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Biodiversity, agroecological status and farmers' perception of non-coffee plants species in Robusta Coffee Agrosystems in the Noun Division, West Region of Cameroon

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Abstract

The study aimed to assess the biodiversity, ecological status and farmers' use/perception of non-coffee plants species (NCPS) in contrasting locations, due to the lack of these valuable data regardless of agroecological services and/or environmental conservation. Thus, investigations through the transverse study have been carried out within 17 Robusta coffee plantations, 7 villages and 3 sub-divisions of Noun Division. NCPS were identified using relevant dichotomous keys whereas their recovery rate was estimated via Braun-Blanquet method. Biodiversity of NCPS was estimated using the specific richness and/or diversity indices while their ecological status and farmers' use/perception were determined through Dajoz (1982) modified method and structured questionnaires respectively. In total, 48 NCPS divided into 38 genera and 17 families were inventoried. *Elaeis guineensis* revealed most frequent species, with 30.85% of occurrence while *Albizia adianthifolia, A. glaberrima, Antidesma laciniatum, Citrus medica, C. sinensis, Erythrophleum suaveolens, Ficus mucuso, F. polita, F. umbellata, Macaranga* sp., *Mangifera foetida, Piptadeniastrum africana, Pterocarpus erinaceus, P. milbraedii, Pycnanthus angolensis, Sarcocephalus diderrichii, Sterculia tragacantha, Trilepisium madagascariense* and *Voacanga africana*, were found scarce, with 0.25% of occurrence each. NCPS circumference and recovery rate varied significantly ($p<5\%$) between the studied plots, from 64.75 ± 3.17 to 181.86 ± 43.81 cm and 8% to 100% respectively. Plants abundance and specific richness/diversity also varied between plots, villages and sub-divisions, with respective values of 2 to 44 individuals, 28 to 117 and 91 to 177 (for abundance) versus 0.00 to 3.34, 0.57 to 5.04 and 0.58 to 7.54 (for specific richness/diversity). 66.66% of inventoried NCPS were abundant and 33.34% were extremely rare. According to the respondents, NCPS have different status/functions: 89.47%, 34.21%, 23.68 and 7.89% serve as shade trees, timber, therapeutic purposes/food, and soil enrichment respectively. Our findings revealed the need to take appropriate measures to preserve endangered species for sustainability environmental conservation of the studied agrosystems.

Keywords: Specific richness/diversity, associated perennial trees, Robusta Coffee Agrosystems, environmental conservation, ecosystem services

INTRODUCTION

Originally from Ethiopia and Soudan, Coffee is one of the most major traded commodities worldwide and **its** contributes economically as an important income source of foreign exchanges for farmers and/or the States for about 80 countries in the World (Waller *et al*., 2007; Vega *et al.,* 2015; Asfaw *et al.,* 2019). World Robusta coffee production is estimated to 70 million bags of 60 kg in 2020 and Cameroon ranked fourth in Africa with 280,000 (0.40%) bags of 60 kg, after Ouganda with 5, 65 million (8,07%) bags of 60 kg, Ivory Coast with 1,4 million (2,53%) bags of 60 kg and Democratic Republic of Congo with 300, 000 (0.42%) bags of 60 kg (Anonymous, 2024). Coffee global consumption exceeds 3 billion cups a day (CCI, 2021), and the coffee's value chain i.e. from cultivation to marketing employed approximately 100 million peoples in the World (Bunn *et al*., 2014).

Since several decades, coffee is produced under single monoculture and/or highly complex agroforestry systems worldwide (Jagoret *et al*., 2006; Toledo and Moguel, 2012; Mbarga Manga *et al*., 2013; Cerda *et al*., 2020, Ngomeni *et al*., 2021; 2023). Agroforestry systems are an innovative man-made environment within which crops grow/develop in association with others perennial and/or rearing livestock species (Mbarga Manga *et al*., 2013; Vroh *et al*., 2019; Ngomeni *et al*., 2021; 2023); this new agricultural complex systems provide multiple ecosystem services such as biodiversity conservation, income or vegetational diversification for the well-being of the peoples (Sonwa *et al*., 2007; Kouadio *et al*., 2011; Mbarga Manga *et al*., 2013; Adou Yao *et al*., 2018; Vroh *et al*., 2019; Cerda *et al*., 2020; Essomba *et al*., 2021; Ngomeni *et al*., 2021; 2023). Another agroforestry concept currently used nowadays is the agroecology (FAO, 2021; Jones *et al*., 2022) which known as using ecological tools and principles to optimize interactions between plants, animals, humans and the environment under agricultural system conditions, including the social aspects that need to be addressed for a maintainable and fair food system (FAO, 2021). Regarding the agroecological and economical virtues of agroforestry, these systems needed to (a) be implemented worldwide as an ultimate solution to face challenge towards the agrosystems global change (Madountsap *et al*., 2019; Ngomeni *et al.,* 2023) and (b) investigated on to their biodiversity, the ecological status and farmers' perception or use of associated perennial species such as non-coffee plants encountered in the Robusta coffee plantations in Cameroon for example in order to optimize biodiversity management of these systems (Jones *et al*., 2022; Ngomeni *et al*., 2023).

In several growing area of coffee agrosystems in the World (Toledo and Moguel, 2012; Cerda *et al.,* 2020), and particularly in Cameroon, coffee plantations present a structure that is either simple or highly complex agroforest systems (Cerda *et al.,* 2020; Ngomeni *et al.,* 2023). The perennial species richness and diversity within these agrosystems favor the diversification of products (fruits, timbers, firewood, etc.), and consequently improves income and food security for farmers and other peoples in the producing countries (Rice, 2008; Cerda *et al*., 2020). To increase knowledge of the trade-offs, ecological function or synergistic interactions between the ecosystem services in complex agroforestry systems such as Robusta coffee plantations of Noun Division in the Western Region of Cameroon, is important to investigate the biodiversity of the non-coffee plants species to (1) improve knowledge of the Robusta coffee biodiversity of the studied area, (2) define ecological status of the associated plants species and (3) determine their use or perception by farmers. According to Schroth *et al.* (2004), agroforestry systems, due to its structural complexity and specific richness, maintain a physiognomy significantly close to the original forest biodiversity.

In Cameroon, studies on Robusta coffee agrosystems (RCAs) are fragmentary and/or poorly documented; data recorded were focused only on the biodiversity assessment and/or structural organization of RCAs at the level of study sites in some specific growing area (Mbarga Manga *et al*., 2013; Temgoua *et al*., 2020; Ngomeni *et al*., 2023). Therefore, biodiversity data of associated non-coffee plants species (NCPS) are required at large scale throughout the great producing basins as well as their ecological status and use or perception according to farmers for sustainable management and/or conservation of the biodiversity in the Noun Division. The aim of this work was to determine the biodiversity of NCPS at the Level of plots, villages and subdivisions as well as their ecological status and farmers' use or perception. We hypothesize that the biodiversity of NCPS varies between the level of study (plots, Villages and Subdivisions) and their ecological status and farmers' use or perception differs between the species.

MATERIALS AND METHODS

Study area

The study was carried out, from December 2022 to March 2023, within 17 Robusta coffee plantations located in 7 Villages (Ngounso, Manoueri, Kourap, Matoupou, Malam, Manfu and Mambouo) and 3 Subdivisions: Foumban

(5°43'N; 10°55'E; 980 m a.s.l.), Magba (11°57'N; 11°13'E; ≈ 738 m a.s.l.) and Malantouen (5°48'N; 11°57'E; ≈ 711 m a.s.l.) of Noun Division, West Region of Cameroon (Figure 1).

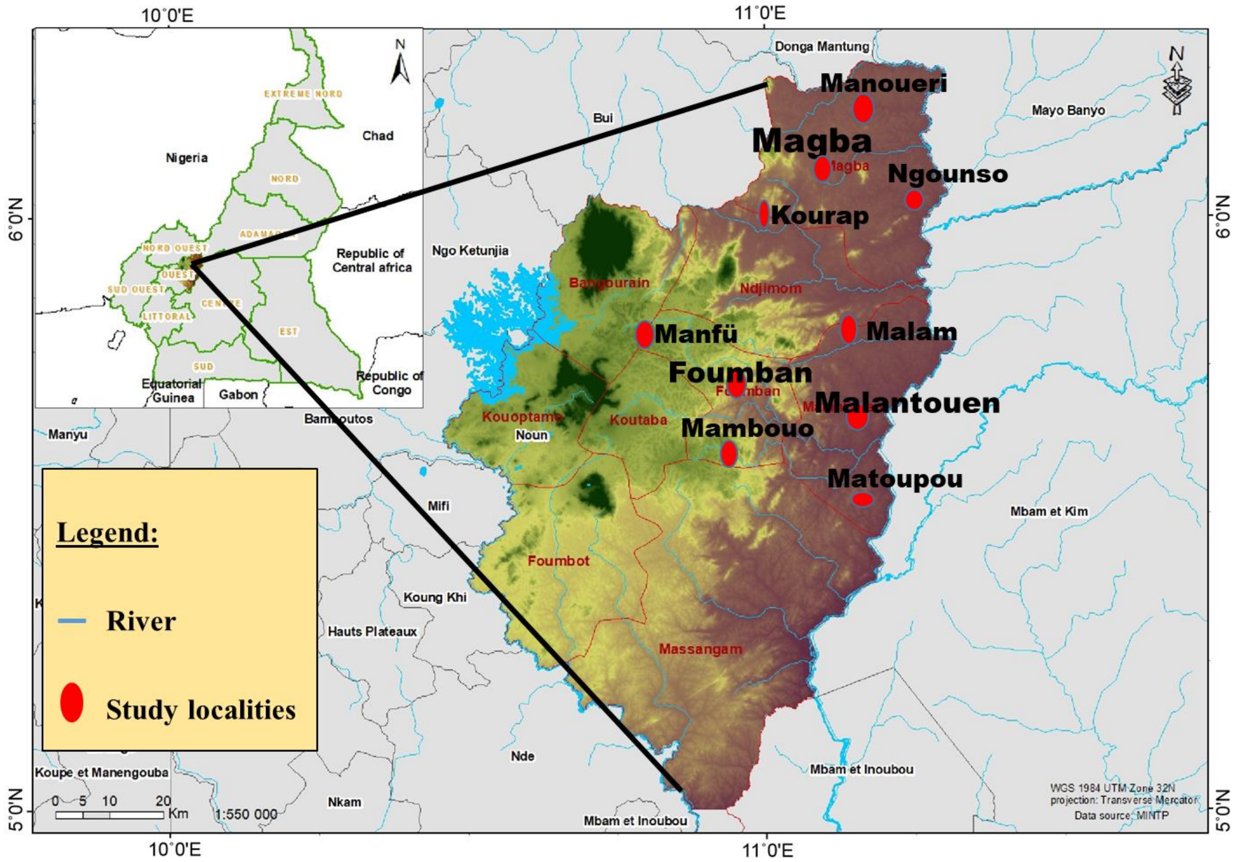

Figure 1: Geographical location of the study area

The study area is 7,787 km² of size, belonging to the great coffee production basin in Cameroon and characterized by Cameroonian altitude climate with two seasons: one rainy (from April to September) and one dry (from November to March) (Suchel, 1987; Onana, 2018; Fon *et al*., 2020). Agricultural activities and practices, fauna and flora composition, orographical and pedological data of the study zone have been widely reported in the literature (Letouzey, 1985; Onana, 2018; Fon *et al*., 2020; Kenfack *et al*., 2022).

MATERIALS AND METHODS

Description of the selected coffee plantations

In our study area, coffee and associated NCPS growth under complex multistrata systems and/or shaded conditions also known as agroforestry systems (Ngomeni *et al*., 2021; 2023). In this agrosystem, coffee trees were planted with local material (coffee plants) and/or IRAD-Research Station ones, without respect of the agronomic recommendations concerning trees spacing within and between the rows (2.5 x 3 m or 2.5 x 2 m for approximately 1,300 and 2,000 coffee trees respectively) per hectare (Anonymous, 2002). The area size of the selected Robusta coffee plantations was varied from 1 to 4 hectare(s) (Table 1), using the Garmin Global Positioning system (GPS).

Experimental plots design and sampling procedure

In each plot, an area size of 3600 m² (60 m x 60 m) was delimited using a Suunto Compass and double decameter inside each selected plantation to avoid border effects, following Jagoret (2011) and Jagoret *et al.* (2011) modified methods. A systematical sampling of all non-coffee plants species present in the experimental unit was done in the 17 studied plots. Organs/tissues of associated coffee trees unidentified in situ in plantations were preserved into a plastic bag (60 cm x 40 cm) and transported to the National Herbarium of Cameroon (HNC) and/or Botanic Laboratory of the Faculty of Science of the University of Yaounde I (BLFSUY) for taxonomic identification. The number of plots per village and/or subdivision as well as the geographical coordinates and agroecological characteristics of each plot in the study area were presented in Table 1.

Table 1: Agroecological, geographical coordinates and management characteristics of the selected plots

Variables	**Subdivisions and villages**																
	Magba							**Malantouen**						**Foumban**			
	Ngounso			**Manoueri**		**Kourap**		**Matoupou**			**Malam**			**Manfü**		**Mambouo**	
	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**P11**	**P12**	**P13**	**P14**	**P15**	**P16**	**P17**
Geographical coordinates	0736 362 N 0651 529 E	0744 090 N 0654 (485) E	0744 090 N 0654 498 E	0744 603 N 0652 151 E	0744 747 N 0652 030 E	0741 996 N 0665 350 E	0742 825 N 0664 971 E	0737 368 N 0629 555 E	0737 668 N 0630 165 E	0737 608 N 0619 752 E	0736 961 N 0630 061 E	0737 370 N 0629 736 E	0736 974 N 0629 113 E	0708 638 N 0624 302 E	0708 071 N 0625 365 E	0712 877 N 0626 490 E	0712 196 N 0626 410 E
Altitude (m)	733	730	726	728	716	750	736	719	717	709	703	715	707	1090	1107	869	870
Approximately area (ha)	1	1	1	4	4	2	2,5	1	2	1,5	2	3	1,5	3	1,5	1	4
Weeding(s) number per year	1	1	1	2	1	1	2	1	1	2	2	1	1	2	2	1	1
Environment	Savannah, young and secondary forests							Shrubby savannah			communal and reserve forests						

Pi: studied plots number

NCPS associated with Robusta coffee trees in each sample unit were identified *in situ* in the studied plot or in botanic Laboratory of HNC and/or BLFSUY by a Botanist Expert, using endogenous knowledge and relevant dichotomous identification keys (Keller, 1992; Puig *et al.*, 2003; Meunier *et al.*, 2015; Onana and Mezili, 2018)

Assessment of the biodiversity of NCPS

The biodiversity of NCPS was assessed at the plots, villages and Subdivisions scale using the specific richness indices of Margalef and Menhinick (Peet, 1974), specific diversity indices of Shannon and Simpson and equitability/similarity index of Sorensen (Washinghton, 1984; Krebs, 1985). The abundance-dominance index also known as recovery rate (Rr) was estimated using Braun-Blanquet modified method (Braun-Blanquet, 1964); then when Rr < 25%, the abundance-dominance is low, 25% ≤ Rr ≤ 50%, is high and Rr > 50% is higher. All calculations were computed with the help of PAST software (version 3.1).

Agroecological status of NCPS and their use/perception by farmers

The agroecological status of NCPS was determined using the modified method of Dajoz (1982 and 2006). Then, the occurrence in percentage (Oc) for a given species in the inventoried community was used to reach that goal according to the following classification: Oc > 50% the species is considering as very abundant; 25% ≤ Oc ≤ 50% the species is considering as abundant; 1% ≤ Oc < 25% the species is considering as little abundant and Oc < 1% the species is considering as scarce.

We determined farmers' use or perception of NCPS through an individual structured questionnaire near the farmers of selected experimental plots (Fon *et al.*, 2020); the questions focused mainly on the farmer's social use or perception of the NCPS and their on-farms origin.

Data analysis

Data of the diameter (in cm) of NCPS were used to compute their average circumference per study plot. After the logarithmic transformation [Log(x+1)] for normality reasons, the one-way analysis of variance (ANOVA) was used via the Generalized Linear Model (GLM) to compare the means of the non-coffee trees in the different study plots. When the model found the difference between the multiple comparisons of means, we used the Tukey's post hoc test for pairwise comparisons of means. Similarity of the associated non-coffee plants species between plots, villages and Subdivision was performed using the Cluster's, with the occurrences of each associated tree species (as column individuals) and in each study plot, village and Subdivision (as row individuals). All statistical analyzes were performed with the STATISTICA (version 10) and PAST (version 3.1); the differences were deemed to be significant at $p<5\%$.

RESULTS

Biodiversity of NCPS and their use/perception by farmers in the study area

The studied plots showed high NCPS biodiversity, with a total of 48 species inventoried belonging to 38 genera and 17 families (Table 2). *Elaeis guineensis* was the most frequent species with 30.85% of occurrence while *Albizia adianthifolia, Albizia glaberrima, Antidesma laciniatum, Citrus medica, Citrus sinensis, Erythrophleum suaveolens, Ficus mucuso, Ficus polita, Ficus umbellata, Macaranga* sp, *Mangifera foetida, Piptadeniastrum africana, Pterocarpus erinaceus, Pterocarpus milbraedii, Pycnanthus angolensis, Sarcocephalus diderrichii, Sterculia tragacantha, Trilepisium madagascariense* and *Voacanga africana,* were the least frequent ones, with a respective occurrence of 0.25%. The others 28 taxa showed intermediate values of occurrences. However, according to the respondents, associated NCPS have varied status/functions: 89.47%,34.21%, 23.68% and 7.89% serve as shade trees, timber, therapeutic purposes/food, and soil enrichment respectively (Table 2).

Table 2: **Biodiversity of NCPS inventoried and their use/perception by farmers in the studied area**

Plant species	Family	Occurrences (%)	Use/perception Code
Elaeis guineensis	Arecaceae	30.85	a ; d
Albizia zygia	Leguminoseae	12.69	a ; b
Terminalia glaucescens	Combretaceae	7.96	a ; d
Parkia clappertoniana	Leguminoseae	6.22	a
Dacryodes edulis	Burseraceae	5.97	a ; d
Milicia excelsa	Moraceae	3.73	a ; b
Parkia sp.1	Leguminoseae	3.73	a ; b ; c
Parkia sp.2	Leguminoseae	3.23	a ; b ; c
Persea americana	Lauraceae	3.23	a ; d
Lannea welwitschii	Anacardiaceae	2.24	a
Afzelia bipindensis	Leguminoseae	1.74	a ; b
Lannea schimperi	Anacardiaceae	1.24	a ; c
Lannea sp.	Anacardiaceae	1.24	a
Senna pinnata	Leguminoseae	1.24	a
Allophylus sp.	Sapindaceae	1.00	a ; c
Piliostigma thonningii	Leguminoseae	1.00	a

Piptadeniastrum africanum	Leguminoseae	1.00	a ; b
Canarium schweinfurthii	Burseraceae	0.75	a ; d
Pterygota oblonga	Malvaceae	0.75	a
Vitex doniana	Lamiaceae	0.75	a ; c
Ceiba pentantra	Malvaceae	0.50	a ; b
Cola nitida	Malvaceae	0.50	a ; d
Ficus exasperata	Moraceae	0.50	a ; d
Ficus sp.1	Moraceae	0.50	a ; e
Ficus sp.2	Moraceae	0.50	a ; e
Myrianthus arboreus	Urticaceae	0.50	a
Persea clappertoniana	Leguminoseae	0.50	a
Sterculia rhinopetala	Malvaceae	0.50	a
Terminalia superba	Combretaceae	0.50	a ; b
Albizia adianthifolia	Leguminoseae	0.25	a
Albizia glaberrima	Leguminoseae	0.25	a
Antidesma laciniatum	Phyllanthaceae	0.25	c
Citrus medica	Rutaceae	0.25	c ; d
Citrus sinensis	Rutaceae	0.25	c
Erythrophleum suaveolens	Leguminoseae	0.25	a ; b
Ficus mucuso	Moraceae	0.25	a ; e
Ficus polita	Moraceae	0.25	a
Ficus umbellata	Moraceae	0.25	a
Macaranga sp.	Euphorbiaceae	0.25	a
Mangifera foetida	Anacardiaceae	0,25	a ; d
Piptadeniastrum africana	Leguminoseae	0.25	a ; b
Pterocarpus erinaceus	Leguminoseae	0.25	a
Pterocarpus milbraedii	Leguminoseae	0.25	a ; b
Pycnanthus angolensis	Myristicaceae	0.25	a ; b
Sarcocephalus diderrichii	Rubiaceae	0.25	a ; b
Sterculia tragacantha	Malvaceae	0.25	a
Trilepisium madagascariense	Moraceae	0.25	a
Voacanga africana	Apocynaceae	0.25	c

Legend: Use/perception of NCPS: a= shade; b= Timber, c= medicine; d= food; e= soil

Evaluation of the circumference (in cm) of NCPS in the studied plots

Means value of the circumference of the associated non-coffee trees in the study area varied between the studied plots, and ranged from 64.75 ± 3.17 cm (plot 5) to 181.86 ± 43.81 cm (plot 2) (Table 3). ANOVA classified mean diameter values of the non-coffee plants species into five homogeneous groups; there is significant ($F_{(16,400)} = 8.69$; $p < 0.001$) difference between Plot 5 and plots 1, 2, 6, 8, 9, 10, 11, 12, 13, 14 and 16; the five other plots showed comparable means circumference (Table 3).

Table 3: Comparisons of the average circumference (± ES in cm) of NCPS between the selected plots

Plots	Average circumference of NCPS (± ES in cm)
P5	64.75 ± 3.17[a]
P4	71.45 ± 5.53[ab]
P3	87.88 ± 13.25[abc]
P17	94.77 ± 8.14[abc]
P15	103.90 ± 9.34[abcd]
P11	112.38 ± 5.70[bcd]
P16	121.8 ± 14.71 [bcde]
P14	131.39 ± 20.09[bcde]
P7	137.55 ± 24.23[abcde]
P10	138.06 ± 23.42 [bcde]
P13	138.50 ± 19.38[bcde]
P8	147.29 ± 14.84[cde]
P9	149.96 ± 8.38[cde]
P1	169.54± 20.64 [cde]
P12	169.84 ± 12.38 [de]
P6	178.28 ± 21.82[de]
P2	181.86 ± 43.81[e]

In column two, values with the same letters are statistically comparable, according to ANOVA test.

Assessment of the specific richness and diversity of the NCPS in the study area:

At the plots scale

From our investigation, abundances, specific richness and/or diversity of NCPS varied between the study plots (Table 4). With 44 individuals and 12 species, plot 5 was the most diversify in terms of abundance and specific richness, while plots 9 and 13 showed less abundance (2 individuals) and biodiversity (1 species) respectively (Table 4). Ecological indices values of Specific richness and diversity were ranged from 0.00 for plot 13 (less diversified) to respectively 3.34 and 2.16 for plot 6 (most diversified). Compared with plots 3, 4, 5, 6, 8, 10, 12 and 17, which showed low recovery rate ($Rr < 25\%$), plots 1, 2, 7, 9, 15 and 16 showed a high Rr (i.e. $25 \leq Rr \leq 50\%$), whereas plots 11, 13 and 14 presented higher Rr (i.e. $Rr > 50\%$). However, a clear degree of Equitability ($Is > 50\%$) was observed in the specific composition of the associated trees community in the studied plots (Table 4).

Table 4: Biodiversity comparison of the NCPS between the studied plots

Variables	Studied plots

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17
Species_S	5	4	7	10	12	11	5	6	2	8	2	7	1	2	3	4	7
Individuals	14	15	15	34	44	20	9	8	2	19	5	13	5	15	14	11	31
Dominance_D (x 100)	0.39	0.49	0.20	0.16	0.26	0.15	0.36	0.19	0.50	0.16	0.68	0.22	1.00	0.61	0.50	0.39	0.20
Simpson_1-D	0.61	0.51	0.80	0.84	0.74	0.85	0.64	0.81	0.50	0.84	0.32	0.78	0.00	0.39	0.50	0.61	0.80
Shannon_H	1.22	0.95	1.77	2.02	1.82	2.16	1.30	1.73	0.69	1.93	0.50	1.73	0.00	0.58	0.83	1.12	1.75
Menhinick	1.34	1.03	1.81	1.72	1.81	2.46	1.67	2.12	1.41	1.84	0.89	1.94	0.45	0.52	0.80	1.21	1.26
Margalef	1.52	1.11	2.22	2.55	2.91	3.34	1.82	2.40	1.44	2.38	0.62	2.34	0.00	0.37	0.76	1.25	1.75
Equitability_Is (x 100)	0.76	0.69	0.91	0.88	0.73	0.90	0.81	0.97	1.00	0.93	0.72	0.89	0.00	0.84	0.76	0.81	0.90

P_i = number of studied plots

At the villages scale

NCPS abundance and biodiversity also varied between the Robusta coffee plantations in the 7 study villages. Plantations of village Ngounso showed a high abundance (117 individuals) and specific richness (25 species), while those of Manoueri and Mambouo showed low values of abundance (28 individuals) and specific richness (6 species) respectively (Table 5). Ecological indices values of specific diverstity were ranged from 0.57 for Matoupou (less diversified) to 2.66 for Manoueri (most diversified), whereas those of specific richness ranged from 0.97 for Mambouo (less diversified) to 5.04 for Ngounso (most diversified). The recovery rate (Rr) of NCPS was lower (Rr < 25%) in Robusta coffee farms of Koufen, Manoueri and Ngounso villages, and higher (25 ≤ Rr ≤ 50%) within those of Kourap, Malam, Mambouo and Matoupou ones. Our results also showed a clear degree of Equitability (Is > 50%) in the specific composition of the community of NCPS in the study villages (Table 5).

Table 5: Biodiversity comparison of NCPS between the studied villages

Variables	Koufen	Kourap	Malam	Mambouo	Manoueri	Matoupou	Ngounso
Species_S	9	8	13	6	17	11	25
Individuals	57	30	76	38	28	76	117
Dominance_D (x 100)	0.20	0.33	0.40	0.33	0.08	0.43	0.12
Simpson_1-D	0.80	0.67	0.60	0.67	0.92	0.57	0.88
Shannon_H	1.82	1.41	1.54	1.41	2.66	1.39	2.65
Menhinick	1.19	1.46	1.49	0.97	3.21	1.26	2.31
Margalef	1.98	2.06	2.77	1.38	4.80	2.31	5.04
Equitability_Is (x 100)	0.83	0.68	0.60	0.79	0.94	0.58	0.82

And at the subdivision scale

Our results showed the variability of the abundance and specific richness/diversity of NCPS in Robusta coffee plantations in the three study subdivisions (Table 6).

Table 6: Biodiversity Comparison of NCPS between the studied subdivisions S

Variables	Foumban	Magba	Malantouen
Species_S	10	40	17
Individuals	91	177	152
Dominance_D (x 100)	0.21	0.09'	0.41
Simpson_1-D	0.78	0.91	0.58
Shannon_H	1.76	2.91	1.56
Menhinick	1.05	3.01	1.38
Margalef	1.99	7.54	3.18
Equitability_Is (x 100)	0.76	0.79	0.55

Compared with plantations of Foumban and Malantouen subdivisions, those of Magba presented highest biodiversity, with 117 individuals and 40 species inventoried, followed by Malantouen (17 individuals and 152 species), and then Foumban (10 individuals and 91 species). Ecological indices values of specific diversity ranged from 0.58 for Malantouen to 2.91 for Magba, while those of specific richness varied from 1.05 for Foumban to 7.54 for Magba. The recovery rate of NCPS was lower at Foumban and Magba (Rr < 25%), and higher at Malantouen (25 ≤ Rr ≤ 50%). The highest Specific richness and diversity at Magba than Foumban and Malantouen subdivisions was clearly confirmed by Simpson/Shannon and Margalef/Mehenick indices. The results also showed strong degree of similarity/ Equitability (Is > 50%) in the community of NCPS in the coffee plantations of the three study subdivisions (Table 6).

Estimation of the degree of similarity of NCPS in the study area

Cluster analysis divided the NCPS into four homogeneous subsets at plots scale (figure 2), three homogeneous subsets at villages scale (figure 3) and two homogeneous ones at subdivisions scale (figure 4); within which there were also close similarity of NCPS by pairs due to the different

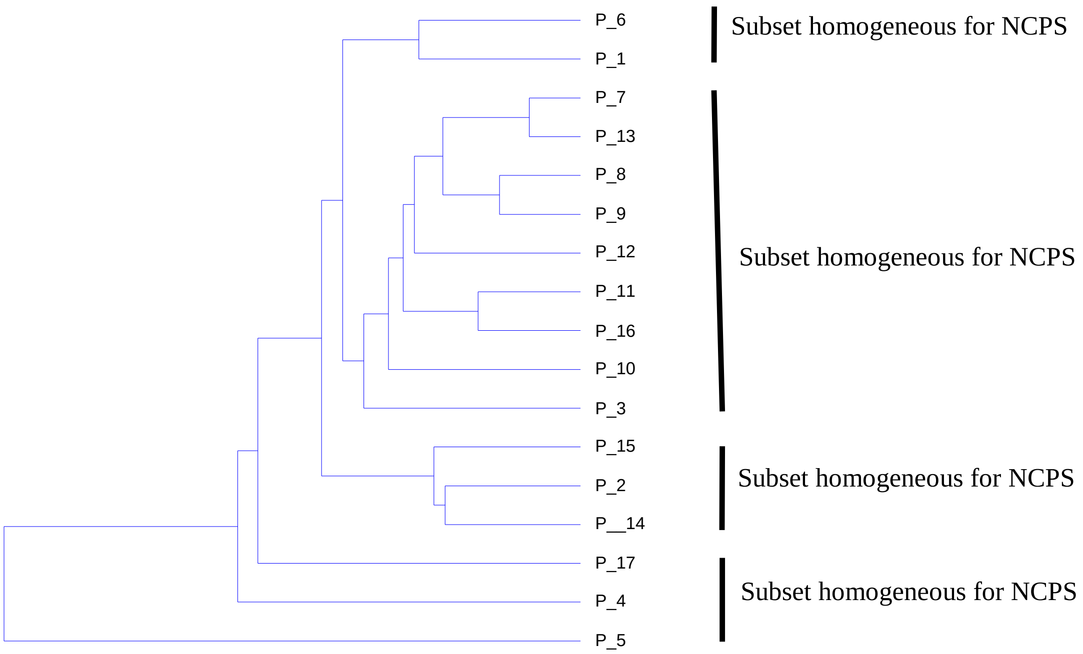

Figure 2: Dendrogram showing the distribution of plots according to their similarity in terms of NCPS

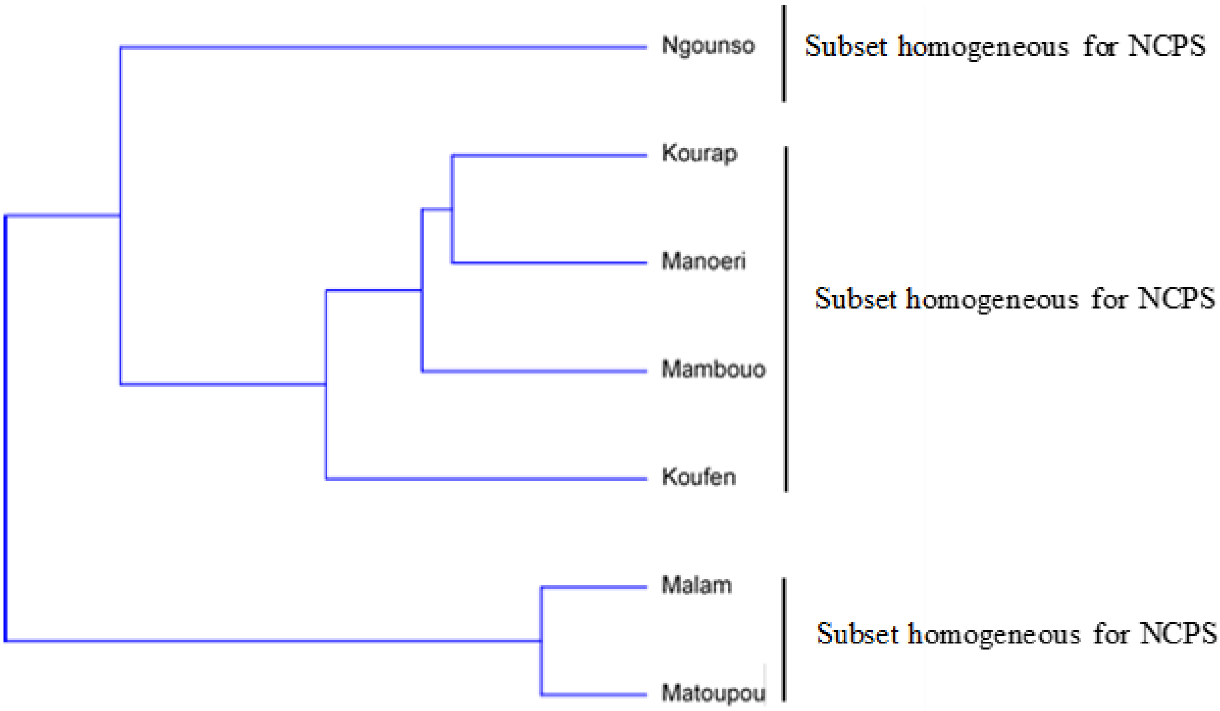

Figure 3: Dendrogram showing the distribution of villages according to their similarity in terms of NCPS

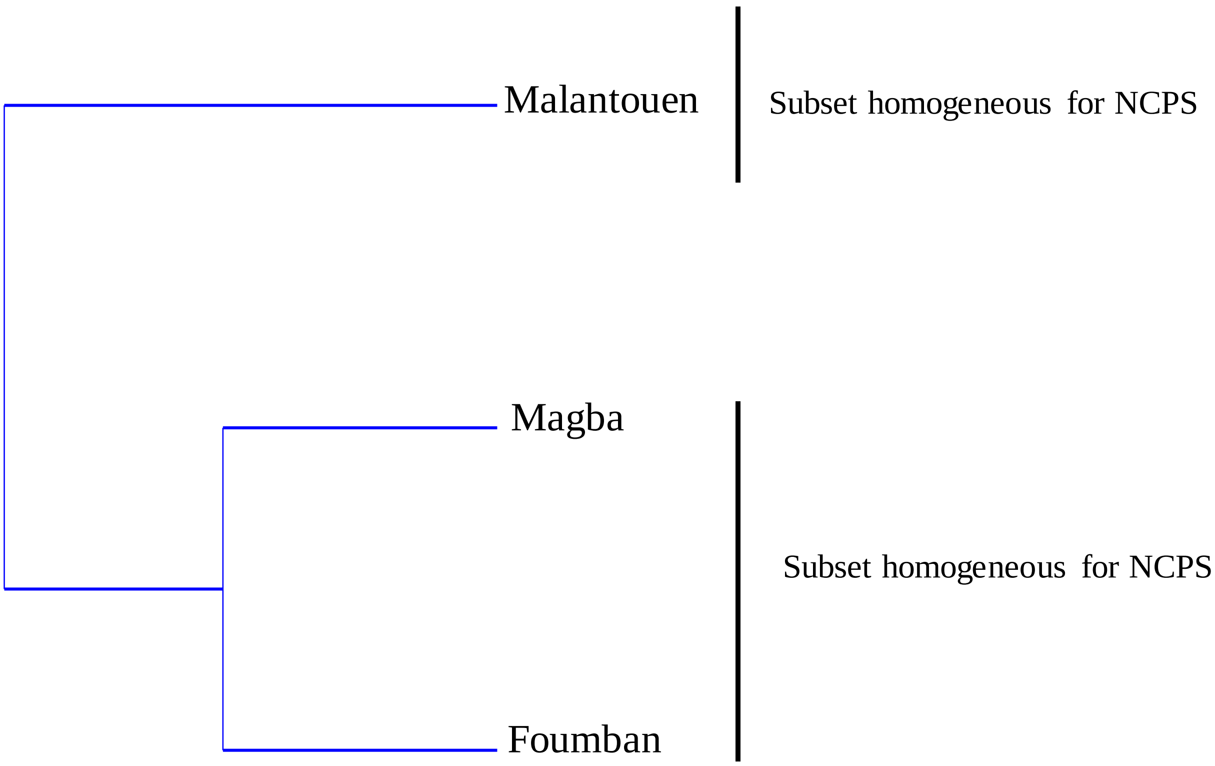

Figure 4 : Dendrogram showing the distribution of subdivisions according to their similarity in terms of NCPS

Determination of the ecological status of NCPS in the study area

The ecological status of NCPS inventoried revealed that only one taxon *Elaeis guineensi* is abundant, 25%≤ 0c ≤ 50%, in the selected plantations of the study area, while 15 species: *Albizia zygia, Terminalia glaucescens, Parkia clappertoniana, Dacryodes edulis,* Milicia *excelsa, Parkia* spp. *Persea americana, Lannea welwitschii, Afzelia bipindensis, Lannea schimperi, Lannea* sp., *Senna pinnata, Allophylus* sp., *Piliostigma thonningii* and *Piptadeniastrum africanum*,1%≤ 0c ≤ 25%, were little abundant and 32 other NCPS recorded in our investigation were scarce, Oc < 1% (Table 2).

DISCUSSION

The main objectives of this study were to determine the biodiversity of NCPS as well as their ecological status and/or farmers' social use or perception in Robusta coffee plantations in Noun Division, Western Region of Cameroon, using the taxonomist (botanist) expert, ecological indices and structured questionnaire close to farmers. From our study, 48 NCPS belonging to 38 genera and 17 families were inventoried. Our findings clearly showed that agrisilviculture also kown as silvoarable, defined as trees intercropped with annual and/or perennial crops on a land management unit, taking place in our study area; confirming the hypothesis that coffee and/or cocoa farms were mainly established following the agroforestry systems models in Africa, and particularly in Cameroon (Jagoret *et al.*, 2006; Sonwa *et al.*, 2007; Brown *et al.*, 2018; Vroh *et al.*, 2019; Cerda *et al.*, 2020; Ngomeni *et al.*, 2021; 2023; Ndo *et al.*, 2023). The statistics obtained in our investigation, in terms of on-farms associated plant species (APS) biodiversity, were lowest compared to those obtained in Cameroon within the (1) Robusta coffee plantations by Ngomeni *et al.* (2023): 102 NCPS belonging to 83 genera and 41 families and, (2) cocoa based-agroforestry systems by

Sonwa *et al.* (2007): 206 APS set out into 17 genera and 13 families, and Essomba *et al.* (2021): 78 APS, 73 genera and 30 families. This numerical gap of APS between the different studies could be explained by the heterogeneity (a) of the experimental conditions/study environment or/and targeted crops on the one hand, and (b) farms management by farmers. According to ecological indices analyses, the specific richness/diversity varied between the studied plots, villages and subdivisions; the highest biodiversity of NCPS were overall obtained in two plots (namely P5 and P6), 02 villages (Manoueri and Ngounso) and 01 subdivision (Magba). This situation was explained by, as we previously said, the differential management of coffee plantations by farmers and/or the diversity awareness of farmers of the study area regardless the ecosystem services/socio-economic use of NCPS. Indeed, it is known nowadays that monoculture strongly exposed crops such as Robusta coffee ones to pests and diseases infestations/infections, with potential high economic losses for farmers, while the vegetational diversification improve fields pests and disease control or damage towards the host plant (Radnadass *et al*., 2012; 2021); beside this scenario, we also have the international market fluctuation of the coffee prices which always reduce more farmer's incomes (Ngomeni *et al.,* 2023). Then, since several decades, agroforestry systems as the based-coffee ones are widely spread because they provided food security, income diversification, environment preservation, and increase soil fertility and socio-economic benefits of farmers (Cerda *et al.,* 2014; Somarriba *et al.,* 2014; Mbolo *et al.,* 2016; Leakey, 2017; Ngomeni *et al.,* 2021; 2023; Ndo *et al.,* 2023). Thus, the farmer who has adopted agroforestry systems model will diversify his farm with several plant species (known as agrisilviculture/ silvoarable according to Brown *et al.*, 2018) compared to the one who does not adhere or only slightly to agroforestry model; therefore, justifying the variation in the biodiversity of NCPS observed in our study at the scale of plots, villages and subdivisions. Our results support findings of Ngomeni *et al.* (2023) and Sonwa *et al.* (2007) and Essomba *et al.* (2021) in Cameroon, which reported the heterogeneity in the distribution frequencies of the APS within the highest generating cash crops such as coffee and cocoa-based agroforestry systems respectively. However, the ecological indices obtained in our findings varied between the study sites and differ numerically from those recorded (a) in Robusta coffee plantations by Ngomeni *et al.* (2023) in Littoral, Centre and West Regions of Cameroon, either 1.45 to 3.03 for Shannon index; 0.67 to 0.88 for Simpson index and 0.41 to 0.71 for equitability index, (b) in cocoa plantation by Sonwa *et al.* (2007), either 3.10 to 4.20 for Shannon index, 0.07 to 0.18 for Simpson index and 0.60 to 0.75 for equitability index in Southern Region of Cameroon, and by Essomba *et al.* (2021), either 0.96 to 2.58 for Shannon index, 0.0006 to 0.004 for Simpson index and 0.16 to 0.44 for equitability index in East Region of Cameroon. Difference of ecological indices between the different studies was a reflection of the heterogeneity of APS across coffee/cocoa based-agroforestry in Cameroon; in fact the highest diversity of structure and/or composition of associated trees within cocoa/coffee based-agroforestry systems is widely documented (Sonwa *et al*., 2007; Gidoin, 2013 ; Mbarga Manga *et al*., 2013; Jagoret *et al*., 2014; Akoutou Mvondo *et al*., 2019; Manga Essouma *et al*., 2020; Temgoua *et al*., 2020; Mvondo *et al*., 2022; Ngomeni *et al*., 2023). In addition, it is known that the presence of an APS in a given crop depends on its use value in the study zone (Jagoret *et al*., 2014); this is what likely justifies the biodiversity variability of integrated plant species in plantations between the different study sites in Cameroon.

From our findings, the biodiversity of NCPS was highest at Magba than Foumban and Malentouen. This biodiversity difference of NCPS between the studied locations could be explained by the low anthropisation and/or the use value of NCPS in Magba compared to both other localities. Indeed, according to the data collected from questionnaire respondents, Foumban and Malentouen populations are geographically closely, urban, and composed mainly of Bamouns' people who have many sources of income, including agriculture ones. Conversely, Magba populations are indigenous, and composed mainly of Tikars' people which essentially live from agriculture or natural resources of their environment, and therefore preserve more their ecosystems in terms of plants in general and NCPS in particular for multiple ecosystem services to human welfare such as: medicine, economic income, food, firewood, soil enrichment, etc.

In our study, average circumference of NCPS significantly varied between the studied plots. This situation would be linked to the specific intrinsic characteristics of each NCPS in the selected Robusta coffee and/or to the environmental conditions/ecological factors that occurs on the studied plots; our results confirm those made by Ngomeni *et al.* (2023) in different growing coffee area in Cameroon.

The ecological status of NCPS clearly showed that only one taxon *Elaeis guineensis* up to 48 inventoried is abundant, 25%≤ 0c ≤ 50%, while 16 species 1%≤ 0c ≤ 25%, and 31 Oc < 1%, were respectively little abundant and rare (Table 2). Consequently, based on results of our study, we can predict that *E. guineensis* is more beneficial from a socio-economic point of view to the populations than others NCPS recorded in the plantations of our study area. Indeed, the data collected through the questionnaire from respondents indicates that, the on-farms predominance of palm tree (*E. guineensis*), compared to the others NCPS, because it contributes more directly and daily to the well-being of the studied populations via its multiple services such as: food, medicine, economic income, drink, etc. However, others NCPS recorded in our study, particularly rare species, deserved singular attention related to their protection for reasons of preservation of the environment and/or the biodiversity in the study area.

CONCLUSION

The current study shows that the Robusta coffee plantations in Noun Division are widely diversified, with a total of 48 NCPS inventoried in the studied plots. The biodiversity of NCPS varies between plots, villages and subdivision of the study area. *Elaeis guineensis* is the most dominant species due to their socio-economic impact on the welfare of the populations of the study localities, whereas the others NCPS are little dominant or rare; this result suggests that NCPS within Robusta coffee farms with both latter ecological status, especially rare species, should be protected for the preservation of the environment/biodiversity and its multiple ecosystem services for the populations of the study zone. However, NCPS plays several roles according to the farmers such as shade, timber, medicine, food and soil enrichment; the data of NCPS related to the (a) ecosystem services needed to be taking into consideration in the management of the coffee-based agroforestry systems on the one hand, and (b) ecological status raises to take appropriate measures to preserve endangered species for sustainability environmental conservation of the studied agrosystems on the other hand.

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COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interest: All authors agree that the article be published for the benefit of the scientific community and other actors in the coffee sector.

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