Chapter

Farmer's Perception of Associates Non-Cocoa Tree's Leaf Litterfall Fertilizing Potential in Cocoa-Based Agroforestry System

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Abstract

Investigations to assess farmer's perceptions on the fertilizing potential of associated trees species in cocoa agroforest of degraded forest ecology were carried out in southern Cameroon. The perception of the farmers was based on the ability of the trees to maintain or improve soil fertility of their farms. The verification of these perceptions was done through an evaluation of litter fall biomass nutrient content (N, P, K, Ca and Mg) of selected trees. The top 5 associates trees ranked by farmers was: *Milicia excelsa, Ceiba pentandra, Ficus mucuso, Asltonia boonei, Terminalia superba*. The chemical analysis of the leaf litter from the different tree species revealed a significant different between their chemical components. N appeared to have the highest concentrations varying from 2.82 to 5.57% with a mean value of 4.25 ± 1.065%, P had the lowest concentrations typically around 0.001%. The top 5 tree species based on the chemical analysis ranking were: *C. pentandra*, *M. excelsa*, *Eribroma oblungum*, *Alstonia boonei*, *Zanthoxylum heitzi*. Farmer's perceptions thou holistic, are not completely different from scientific finding. Therefore, they should be taken in consideration in management plans for cocoa- based systems in order to enhance their ecological and economic performance.

Keywords: Farmer's perception, associated trees, fertilizing potential, Cocoa, Agroforestry

1. Introduction

The cocoa tree (*Theobroma cacao* L.) belongs to the Malvaceae family and is native to the tropical rain forests of Central and South America [1]. The Germans first introduced cocoa in Africa through Ghana in 1857 and in Cameroon precisely through Victoria (Limbe) in 1886 [2]. The nutritional and pharmaceutical importance of cocoa makes it one of the main export products for certain tropical countries. In Cameroon, and particularly in the center region, Cocoa is still grown in the traditional Agroforestry way with the shade of some forests, fruits trees and oil palms [3–5]. These systems have been widely described in relation to the environmental and ecosystem services they provide, but much less regarding productivity related to their structure [4, 6, 7].

Soil fertility under tropics is mainly influenced by biological interactions, and trees are the main driver of these, as they provide the rough material to achieve these [8]. Bellow and above grounds interactions significantly influence the status of soil health through their rooting habit, but also through the decomposition and mineralization of the litter fall. Several studies have demonstrated that the reduction of nutrient and organic matter content in the soil is a serious threat for agricultural production and food security in many tropical countries [9, 10]. Research has been involved in this theme to understand the mechanisms of conservation and improvement of soil fertility by trees. Numerous studies have identified links between traditional knowledge of trees associated with cocoa agroforest and soil health (fertility), although some processes are difficult to codify [8, 11, 12].

Although not always recognized by agronomists, trees in cocoa-based agroforests have more uses for local farmers than just providing a suitable microclimate for cocoa trees [3, 8]. Some indigenous species are maintained in the system by local farmers for their fertilizing capacities through nutrient recycling. Such tree species most mentioned as positively influencing fertility of soils and/or having other desirable attributes in traditional land used as described by [8, 11] include species such as *Ceiba pentandra* described to have floral and leaf litter fall that improves soil upon decomposition in rainy season, gathers dew in the dry season and prevents soil from drying, woody parts decompose rapidly and add to fertility, soil around always wet; *Milicia excelsa* described to provides good shade, improve microclimate, leaf litter improve soil conditions, deep rooting habit, abundant leaf litter and high leaf litter decomposition rate and soil fertility value; *Alstonia boonei* have *a* deep rooting habit, tall tree, wide and open crown, intermediate leaf area, abundant leaf litter with high decomposition rate, provides good shade and maintains soil moisture, gathers dew/exudes water, fertility value; *Ficus mucuso and Ficus exasperate* described to possess deep rooting habit, tall tree, wide and open crown, big leaf area with high leaf litter decomposition rate, high fertility value etc. Yet, little information is available on the contribution of these species leaf litter nutrient to the productivity of soils under cocoa fields. It is therefore hypothesized that trees species in cocoa-based agroforests play a major role in the improvement of soil conditions, hence the productivity of the entire system.

Appropriate tree species selection based on nutrient cycling is a vital issue in agroforestry practices [13]. So far, the screening or prioritization of commonly present indigenous trees species of cocoa-based agroforestry systems (CBAFS) is based on ethnoecological and ethnopedological studies [11, 12] but a scientific approach was carried base on the rate of mychorrizal colonization of the roots of some of these indigenous tree species. The results established a positive correlation between local farmer's classification of ten indigenous tree species with high fertility potential, and the colonization of the roots of those by mychorrizal [11]. However, no or little attempt has been taken to assess the fertility potential of these trees in term of their nutrient content present in their leaf litterfall, hence the need for this study.

This study, therefore, aims to investigates farmer's perceptions and knowledge on the fertilizing potential of the leaf litterfall of the non – cocoa tree associated to cocoa in CBAFS. If the pertinence of the perceptions is established, such measures could be introduced in management plans for cocoa- based systems in order to enhance their ecological and economic performance.

2. Methodology

2.1 Study site

This multiscale study encompassed the village area, the household and farming unit, the cocoa farm and homogeneous cocoa plantations. The study was conducted in the Centre Region, i.e., in the Evodoula subdivision (Latitude: 4° 04′ 60.00“ N Longitude: 11° 11’ 60.00” E) (**Figure 1**). Located in one of the oldest cocoa producing basin in a degraded forest zone, the Evodoula village (≈76 Pop/km^2) is characterized by a high land use intensity.

The climate is hot and humid with average temperatures and relative humidity of 25°C and 75% respectively. The rainfall pattern is bimodal with a heavy rainy season running from mid-September to mid-November, and a severe dry season running from December to mid-March.

Pedologically, there is a wide variety of soils based on structure and texture. The soils are mostly ferralitic, sandy clay and hydromorphic in the lowlands found around certain places. These soils are 90% agricultural land, favorable to the cultivation of cocoa and to a wide range of food and market garden products and are intensively exploited because of the strong demography. The operating method is based on clearing, cutting, burning and plowing, which helps to strip the vegetation cover and exposes the soil to severe erosion and reduced fertility. Unfortunately, the amendments (organic fertilizers) recommended by the competent services are used very little [14].

Vegetation is semi-deciduous evergreen and degrades from the gradient Equator to north [11].

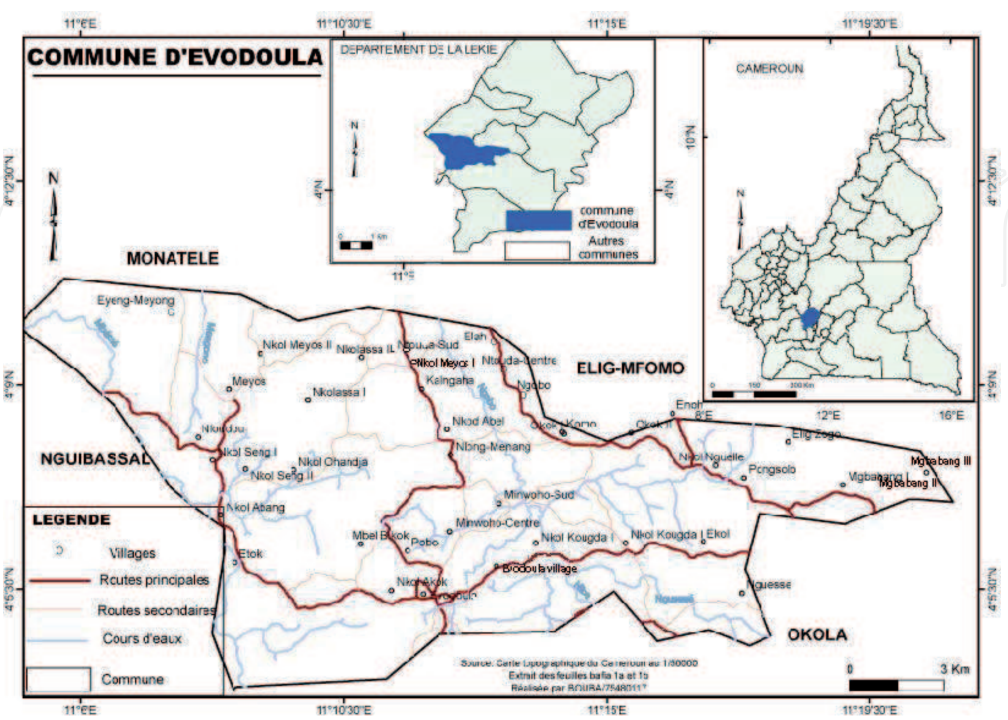

Figure 1.
Location of the study site in it agro-ecological zone.

2.2 Data collection

Both qualitative and quantitative data were collected from August 2013 to March 2014. Two different methods were used for data collection: (1) semi-structured socioeconomic surveys with households, and (2) direct observations and measurements in cocoa plantations. A total of forty (40) cocoa growers, were selected randomly for the semi-structured socioeconomic interview. These were focused on cocoa plantation characteristics (plantation status, age, history since its initial planting, area, cocoa tree ages, etc.) and the identification/selection and ranking of 10 tree species with leaf litterfall of high fertility potential was done. This identification/selection and ranking was based on their ethno-botanical knowledge of associated indigenous species, and the productivity of cocoa stands around those species. A generalized farmers' ranking was obtained by calculating the mean value of the position occupied in the individual farmers' ranking. The empirical classification by farmers of the fertility potential of these ten species was then compared to the classification of the same species based on their respective nutrient contents (Test Ranking).

Following these interviews with the cocoa growers, field visits to plantations were organized to select fifteen (15) cocoa agroforestry systems, through an in – depth assessment, for specific farm characterization. In each of the fifteen cocoa agroforestry systems, a systematic inventory of all non-cocoa trees exceeding 1 m in height were inventoried over the total area of each cocoa plantation following the method of [15]. Each tree species (forest, exotic as well as palm tree) was counted, numbered, identified and their density per plot estimated. The species identifications were based on vernacular names in the 'Eton' language with the assistance of the farm owner and correspondences with the scientific names were established from literature review [16].

From the above fifteen cocoa farms, litterfall of the 10 trees species of high fertility potential as rank by farmers was collected daily. Here, every newly fallen leaf was collected systematically at the same time after every two (02) days for one (1) week. The collection of fresh litterfall was done by a random walk around the specific tree species studied and the distance covered was from the base of the trunk to the longest branch of tree when the sun is at the zenith. Litterfall was conditioned according to standard procedure and taken to the laboratory for compositional analysis of macro-nutrients (nitrogen, phosphorus, potassium, calcium, and magnesium) and analyses were carried in conformity with standard analytical procedures of [17].

2.2.1 Data analyses

The data collected from the questionnaire and inventory forms were checked, entered into Microsoft Office Excel 2007 software and were analyzed using the Statistical Package for Social Sciences (SPSS) version 12.0. These analyzes consisted of descriptive statistics (sum, frequency, percentage, tree species densities and cross-tabulations of results), interactive graphs, and the total litter primary macro-nutrient (PMM) contents of the tree's species; which was obtained by summing the proportion of the respective elements analyzed. This, enable us to established the Test ranking of trees species. Data obtained from the chemical analysis were analyzed as a one-way analysis of variance (ANOVA) using the Proc GLM IN in SAS version 9.0. Separation of means was done using the DUNGAN Multiple Range Test, to test for significant effects between the leaf litters nutrient compositions of the different tree species at 5% probability level.

3. Results and discussions

3.1 Results

3.1.1 Cocoa farms characteristics

Many of the CBAFS monitored in the study area were cultivated and managed in very traditional ways resembling the approaches implemented previously by the elders. Among the households surveyed, 20% of the cocoa plantations had been established by the current owners, 80% had been established by grandparents or parents of the current owners (inherited). Those cocoa plantations had been established from food-crop fields (13%) or forest areas (73%). As a whole, 40% of the farms fall in the age range of (> 10–30 years), while 27% and 33% represent the age range of (≤ 10 years) and (> 30 years) respectively. Local classification of Cocoa cultivars used in the area identified two varieties; the local Cocoa landraces locally called "German variety" (80%) (**Figure 2**), mostly made up of Forastero-Amazonian or upper Amazon varieties and a considerable population of Trinitario in the old Cocoa orchard. Due to the fact that 40% of the plantation studied are old plantations that is >30-year-old, some of the farmers turn to regenerate their plantations consequently, some systems (13%) had a mixture of the "German cocoa" and the Hybrids while, the young systems (7%) were mostly dominated by the improved varieties or hybrids locally called 'SODECAO' from the name of the parastatal in charge of the distribution of the cultivars of that variety. Farmers had specific knowledge of the behavioral characteristics of each of cocoa cultivars.

3.1.2 Associate's tree species diversity

The results of the inventory of non-cocoa tree species diversity showed that there were in total 122 different non-cocoa trees species, with in total 1417 shade trees recorded over a total surface area of 29.5 ha, resulting to a shade tree density of 48 trees/ha of the different cocoa systems of the studied. Species sampled belonged to 37 tree families. The families mostly represented were: Sterculiaceae (28 species), Moraceae (22 species), Mimosaceae (15 species), Apocynaceae (13 species), Anacardiaceae (11 species), Euphorbiaceae (10 species), Meliaceae (10 species), Rutaceae (10 species), Bombaceae (8 species), Burseraceae (8 species) and Musaceae (8 species). Also, 493 trees belonging to 43 species were of the fruit types, while, 924 trees belonging to 79 specie were of the forest type. The 17 most occurring trees species are shown in **Table 1**.

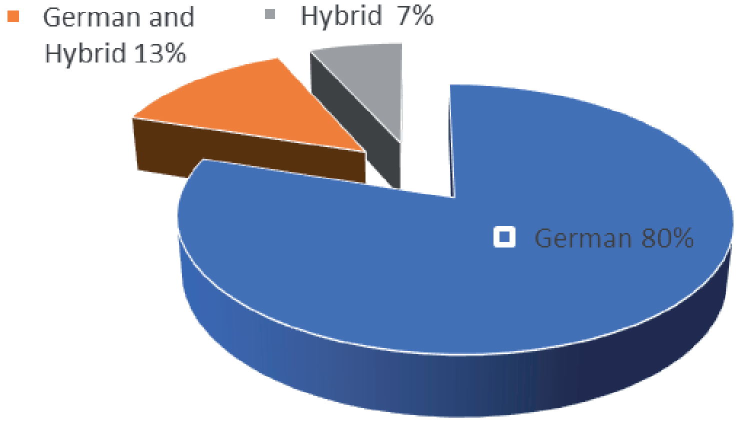

Figure 2.
Type of vegetative material used in the study zone.

No.	Scientific name	Local name	Family	Frequency	Percentage (%)
1	*Mangifera indica*	Andok ntangani	Anacardiaceae	135	18%
2	*Persea americana*	Pia	Lauraceae	131	17%
3	*Dacryodes edulis*	Sa'a	Burseraceae	81	11%
4	*Milicia excelsa*	Abang	Moraceae	66	9%
5	*Terminalia superba*	Akom	Combretaceae	64	8%
6	*Elaeis guineensis*	Allen	Arecaceae	59	8%
7	*Albizia adianthifolia*	Sayeme	Mimosaceae	37	5%
8	*Mansonia altissima*	Opong	Sterciliaceae	34	4%
9	*Citrus recticulata*	Opouma	Rutaceae	33	4%
10	*Ficus mucosa*	Ekokolle	Moraceae	24	3%
11	*Cola accuminata*	Abel	Sterculiacaeae	17	2%
12	*Musanga cecropoiides*	Eseng	Cecropiaceae	15	2%
13	*Lovoa trichilioides*	Bibollo	Meliaceae	14	2%
14	*Tieghemella africana*	Avo	Sapotaceae	13	2%
15	*Citrus sinensis*	Nia opouma	Rutaceae	13	2%
16	*Entandrophrama cylindricum*	Asse	Meliaceae	12	2%
17	*Nesogordonia papaverifera*	Kodibé	Sterculiacaeae	11	1%

Table 1.
Frequency and percentage of the 17 most common species present in the study location.

3.1.3 Farmers' perceptions and ranking of trees species indicators of fertile soils

Cocoa farmers interviewed confirm that, all cocoa-based systems studied (100%) were dominated by the presence of indigenous trees species. The latter produced more litter than the exotic trees species. The organic matter they produced played a favorable role in maintaining the soils' fertility. The farmers believe in their protecting ability against soil erosion (13%), maintenance and improvement of the soils' physico-chemical properties (structure; porosity; water retention, and soil nutrient) (100%), modification of the soil temperature (13%), and the rapid decomposition of organic matter (87%).

Farmers based their perceptions of the fertility potential of certain tree species on the observation of cocoa productivity around the tree (100%), vegetative aspect such as the size; the consistency and the arrangement in relation with the crown cover (93%). It is understood that, tree species introduced or maintained by farmers are those closer to the cocoa trees and through the quality of litterfall, shade, and eventual improvement of the soils' fertility plays an essential role on the cocoa productivity.

The ranking of the tree species with respect to their fertility potential, by local farmers, in decreasing order of importance is shown in **Table 2**.

3.1.4 Nutrient content of the litterfall of the rank tree species

Significant difference was found to exist in the chemical composition (quality) between litterfall from the different studied tree species ranked by farmers and within the different nutrient elements tested. Nitrogen was the main nutrient in leaf litter of different tree species with its concentration

No.	Trees species	Mean rank
1	*Milicia excelsa*	1.4
2	*Ceiba pentandra*	1.9
3	*Ficus mucoso*	2.8
4	*Alstonia boonei*	2.8
5	*Terminalia superba*	3
6	*Eribroma oblungum*	3.3
7	*Irvingia gabonensis*	4.2
8	*Zanthoxylum heitzi*	5.5
9	*Musanga cecropoides*	7.7
10	*Coula edulis*	9.9

Table 2.
Farmers mean ranking of tree species of indicators of fertile soil.

varying from 2.82 to 5.57% and a mean of 4.23 ± 1.065%. Phosphorus is present in very low concentration, typically around 0.001% while K varied widely from 1.95 to 18.9 cmol/kg. Mg was quantitatively the second element in leaf litter, with values ranging from 20 to 310.75 cmol/kg (**Table 3**).

Considering the importance of these nutrient elements to the growth of cocoa, its can be observe that, they are presence in very high concentration in the leaf litter of these trees' species. Concentration which are a way too far higher than the threshold values required for cocoa cultivation (**Table 4**).

Nutrient content species	N (%)	P (%)	K (cmol /kg)	Mg (cmol /kg)	Ca (cmol /kg)
Ceiba pentandra	5.57^{a}	0.17^{ab}	15.36^{abc}	108.25^{b}	50.25^{b}
Eribroma oblungum	5.36^{ab}	0.14^{abc}	16.36^{abc}	310.75^{a}	28.2^{cd}
Milicia excelsa	5.35^{ab}	0.192^{a}	15.62^{abc}	66.83^{bc}	6.78^{bc}
Alstonia boonei	4.95^{ab}	0.116^{abcd}	13.41^{c}	57.25^{bc}	33.9^{bc}
Zanthoxylum heitzi	4.58^{abc}	0.072^{cde}	18.90^{a}	60.17^{bc}	23.9^{bc}
Ficus mucoso	4.08^{bcd}	0.173^{ab}	17.49^{ab}	59.33^{bc}	168.35^{bc}
Musanga cecropoides	3.35^{cd}	0.033^{e}	5.26^{d}	244.5^{a}	29.2^{a}
Terminalia superba	3.27^{d}	0.109^{bcde}	13.90^{bc}	49^{bc}	13.7^{bc}
Irvingia gabonensis	2.98^{d}	0.087^{cde}	15.19^{abc}	20^{c}	60.55^{c}
Coula edulis	2.82^{d}	0.04^{de}	1.95^{d}	73.67^{bc}	16.45^{bc}
Anova/Duncan's Multiple Range Test					
Df	9	9	9	9	9
F value	6.92	5.28	22.09	17.15	30.71
Pr (>F)	0.0002	0.001	<.0001	<.0001	<.0001

Values in the same column followed by different superscript are statistically different at P < 0.05 level using Duncan's Multiple Range Test.

Table 3.
Chemical composition of the litter falls of the 10 trees species ranked by farmers.

Macronutrient	Unit	Threshold values
Total Nitrogen	%	0.2–0.4
Available Phosphorous	ppm	6.0–15.0
Potassium	Cmol + kg^{-1}	0.2–1.2
Calcium	Cmol + kg^{-1}	4.0–18.0
Magnesium	Cmol + kg^{-1}	0.9–4.0

Source: Snoeck et al., 2016.

Table 4.
Average soil macronutrient threshold values for cocoa cultivation.

N^0	Local ranking	Ranking according to the sum of the PMN content	Sum of the PMN Content (g/kg)
1	*Milicia excelsa*	*Ceiba pentandra*	63.3
2	*C. pentandra*	*M. excelsa*	61.5
3	*Ficus mucoso*	*Eribroma oblungum*	61.3
4	*Alstonia boonei*	*Alstonia boonei*	55.9
5	*Terminalia superba*	*Zanthoxylum heitzi*	53.9
6	*Eribroma oblungum*	*Ficus mucoso*	49.4
7	*Irvingia gabonensis*	*T. superba*	39.3
8	*Zanthoxylum heitzi*	*Irvingia gabonensis*	36.6
9	*Musanga cecropoides*	*Musanga cecropoides*	35.8
10	*Coula edulis*	*Coula edulis*	29.4

Table 5.
Comparison of farmer's ranking (local) with the ranking from the sum of PMN content of the studied trees species.

3.1.5 Comparison between farmers' ranking and measured nutrient contents

Contribution of trees species in soil fertility sustenance in general was based on indicators such as cocoa productivity, abundance of biomass produced, functional attributes of certain organs of these species and interactions with the medium. The litterfall of the associated tree species, based on farmers' perceptions determine the biomass produced, which once decomposed, improves soil fertility. The above-mentioned criteria were the basis of the ranking of 10 species of high fertility potential in descending order of importance (**Table 1**) by farmers. Comparison of farmers ranking with the ranking obtained by summing the nutrient content of the primary macro-nutrients (PMN) (N, P and K) (Test ranking) is presented in **Table 5**. Farmers' ranking, though closer, but is different from the Test ranking.

3.2 Discussion

3.2.1 Characteristics of cocoa based agroforestry systems

This study was performed in an attempt to acquire farmers' perceptions of the fertility potential of associated non-cocoa trees in cocoa systems in order to develop more knowledge about the soil-trees interactions. The maximal farm size in the entire study area is 5 ha and the smallest cocoa fields have a surface area of 0.5 ha.

The smallest surface area observed in this zone is due to the fact that 60% of the cocoa agroforests are inherited. In this zone the beneficiaries share the heritage left by their parents or relatives. This factor further contributes to the reduction of the surface area of the plantation and does not facilitate the creation of new plantation because the pressure on the available land is high, these further account for the small number of cocoa agroforests of age range ≤ 10 years within the study area. These results are similar to those obtained by [18].

The fact that most cocoa agroforest ownership is acquired by inheritance could further explain the age of the cocoa agroforest. These results are closer to those found by [19]; [18] who confirms that Cocoa orchard of Center Cameroon are old from the fact that 70% of the cocoa farms are more than 40-year-old. These results practically indicate that farmers of the study zone do not create new plantations. This is due to the high pressure exerted on the available land, which does not facilitate the acquisition of land by the younger producers. This was also observed by [20, 21] who further noted that cocoa trees were not renewed in cocoa plantations and were as old as the plantations.

3.2.2 Non-cocoa trees species densities, frequencies and abundance

Cocoa based agroforestry systems (CBAFS) of the study area are complex multispecies cropping systems whose performances are usually difficult to assess. The associated non – cocoa tree species diversity was high, with a predominance of timber species. Nevertheless, the fruit tree species *Mangifera indica*, *Persea American* and *Dacryodes edulis* were the most occurring species. Located in the lekié division, near Yaoundé urban city this further confirm the finding of [22, 23], who demonstrated in their study that farmers introduced and maintained fruit trees in plantation for the sake of income diversification. The high abundance of non-primary forest species points to the degree of alteration of the cocoa agroforests compared to primary forest. These cocoa agroforests have a high tree diversity compared to cocoa production systems in other parts of the tropics. For instance, they are higher than those of 38 species in traditional CBAFS in Central Cameroon [24]. Results of this inventory are similar to those of 38 species in traditional CBAFS in Central Cameroon [24], 21 species identified [25] by and those of 40 species identified in three CBAFS (traditional, innovative and SODECAO) in the locality of Talba (Center Region of Cameroon) by [26]. The differences in species obtained could be explained by the fact that farmers in localities such as Talba established CBAFS following recommendations by SODECAO for cocoa cultivation and maybe by the smaller size of their sampling units.

3.2.3 Farmers ranking of non-cocoa trees of high fertility potential and the nutrient composition of their leaf litterfall

Farmers were able to identify and rank non-cocoa trees species they considered of having a high fertility potential of CBAFS in center Cameroon. These results joined those obtained by [8, 12] in their works, who identified farmers' preferred trees species as far as soil fertility maintenance is concerned. Farmers' ranking of trees consider as indicators of fertile soil in our study though closer but was different from the ranking obtained by [8] in his study on mycotrophy and farmer knowledge of tree species of high fertility potential in cocoa-based agroforest of southern Cameroon. Our results are also in line with the results of [27], through his work on a look at activities on preferred trees in farming systems of the main cocoa producing countries in Africa, also identified and ranked several species as preferred trees for cocoa cultivation by farmers.

The results showed that, there is a significant difference in chemical composition (quality) between leaf litterfall from the different selected tree species and within the different nutrient elements tested. These results also indicate that Nitrogen is the main nutrient in the litterfall of the different tree species concentration varying from 2.82 to 5.57% with a mean data of 4.25 ± 1.065%. Mg is quantitatively the second element in the leaf litterfall of the different tree's species studied. The studied nutrient element where present in very high concentration and and far above the critical value needed for cocoa growth. This is in line with the finding of [28], who stated that a large part of some of these nutrient's elements is found in the vegetation. For instance, it was found that, for Cameroon, N in the litter was about twice the amount removed by the yield, whereas for Malaysia, this ratio was nearly 5 [28].

3.2.4 Comparison between farmers' ranking and measured nutrient contents

Based on the total primary macronutrient content potentially released by associated species, it can be observed that *Milicia excelsa, Ceiba pentendra, Eribroma oblungum, Asltonia boonei* and *Zanthoxylum heitzi* contained the highest nutrient concentration can be considered the best trees species in terms of fertility potential. However, with phosphorus (P) being an essential plant nutrient contributing to the development of fruits (increases flowering), we can say that *M. excelsa* and *Ceiba pentendra* are good sources for the improvement of soil fertility status (good indicators of fertile soil) under cocoa based systems in the study locality.

Compared to farmers' ranking, these two species appear in the 1st and 2nd positions respectively, meanwhile in the test ranking they appear in the 2nd and 1st positions respectively. The order of the primary macronutrient concentrations and returns to the soil through litterfall as observed in the isolated tree is N > K > P while that of the secondary macronutrient is Mg > Ca (an indication of the ranges of nutrient elements in concentrations and returns via litterfall). These results are close to those of [29], working on nutrient stocks, nutrient cycling, and soil changes in cocoa agroforestry. It could therefore be deduced that nutrient concentration in the litterfall of some trees is higher compared to other tree species, consequently some trees have a high fertility potential compared to others. However, in the light of the differences observed between the various rankings: farmers' ranking, test ranking, and the nutrient content of the associated species could not, on its own, serve as a tool for validating farmers' perceptions. Other factors such as the rate of mychoryzal colonization of roots of associated species [11], and soil fauna activities are also known to be important drivers of the biological fertility of the soil and soil health in general [30].

4. Conclusion

The present study which aimed at identifying and classifying 10 top species of good fertilizing potential and then collect and analyze the litter fall from these species trees in other to bring out a link between farmers knowledge and scientific knowledge aimed at, enhancing system sustainability and productivity. An important correspondence was found between the farmers' ranking and the chemical content of the litterfall, supporting the assertion that the integration of local knowledge in global science may contribute to easily understand the above and below grounds interactions in agroforestry systems in general and therefore pave the way for a smooth adoption among end users. Considering the increasing climate change and the predicted negative impact on cocoa production in West Africa, this approach can be a subsequent widespread call for the adoption of climate smart cocoa production.

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Conflict of interest

"The authors declare no conflict of interest."

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