Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 17, Issue, 11, pp.35455-35462, November, 2025
DOI: https://doi.org/10.24941/ijcr.49603.11.2025

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

ANT COMMUNITY COMPOSITION IN SMALLHOLDER AGROFORESTS FROM TWO AGROECOLOGICAL ZONES: RAINY FOREST AND FOREST-SAVANNAH MOSAIC IN CÔTE D'IVOIRE

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ARTICLE INFO

Article History:
Received 27th August, 2025
Received in revised form
18th September, 2025
Accepted 24th October, 2025
Published online 30th November, 2025

Keywords: missing

Agroecosystems, Biodiversity, Conservation, ants, Smallholder Farming.

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ABSTRACT

With the climate change, tropical regions of Africa are witnessing a biodiversity decline within agricultural landscapes. This loss of biodiversity threatens ecological integrity and the resilience of food production systems, particularly for smallholder farming who depend of a range of food and cash crops for subsistence and local markets. Unfortunately, the species and the ecological functions which support these smallholder agroecosystems remain poorly understood, limiting the implementation of sustainable practices. This study aimed to assess the biodiversity of smallholder agroforests using ants as biological indicators. Study was focused on the land-use types of smallholder agroforests, including fallows, rural forests, cocoa and rubbers orchards from two different agroecological zones in Côte d'Ivoire. We sampled ants using the standardized methods of winklers, pitfall trap and baiting. Results revealed a rich ant fauna with 81 ant species belonging 27 genera and 6 subfamilies. We recorded 53 and 48 ant species for forest-savanna mosaic and rainy forest regions, respectively. The subfamilies identified includes Myrmicinae (57% of species richness), Formicinae (26%), Ponerinae (8%), Dorylinae and Dolichoderinae (4%, respectively), and Pseudomyrmecinae (1 %). Shannon diversity index value was high in Cocoa RF (3.26) followed by Fallows RF (.90), Cocoa FSM (2.47) and low in Ruralforest (2.04) and Rubber FSM (2.02) Results also showed a variation of ant species composition (ANOSIM: R = 66.4, P= 0.0002) between the agroforests of the both agroecological zones. The most abundant ant species was the aboreal dominant weaver ant *Oecophylla longinoda*. The most prevalent ant species in rainy forest smallholder agroforests were *Crematogaster* sp. 2, *Nylanderia scintilla*, *Paltothyreus tarsata*, *Hypoponera dulcis*, *Oecophylla longinoda*, *Monomorium* sp. 1 and *Carebara distincta*. In forest-savanna mosaic agroforest, *Oecophylla longinoda*, *Crematogaster* sp. 14, *Camponotus maculatus*, *Paltothyreus tarsata, Pheidole* sp.6, *Crematogaster solenopsides*, *Monomorium floricola*, *Pheidole excellens*, *Carebara thoracica*, *Pheidole* sp.4. Our study demonstrated that ant communities respond differently to land-use in smallholder agroforests across ecological regions. It provides baseline data of valuable importance and emphasises the importance of continued surveys in smallholder agroecosystems to increase knowledges on ants and other groups of insects, including pollinators and by extension biodiversity.

Citation: KOUAKOU Lombart M. Maurice., YODE Dakélé C-V., TADU Zephirin, KONATE Souleymane and KOUASSI K. Philippes. 2025. "Ant community compositionin smallholder agroforests fromtwo agroecological zones: rainy forest and forest-savannahmosaic in Côte d'Ivoire.". ***International Journal of Current Research, 17, (11), 35455-35462.***

INTRODUCTION

Agriculture remains one major driver of the loss of biodiversity and its associated ecosystem services. The loss affects the viability and the ability of community to respond to environmental change and disturbances **(**Gàmez-Viruès *et al.*, 2015). For this purpose, agroecosystems have prompted the researches and adoption of conservation strategies which suggest agricultural land as an alternative solution to preserve biodiversity (Gonthier *et al.*, 2014).

Several studies admitted that incorporating more natural and semi-natural habitats in agroecosystems could help to maintain high habitat diversity (Arroyo-Rodriguez *et al.*, 2020). However, in human-modofied habitats, such as smallholder agroecosystems, knowledge gaps persist on the composition and function of local animal communities locally, but also across a range of spatial scales (Schweiger *et al.*, 2005). Additionally, in most humid tropical regions of Africa there is a paucity of research on insect assemblages and their future in agricultural landscapes although numerous studies link agricultural spread and intensification to insect declines (Van

Klink *et al*., 2020). Otherwises, agroforestry has been well documented to be biodiversity-friendly farming practices. For instance, recent studies reported that smallholder cocoa production centre in Bahia, Brazil, in forest-dominated landscapes can reduce biodiversity loss (Rocha *et al*., 2019). The same is true for Hainan Island in China, where rubber-based agroforestry can reduce tramp ant species prevalence and supports a species composition and a functional diversity similar to secondary forest (Lee *et al*., 2022). In Côte d'Ivoire, intensive exploitation farms of cash crops have been established in humid natural forest areas since colonial times. Cocoa and rubber are among the most important cash crops which currently occupy a key economic value (Tondoh *et al*., 2019). In a recent study Barima *et al* (2019) pointed out the forest decline as a consequence of cocoa economy and, the shift of cocoa production epicentres to the Centre-West to the South-West of the country. They also found that the forest recovery in former cocoa production areas is due to the perennial tree crops such rubber, teaks and oils palm trees, old cocoa orchards and non-producing old cocoa trees transformed in old fallow lands comparable to secondary forests. Considering that, many studies suggest agroforestry as farming practices to mitigate forest decline in Côte d'Ivoire (Sanial, 2015). However, most of the existing studies addressed the negative impacts of cocoa and rubber trees on soil physico-chemical components, soil degradation and soil invertebrate loss (Yeo *et al*., 2011; N'Dri *et al*., 2018; Tondoh *et al*., 2019). Prior to this study, no study has yet directly addressed the potential of cocoa and rubber agroforests to conserve biodiversity in agricultural landscapes.

Insects are key components of agricultural landscapes due to their multiple roles in Agroecosystems (Jankielsohn, 2018). Among insects, ants are well known and form the most ecologically diverse group of social insects (Hölldobler & Wilson, 1990). They are implied in many ecological functions, and therefore are widely utilised to investigate the consequences of biological invasions, (Achury *et al*, 2021), the effects of fire regimes (Kone *et al*., 2018) and contribute to improving soil physical and chemical properties (Ouattara *et al*., 2023). They play important roles in food webs as herbivores, predators and mutualists (Hölldobler & Wilson, 1990). Ants also ensure the dispersal of many plant species and their sensitivity to sudden habitat transformation make them an adequate target insect to monitor and evaluate the integrity of biological diversity (Yeo *et al*., 2016). Additionally, past studies demonstrated that habitat complexity structures ant assemblage at local scales (Larrea *et al*., 2022), but the compositions of ant assemblages are influenced by spatial and temporal variation in climate and resources availability (Gibb *et al*., 2022). Here, we assess the biodiversity conservation potential of smallholder cocoa and rubber plantation-based agroforests. Using ants as biological indicators, we were focused on two agroecological regions: the South-West region (RF) considered as the former cocoa loop and the forest-savanna mosaic (FSM) of the country Centre, where cocoa and rubber farms are currently expanding (Barima *et al*., 2019). Specifically, we tested following hypotheses: (1) ant community structure, abundance and diversity change between smallholder agroforests across agroecological regions, (2) the community composition changes between land-use types of smallholder agricultural landscapes.

MATERIALS AND METHODS

Study sites: The study sites are located in two distinct phytogeographical zones: the transitional forest-savannah region (FSM) and in the tropical rainy forest region (RF) (See Figure 1). In the tropical rainy forest area (RF), sampling was conducted in cocoa orchard and closely fallows near the village of Angbikouakoukro (6.51° W, 5.49° N) located at 20 Km from the TAÏ National Park in the department of Soubré. The fallows were a bushy area dominated by *Chromolena odorata*, *Alchornea cordifolia,* palm trees *Elais guineensis* and tree fern. Located in Guinean forest, this area lies under a subequatorial climate type with an annual average temperature of 27˚C and annual rainfall average around 1700 mm with four seasons (Guillaumet & Adjanohoun, 1971). The rainy seasons are from April to June and September to October, while the dry seasons are from November to March and July to August. The vegetation type dense evergreen rainforest is the same of Taï National Park. It is marked by species likes *Uapaca pynaertii* De Wild, *Uapaca guineensis* Müll. Arg., *Psychotria mangenotii* (Aké Assi) Verdc., *Childowia sanguinea* Hoyle, *Asystasia trichotogyne* Lindau, *Heritiera utilis* (Sprague) Sprague and *Gambeya perpulchra* (Mildbr. Ex Hutch. & Dalziel) Aubrév. & Pellegr. (Guillaumet & Adjanohoun, 1971). In this region, the clearing due to agriculture has destroyed the primitive vegetation, favouring heliophilous species such as *Musanga cercropioides* R. Br. ex Tedlie, *Paullinia pinnata* L., *Alchornea cordifolia* (Schumach. & Thonn.) Müll.Arg., *Ceiba pentandra* (L.) Gaertn., *Terminalia ivorensis* A. Chev., *Alstonia boonei* De Wild (Guillaumet, 1967). In the transitional forest-savanna mosaic region (FSM), sampling was carried out in department of Taabo within the rural domain of Zougoussi village located at 3 Km to the west of LAMTO scientific reserve (5.02°W, 6.13 °N) at the tip of "V Baoulé" of Côte d'Ivoire. This locality is under an intertropical climate with an average temperature of 28.21˚C and annual rainfall average of 1257 mm with four seasons. Rainy seasons span from April to July and September to November and dry seasons lie in August and from December to March (Yeo *et al*., 2017). The vegetation type is a forest-savannah mosaic with three main habitat types, the forest islands, the gallery forest and humid grassy savannah (Yeo *et al*., 2017). For this study, we sampled in cocoa orchards, young rubber orchards and in forest islands located closely in rural domain. These forests are surrounded by food crops, rubber and cocoa orchards in which samplings were conducted. There are semi-deciduous forests often connected to gallery forest and marked by a discontinuous canopy cover, a shallow layer of leaf litter on the soil. Dominant trees species are *Dialium guineensis* Willd., *Olax subscorpioidea* Oliv., *Trichilia prieureana* A. Juss., *Pouteria alnifolia* (Baker) Roberty and *Lecaniodiscus cupanioides* Planch (**Koulibaly, 2008**). However, in these forests the vegetation subjected to selective logging for daily needs of local population and to anthropogenic pressures such as hunting and clearing. The remaining patches of forest are degraded and /or divided in small fragments as a result of human exploitation.

Sampling and Identification: Sampling was carried out in April 2019 and May 2020 in 100 x 50 m plots in cocoa and rubber plantations, fallows, and secondary forests from rural agricultural landscapes using pitfall traps (Agosti *et al*., 2000) and funnel traps baited with tuna (Yodé *et al*., 2020**)**. Ant were identified using a microscope OLYMPUS SZ8. Ant workers were pinned and primary identified at genus level using Fisher & Bolton (2016), then the species level identification keys of Bolton (1980, 1982, and 1987), the personal reference collection from Yeo (2006) located in Lamto Ecological Station were used for identification at species level. All identified ant workers pinned were gathered in entomological boxes and deposited at Lamto Ecological Research Station, Côte d'Ivoire.

Data analysis: Statistical analyses were performed by pooling data recorded with all sampling methods described above to assure an accurate measurement of ant communities in all sampled habitats. Abundance of ant was estimated using occurrence of individual worker (absence/presence) rather than total number of individual (Yeo *et al*., 2011). Thus, we defined abundant species as all species whose occurrence is at least equal to 100 in the combined data. The representativeness of the sampled species was estimated using sample coverage calculated as the ration of observed and estimated species richness using non-parametric estimator Chao 2 included in EstimateS 9.1 (Colwell *et al*., 2013). Local diversity (alpha-diversity) was estimated using, species richness, Shannon's index (H'), Simpson dominance index, Evenness and the number of unique species (rare species) each land use type. Before comparison of ant community between study sites, Levene's test for homogeneity of variance was used to test the normality of our data. In case of normal distribution, one-way analysis of variance (ANOVA) on repeated measure and the Welch F test were used for comparison. If not, the Kruskall-Walis tests was used for comparison of ant workers between sampled subfamilies. A Multiple Linear regression was performed to estimate the relation. Beta-diversity was estimated using Bray Curtis index to quantify the similarity of species composition between greenspaces of study sites. We then plotted a two-dimensional map with non-metric multidimensional scaling (NMDS) to examine the variation in ant species composition among land use type of both agroecological zones. An analysis of similarities (ANOSIM) by 10,000 permutations was conducted to test significant differences in species composition between land use types. All these statistical analyses were made using Past Software v3.09 and R Software v4.4.3 The value of $p \leq 0.05$ was taken as an indicator of statistical significance.

RESULTS

Ant fauna: The study recorded 81 ant species belonging to 27 genera and 6 subfamilies (Table 1). Fifty-four taxa were identified at species level. The other remaining 27taxa were mainly morphospecies with the genus *Pheidole* as the richest genera (7 morphospecies),*Crematogaster* and *Monomorium* (4 morphospecies, respectively), *Lepisiota* (3 morphospecies), *Solenopsis* (2 morphospecies), and *Dorylus*, *Parasyscia*, *Tapinoma*, *Polyrhachis*, *Strumygenis*, *Paraparatrechina*, *Carebara* with 1 morphospecies, respectively. We found a significant variation of the number of ant workers within each subfamily between the agroforests of the rainy forest and forest-savanna mosaic (Kruskal-Wallis test. $X^2 = 26$, $df = 5$, $P = 0.00001$). Myrmicinae was the most diverse with 57% of speciesobserved, followed by Formicinae (26%), Ponerinae (8%), Dorylinae and Dolichoderinae (4%, respectively). The subfamily Pseudomyrmecinae was the less diverse with 1 % of species observed (Figure 1). The genus with higher number of species were *Pheidole* and *Monomorium* (9 species, respectively). The genus *Oecophylla* recorded the higher number of workers (1764 individuals), followed by *Crematogaster* (1073 individuals), *Camponotus* (981 individuals), *Pheidole* (737) and *Paltothyreus* (549 individuals).

Ant species richness and diversity across the ecological region: We collected 7156ant workers (Workers) belonging to 81 ant species in the both agroecological zones. Agroforests of forest-savanna mosaic were the richest (53 ant species) than in rainy forest regions (48 species) (Welch F test: $F = 3.16$, $df = 198.6$, $P = 0.01$). Similarly, we found a significant difference comparing the ant species richness between the land use types from forest-savanna mosaic and rainy forest regions (ANOVA test: F = 3.74, df = 4, p = 0.005). In rainy forest region, we found 40 ant species in cocoa RF and 33 in fallows RF. In forest-savanna mosaic, we recorded 36 species cocoa FSM, 33 in rubber FSM and 32 species in rural forests FSM. The rarefaction curves showed higher species richness in cocoa RF, while they predict a little difference between Fallows RF and cocoa FSM, rubber FSM and rural forest FSM. The curves also indicated an asymptotic trend was reached for habitat sampled in rainy forest region, while curves steadily grow for all habitats in forest-savanna mosaic region, suggesting an increase in sampling effort in the habitat of this region (**Figure 2**). The species richness estimation showed little variation (Table 2). The sampling completeness showed a coverage included between 57% and 97% suggesting that sampling effectiveness appears acceptable (Table 2).

Overall, Rényi diversity ordering, using a wide family of diversity indices found that diversity is high in the cocoa orchards from rainy forest ecological region, but the diversity in other habitats proven incomparable due to uneven distribution (Figure 3). Additionally, we observed a high value of Shannon diversity index in cocoa orchards and fallows for rainy forest region (**Table 3**). In forest-savanna mosaic region, the high value of Shannon index was recorded also in cocoa orchards while a quite similar value was recorded in rubber orchards and rural forest. The Evenness showed a similar pattern (Table 3). On the other hand, the Simpson dominance was low in cocoa and fallows in rainy forest region and increasing from cocoa towards rural forest in forest-savanna mosaic habitats (Table 3). The number of unique species reflected the Shannon index value in cocoa orchards of rainy forest with 15 unique species. On contrary, the high number of unique species was recorded in rural forests from forest-savanna mosaic region.

Ant abundance and species composition: The comparison of profiles abundance in agroforests showed a different pattern in the both agroecological zones (Figure 4A, 4B). Land use type of rainy forest regions were dominated by seven (7) species with at least 100 workers each with a regular distributed abundance in the community. These dominant species were *Crematogaster* sp. 2, *Nylanderia scintilla*, *Paltothyreus tarsata*, *Hypoponera dulcis*, *Oecophylla longinoda*, *Monomorium* sp. 1 and *Carebara distincta*. They account for 45 % of ant total abundance (1,063 out of a total of 2,362 workers). On contrary, agroforests of forest-savanna mosaic region showed an irregular distributed abundance of the ant species. The most abundant species is *Oecophylla longinoda* with 1640 workers. In addition, nine other ant species are dominant with at least 100 workers each. These species were *Crematogaster* sp. 14, *Camponotus maculatus*, *Paltothyreus tarsata, Pheidole* sp.6, *Crematogaster solenopsides*, *Monomorium floricola*, *Pheidole excellens*, *Carebara thoracica*, *Pheidole* sp.4. These species account for 88% of ant total abundance (4,233 out of a total of 4,3794 workers) in the agroforests of forest-savanna mosaic region. The comparison of average ant species abundance between the both regions did not show a significant difference (ANOVA: F= 0.93; df= 4; p= 0.44). However, in the forest-savanna mosaic region ant abundance in agroforests is ranged from 17% to 28 %, while in the rainy forest region, ant abundance in agroforests was 13% and 20% (Figure 5).

Regarding the species composition, the study revealed that out of 81 species recorded, the agroforests in rainy forest and forest-savanna mosaic regions shared 20 ant species. The species composition showed significant dissimilarity between ant communities in the agroforests of the both ecological regions (ANOSIM: $R = 66.4$, P= 0.0002). NMDS of Figure 6 showed identical species composition for land use types in forest-savanna mosaic region, while in rainy forest region, the obvious dissimilarity between cocoa orchards and fallows was not significant (ANOSIM: $R = 0.25$, P= 0.2). However these habitats shared 25 out of a total of 48 ant species recorded in the rainy forest region.This study also found that some species that depend strictly on agroforests in the two ecological regions are particularly dominants. In the forest-savanna mosaic region, these species are *Crematogaster* sp. 14, *Pheidole* sp.6, *Crematogaster solenopsides*, *Carebara thoracica* and *Pheidole* sp.4.In the rainy forest region these species are *Crematogaster* sp. 2, *Nylanderia scintilla*, *Monomorium* 1, *Hypoponera dulcis*, *Carebara distincta* and *Pheidole* sp. 3.

DISCUSSION

This study aimed to assess the potential of smallholder agroforests to conserve biodiversity in localities across two distinct ecological regions of Cote d'Ivoire, using ants as bioindicators. Prior to our investigations, former research pointed out the negative impacts of cocoa and rubber agroforests on soil invertebrate communities (Yeo *et al*., 2011; Tondoh *et al* 2019). Therefore, understanding how ant communities respond to agricultural-induced habitat transformation in distinct agroecological regions is crucial to promote sustainability in agroecosystems. While former researches were conducted in one ecological region (Yeo *et al*., 2011, Tondoh *et al*., 2019**)**, here we explore the ant diversity and distribution in the smallholder agroforests composed of fields of cocoa, rubber, fallows and rural forest from rainy forest and forest-savanna mosaic regions. Interestingly our sampling provided a good estimation of ant community with a sampling coverage ranged between 57% and 97% for all sampled habitats. Overall, 81 ant species were recorded. They belong to 27 genera and 6 subfamilies that are Myrmicinae, Formicinae, Ponerinae, Dorylinae, Dolichoderinae and Pseudomyrmecinae. These sampled 6 subfamilies were also recorded in previous studies conducted in LAMTO Scientific Reserve from forest-savanna mosaic (Kone *et al*., 2018) and Banco and Ehotilés National Park from rainy forest regions (Yeo *et al*., 2016; Kouakou *et al*., 2024). These results suggest that ant communities found here in this study could be similar to those in undisturbed and protected habitats despites the disturbances led by human activities in the

Table 1. Checklist of ant species with total abundance in different land use types from rainy forest and forest-savanna mosaic regions

	Rainy forest region		Forest-savanna mosaic region			
Subfamily and species	**Cocoa RF**	**Fallows RF**	**Cocoa FSM**	**Rubber FSM**	**Forest FSM**	**Total**
DORYLINAE						
Dorylus sp.1	0	0	2	0	1	3
Parasyscia nitidulus (Brown, 1975)	59	11	0	0	0	70
Parasyscia sp.1	0	0	0	1	0	1
DOLICHODERINAE						
Tapinoma lugubre Santschi, 1917	32	0	22	23	22	99
Tapinoma melanocephalum (Fabricius, 1793)	7	6	3	1	0	17
Tapinoma sp.2	0	0	0	0	1	1
FORMICINAE						
Camponotus acvapimensis Mayr, 1862	0	88	30	14	1	133
Camponotus compressiscapus André, 1889	0	0	0	22	0	22
Camponotus maculatus (Fabricius, 1782)	3	34	167	253	211	668
Camponotus puberulus Emery, 1897	0	0	4	15	5	24
Camponotus solon Forel, 1886	0	0	26	24	8	58
Camponotus vividus (Smith, 1858)	0	35	22	0	0	57
Camponutus schoutedeni Forel, 1911	0	0	5	14	0	19
Lepisiota sp.1	33	1	2	8	28	72
Lepisiota sp.2	43	16	0	0	0	59
Lepisiota sp.3	21	1	0	0	0	22
Nylanderia boltoni LaPolla& Fisher, 2011	0	0	0	0	2	2
Nylanderia scintilla LaPolla & Fisher, 2011	111	76	0	0	0	187
Oecophylla longinoda (Latreille, 1802)	70	54	402	579	659	1764
Paraparatrechina sp.1	37	41	0	0	0	78
Paratrechina longicornis (Latreille, 1802)	7	0	4	2	1	14
Plagiolepis alluandi Emery, 1894	0	0	0	0	1	1
Polyrhachis decemdentata André, 1889	14	0	0	0	0	14
Polyrhachis sp.3	0	0	0	0	2	2
Polyrhachis concava André, 1889	3	0	0	0	0	3
Polyrhachis laboriosa Smith, 1858	11	45	0	0	0	56
Polyrhachis militaris (Fabricius, 1782)	0	9	0	0	0	9
MYRMICINAE						
Cardiocondyla emeryi Forel, 1881	35	10	2	0	0	47
Cardiocondyla neferka Bolton, 1982	0	0	28	0	0	28
Cardiocondyla shuckardi Forel, 1891	7	0	1	0	0	8
Carebara distincta (Bolton & Belshaw, 1993)	112	0	0	0	0	112
Carebara sp.2	22	7	0	0	0	29
Carebara thoracica (Weber, 1950)	0	0	80	0	48	128
Cataulacus pygmaeus André, 1890	0	76	0	0	0	76
Crematogaster africana Mayr, 1895	0	0	3	1	0	4
Crematogaster solenopsides Emery, 1899	0	0	20	28	92	140
Crematogaster sp.1	27	21	0	0	0	48
Crematogaster sp.14	0	0	21	637	21	679
Crematogaster sp.17	0	0	0	0	1	1
Crematogaster sp.2	21	179	0	0	0	200
Crematogaster striatula Emery, 1892	0	0	1	0	0	1
Monomorium inquietium Santschi, 1926	0	0	7	5	0	12
Monomorium bicolor Emery, 1877	0	0	1	0	0	1
Monomorium floricola (Jerdon, 1851)	14	1	71	39	13	138
Monomorium invidium Bolton, 1987	7	1	0	0	0	8
Monomorium pharaonis (Linnaeus, 1758)	0	0	28	0	0	28
Monomorium sp.1	150	20	0	0	0	170
Monomorium sp.2	24	6	0	0	0	30
Monomorium sp.3	7	7	0	0	0	14
Monomorium sp.4	0	0	0	0	3	3
Pheidole excellens Mayr, 1862	0	1	22	66	46	135
Pheidole megacephala (Fabricius, 1793)	0	0	0	11	19	30
Pheidole sp.1	20	10	0	0	0	30
Pheidole sp.12	0	0	0	8	9	17
Pheidole sp.2	0	0	7	0	3	10
Pheidole sp.3	97	0	0	0	0	97
Pheidole sp.4	0	0	14	92	0	106
Pheidole sp.6	0	0	141	18	91	250
Pheidole sp.7	62	0	0	0	0	62
Solenopsis sp.1	11	0	0	0	0	11

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Solenopsis sp.2	34	0	0	0	0	34
Strumigenys nimbrata Bolton, 1983	47	0	0	0	0	47
Strumigenys ninda (Bolton, 1983)	7	0	0	1	8	16
Strumigenys roomi (Bolton, 1972)	6	0	0	0	0	6
Strumigenys rufobrunea Santschi, 1914	7	0	0	0	0	7
Strumigenys sp.2	0	0	2	1	2	5
Tetramorium quadridentatum Stitz, 1910	0	0	0	1	0	1
Tetramorium aculeatum (Mayr, 1866)	7	18	0	0	0	25
Tetramorium anxium Santschi, 1914	14	0	1	1	1	17
Tetramorium eminii (Forel, 1894)	0	5	0	3	0	8
Tetramorium flavithorax (Santschi, 1914)	0	0	0	4	0	4
Tetramorium rhetidum Bolton, 1980	0	0	0	0	1	1
Tetramorium sericeiventre Emery, 1877	0	9	0	1	0	10
PONERINAE						
Euponera brunoi (Forel, 1913)	0	0	1	2	1	4
Hypoponera dulcis (Forel, 1907)	71	52	0	0	0	123
Megaponera analis (Latreille, 1802)	0	0	0	0	5	5
Mesoponera caffraria (Smith, 1858)	12	14	14	5	35	80
Odontomachus troglodytes Santschi, 1914	63	22	10	2	0	97
Paltothyreus tarsatus (Fabricius, 1798)	120	27	76	89	237	549
Plectroctena minor Emery, 1892	0	0	1	0	0	1
PSEUDOMYRMICINAE						
Tetraponera mocquerysi (André, 1890)	0	4	1	3	0	8

Table 2. Sampling completeness metrics of ant communities surveyed in different land use types from rainy forest (RF) and forest mosaic Savanna (FSM) regions.

Efficiency measure	**Rainy forest region**		**Forest savanna mosaic region**		
	Cocoa RF	**Fallows RF**	**Cocoa FSM**	**Rubber FSM**	**Forests FSM**
Number of samples	**60**	**60**	**120**	**120**	**120**
Observed species	40	33	36	32	33
Chao 2 Estimator	41	42.83	37.78	41.1	57.78
Sample Coverage (SC)	0.97	0.77	0.95	0.80	0.57

Table 3. Metrics of ant Diversity indices and unique species in habitats from both ecological regions

Ecological region	Rainy forest		Forest savanna mosaic		
Diversity measures	**Cocoa RF**	**Fallows RF**	**Cocoa FSM**	**Rubber FSM**	**Forest FSM**
Sobs	40	33	36	32	33
Simpson dominance (D)	0.05	0.08	0.15	0.21	0.22
Shannon Index (H)	3.26	2.90	2.47	2.02	2.04
Evenness (e^H/S)	0.65	0.55	0.32	0.22	0.24
Unique species	15	5	8	7	13

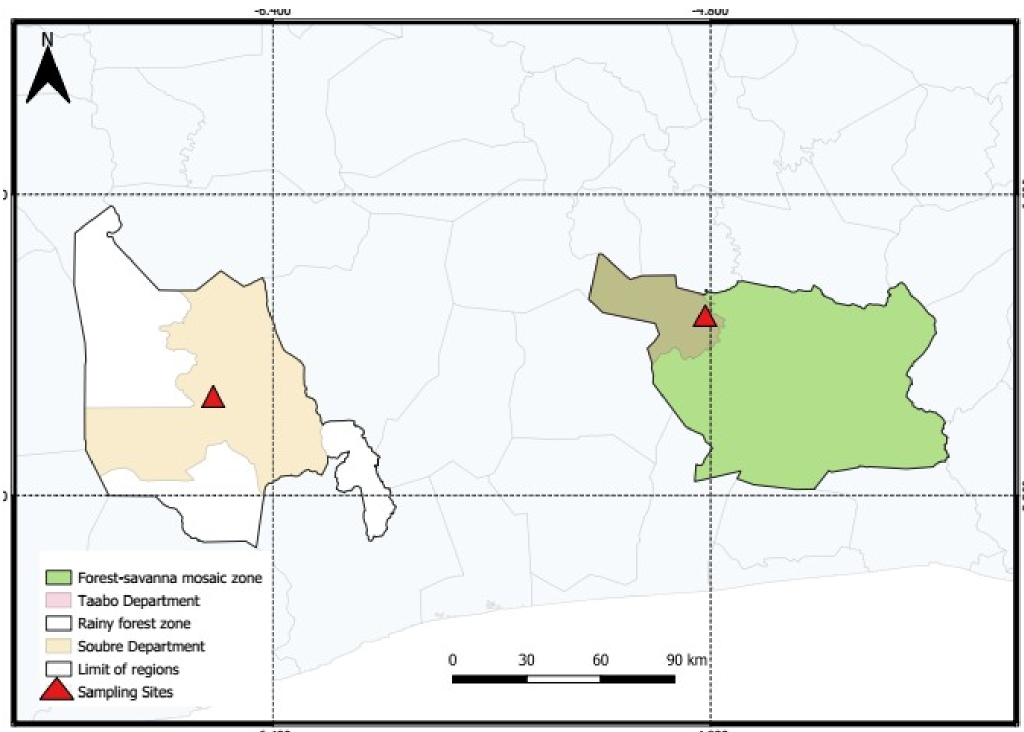


Figure 1. (Map of sampling sites)

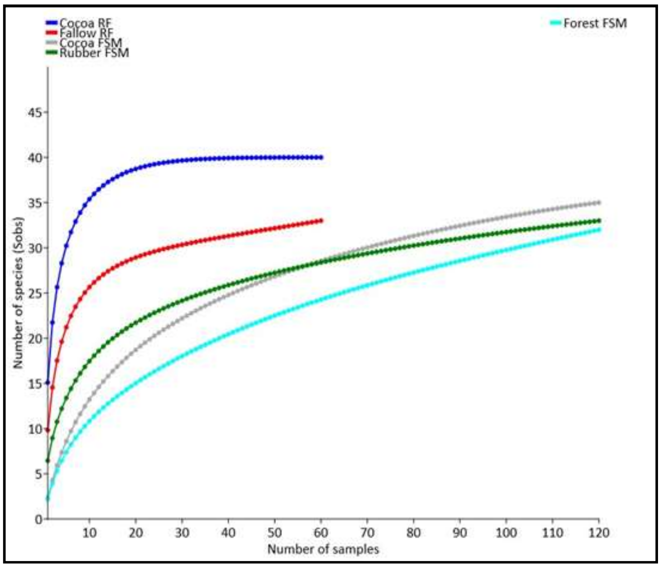


Figure 2. Rarefaction curves of ant communities from land uses types of the two ecological regions. ***RF: rainy forest region; FSM: forest-savannah mosaic region*****.**

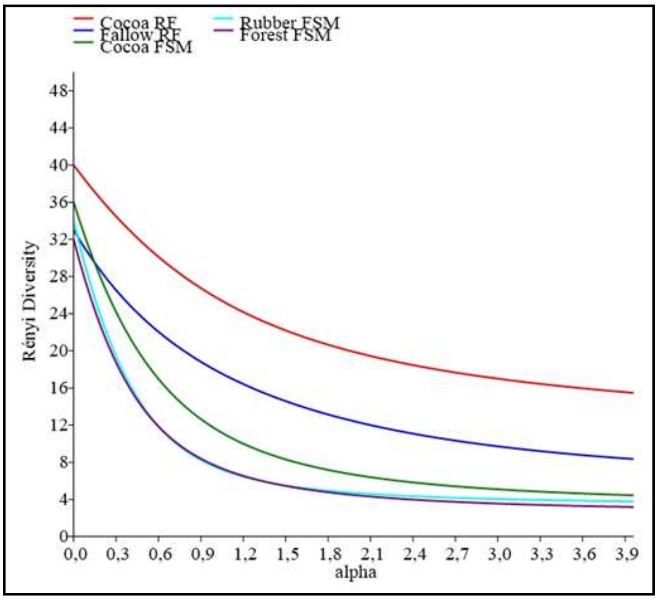
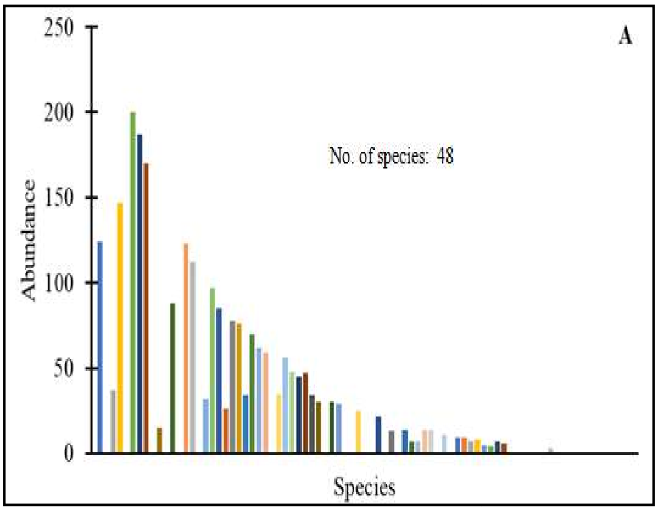


Figure 3. Rényi diversity ordering showed comparison of ant diversity between land use types in rainy forest and forest-savanna mosaic regions



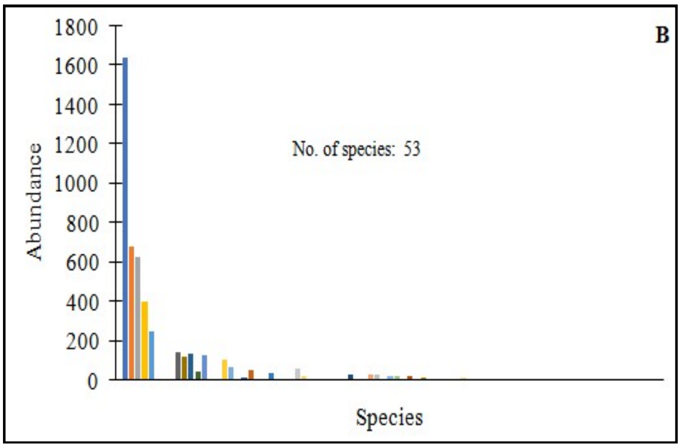


Figure 4. Abundance profiles of ant species recorded in agroforests of both ecological region: (A) rainy forest and (B) forest-savanna mosaic regions.

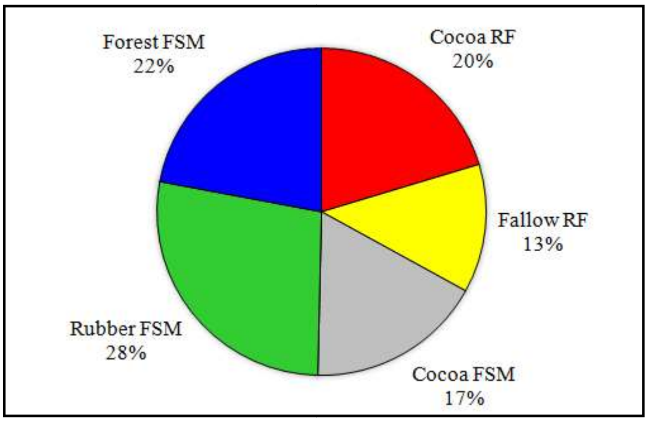


Figure 5. Percentage distribution of ant abundance in the agroforests of rainy forest and forest-savanna mosaic regions

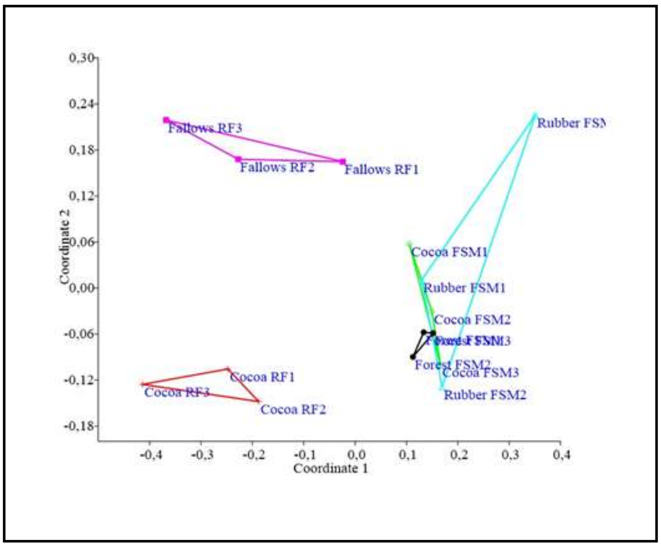


Figure 6. Non-metric multidimensional scaling (NMDS) displaying ant species composition of each land use types sampled on the basis of Bray-Curtis similarity index. (stress = 0.14, Axis 1= 0.70; Axis 2 =

smallholders' agroforests. This is consistent with Tassoni *et al*. (2024) who demonstrated that agricultural landscapes promote insect conservation if they contain diverse cultivated species and host semi-natural habitats. Our study reflected this trend, as the agroforests investigated are exploited by the smallholders. Although we do not have focused specifically at analysing the heterogeneity of our sampling sites, it has been observed that sampling habitats were characterized by various crops, non-crops habitats, livestock and agro forestry practices which may create a heterogenous landscape and favour the increase of insect diversity, and by congruence ants (Azcárate *et al*., 2021, Jankielshon, 2023). We found a significant difference in ant species richness between the rainy forest and forest-savanna mosaic regions. Unexpectedly, ant community from agroforests in forest-savanna mosaic regions recorded a higher ant species than rainy forest regions. This result does not corroborate the general pattern of insect species richness correlate habitat heterogeneity (Stein *et al*., 2014). One possible explanation of this contradiction could be weather conditions such temperature and relative humidity throughout the precipitation which can also shape ant communities. A similar observation has been reported in Hordley *et al*. (2023) who reported that temperature and rainfall can affect insect richness. Another possible explanation of the difference in species richness could be the land-use type like mentioned in previous studies (Yeo *et al*., 2011; Achury *et al*., 2025). For example, we found for this study that species richness and the value of Shannon diversity index were higher in cocoa orchards of both ecological regions rather than fallows RF, rubber FSM and Forest FSM.

Otherwise, Rényi diversity ordering revealed a decreasing ant diversity and richness from cocoa RF orchards toward Fallows RF in rainy forest region. Conversely, land use type in agroforests of forest-savanna mosaic region showed uneven distribution of ant species and diversity suggesting an overlapping of the ant communities between land use type of the agroforest. This finding may suggest that land use type affects ant communities differently across the ecological regions like demonstrated in the former studies (Rabello *et al*., 2021). These works demonstrated that ant functional group and species are affected differently following a gradient of soil management and tree cover in agricultural landscapes. In our case, agroforests in rainy forest are dominated by perennial tree-crops systems like cocoa trees and fallows (bushy landscapes) which can support different ant species contrary to agroforests of forest-savanna mosaic regions dominated only by tree-crops system (cocoa and rubber) and degraded forest. These finding are reinforced by the number of unique species recorded, the regular and irregular distribution of species abundance (see results on evenness in table 3) and the variation of Simpson dominance index value in each land use type of each ecological region. Additionally, we observed a different pattern of distribution was observed in ant abundance across both ecological regions (Figure 4a, 4b and Figure 5), confirming evidence of non-identical response of ant community to land use change in this study. Rainy forest region ant community showed a regular distribution of ant species with high prevalence of was dominated by ant species like *Crematogaster* sp. 2, *Nylanderia scintilla*, *Paltothyreus tarsata*, *Hypoponera dulcis*, *Oecophylla longinoda*, *Monomorium* sp. 1 and *Carebara distincta,* while in the community of forest savanna mosaic region, the species abundance was unevenly distributed with high prevalence of the arboreal ant *Oecophylla longinoda* and *Crematogaster* sp. 14, *Camponotus maculatus*, *Paltothyreus tarsata, Pheidole* sp.6,*Crematogastersolenopsides*, *Monomorium floricola*, *Pheidole excellens*, *Carebara thoracica*, *Pheidole* sp.4. Furthermore, our results on species composition reinforce those obtained on species richness, diversity and abundance between land use type in agroforests of both ecological regions. As predicted with species richness and abundance, our NMDS analysis also demonstrated a difference in ant species composition between the agroforests of the both ecological regions. This finding may highlight the influence of landscape characteristics and ecological conditions on ant community composition in agroforests from the both regions. In fact, it is possible that rainy forest and forest-savanna mosaic regions provide contrasting environmental conditions and thus harbouring distinct ant assemblage. This finding is consistent with others studies conducted on ants in agricultural landscape in Brazil (Carvalho *et al*., 2025). These studies reported that ant diversity is determined at local and landscape scale by ecological drivers which can vary depending on landscape context. He re, we observed two ant communities, one gathering ant species of cocoa orchards and fallows in rainy forest region and a second community gathering ant species of cocoa and rubber orchards and rural forests. A similar observation had been made conducting research on others insect group like moths in temperate forest and grassland (Achury *et al*., 2025). These experiments demonstrated that geographic distance and habitat type had strong influence on moth species turn over. Another possible explanation to the variation in ant species composition could be explained by the change in ant functional group within the communities across the agroforests of each ecological region. This is consistent with Bihn *et al*. (2010) who reported that variation in species composition can affect important ecosystem functions because compositional change means different species plays different roles in ecosystems. This change between the two communities is reflected by the collection of high prevalent species that can be considered as indicator species. They are the species *Crematogaster* sp. 14, *Pheidole* sp.6, *Crematogaster solenopsides*, *Carebara thoracica* and *Pheidole* sp.4 with an important prevalence in the agroforests of the forest-savanna mosaic region. In the rainy forest region these species are *Crematogaster* sp. 2, *Nylanderia scintilla*, *Monomorium* 1, *Hypoponera dulcis*, *Carebara distincta* and *Pheidole* sp. 3. Additionally, we collected *Oecophylla longinoda*, a tree-dwelling dominant ant in high prevalence land-use types of agroforests in forest-savanna mosaic region. This species is known for its predatory activity and is therefore widely used as bio-control agent in tree-crops in Africa (Vayssières *et al*., 2011).

CONCLUSION

Our study of assessing the biodiversity of smallholder agroforests allowed to do a preliminary characterization of ant community within two different agroecological zones in Côte d'Ivoire. The study demonstrated that smallholder agroecosystems harbour a rich community of ant species. More importantly, we demonstrate that ant communities respond differently to land use types in the smallholder agroforests across agroecological zones in Côte d'Ivoire. This corroborates the potential of ants as indicators taxa for monitoring the state of biodiversity in agroecosystems with distinct ecological features. Overall, this study showed that the Weawer ant *Oecophylla longinoda* prevailed in all the ant community and was more abundant in agroforest of forest-savanna mosaic region than rainy forest region. In the light of these observations, and its key role as bio-control agent in tree crops, this ant species could be considered as indicator species. Future research must be conducted to clearly explore the factors that determine the variation of its abundance in agroforest of different ecological regions.

Acknowledgments: The authors are grateful to Yao Koffi Jerome and Kouassi Dorgeles, the owners of the cocoa and rubber orchards. The also thank Koffi François, for it help during the fieldworks.

Conflicts of interest: None declared

Fundings: This study had been partly funded by the World Bank group and African Excellence Center on Climate Change, Biodiversity and Sustainable Agriculture (CEA-CCBAD) of Felix Houphouët Boigny University of Côte d'Ivoire.

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