Platythyrea modesta (Emery, 1899)	2 (0.20)	13 (0.95)	6 (0.39)	21 (0.54)
Pseudomyrmicinae	*Tetraponera anthracina* (Santschi, 1910)	26 (2.61)	0 (0.00)	0 (0.00)	26 (0.67)
	Tetraponera ophthamilca (Emery, 1912)	0 (0.00)	15 (1.10)	3 (0.20)	18 (0.46)
	Tetraponera sp.1	4 (0.40)	0 (0.00)	0 (0.00)	4 (0.10)
	Tetraponera sp.2	9 (0.90)	0 (0.00)	0 (0.00)	9 (0.23)
	Tetraponera tessmani (Stitz, 1910)	0 (0.00)	32 (2.35)	37 (2.42)	69 (1.77)*
Total		995 (100.00)	1364 (100.00)	1529 (100.00)	3888 (100.00)

Relative occurrence is given in brackets. *: represents most occurring species (relative occurrence is ≥ 1% for cumulative occurrence for all study sites