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Cocoa Farmers' Perceptions of the Role Played by Tree Diversity and Density on Soil Macro-Fauna Diversity and Density in Cocoa-Based (*Theobroma cacao*) Agroforestry Systems in Cameroon

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Tree diversity and density in agroforestry systems has been found to increase the diversity and density of soil macro-fauna. However, very little is known of the relationship between tree diversity and density in cocoa agroforests and soil macro-fauna diversity and density. This study was therefore undertaken to fill this knowledge gap. A mixed research approach was adopted and data analysis was done using descriptive and inferential statistics. From the findings, most cocoa farmers perceived that tree diversity in cocoa agroforests was either average, high or very high. Most cocoa farmers perceived that tree density on its part was either average or low. Concerning soil macro-fauna diversity in cocoa-based agroforestry systems, most of the cocoa farmers perceived that soil macro-fauna diversity was either average or high. For soil macro-fauna density

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in cocoa agroforests, most cocoa farmers perceived that soil macro-fauna density was either average, high or low. Through correlation and regression analyses, it was found that a statistically significant ($p<0.05$) direct non-cause-effect and cause-effect relationship existed between the level of tree diversity and density in cocoa-based agroforestry systems (very high tree diversity, high tree diversity, average tree diversity, low tree diversity, very low tree diversity), and the level of soil macro-fauna diversity and density. This implies that increasing tree species diversity and density leads to increasing soil macro-fauna diversity and density in cocoa-based agroforestry systems. It is therefore recommended that policy makers take drastic measures to ensure greater tree diversity and density in cocoa agroforests in order to ensure higher soil macro-fauna diversity and density.

Keywords: Soil; soil fauna; cocoa; cocoa-agroforests; cocoa farmers; tree diversity; tree density; Cameroon.

1. INTRODUCTION

Agroforestry systems by their very nature are characterized by relatively high levels of tree/shrub diversity and density [1–4]. This diversity and density of trees/shrubs however varies from one agro-ecological zone to another [4–6]. Agroforestry systems in the humid forest zones for example are characterized by more tree diversity and density than agroforestry systems in the Savannah and Sahel regions [7–9]. Most of the tree/shrub species found in agroforestry systems are either planted or conserved by farmers for a plethora of reasons including fuelwood, fruits, soil fertility enhancement, building materials, shade, wind protection, erosion control and many others [7,10–14].

Today, the growing trend in most agroforestry systems is for farmers to integrate fruit trees like avocado, plums, oranges, guava, oranges, in order to diversify their sources of income [15–18,19]. These fruit trees are planted either alongside food crops like maize, beans, groundnuts, potato, sweet potato, cassava, cocoyams (Taro), yams, etc, or cash crops like cocoa, oil palms, coffee, and rubber [7].

Tree diversity and density in agroforestry systems has been noticed to improve soil fauna diversity and density [20–27]. This has been attributed to the fact that some of these tree species act as bait, attracting certain soil fauna [28,29].

In Cameroon some studies have been carried out on tree diversity and density in cocoa-based agroforestry systems [7,30–33,19]. However, very little has been done to examine the relationship existing between tree diversity and density and its relationship with soil macro-fauna diversity and density in agroforestry systems in general and cocoa-based agroforestry systems in particular. It was in this light that this study sought to assess the relationship between tree diversity and density and soil macro-fauna diversity and density in cocoa-based agroforestry systems. More specifically the study sought to: (1) Assess the degree of tree diversity and density in cocoa-based agroforestry systems; (2) Identify the level of soil macro-fauna diversity and density in cocoa-based agroforestry systems; (3) Examine the influence of tree diversity on soil macro-fauna diversity and density in cocoa-based agroforestry systems; (4) Assess the influence of tree density on soil macro-fauna diversity and density in cocoa-based agroforestry systems.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The study was carried out in the Mungo Division of Cameroon. This division lies between longitude 9°17' to 10°52' E and latitude 4°22' to 6°20' N. The study area constitutes part of the Western Highlands of Cameroon – a major agro-ecological and relief region in Cameroon. The Western Highlands covers four administrative regions in Cameroon (part of the littoral, part of the south west, and the entire west and north-west regions) and has a surface area of roughly 75,000 square kilometres [34]. Agriculture is the principal economic activity of the population. Owing to the predominance of agricultural activities, the Western Highlands of Cameroon (Mungo division inclusive) is considered one of the major breadbaskets of Cameroon and the Central African sub-region [34].

The field survey proper was done in one study area i.e. the Mungo Division (more precisely Melong sub-division), found in the Littoral region of Cameroon. The climate is the humid tropical and the vegetation type is degraded forest

interspersed with patches of savannah grassland. The soils are mostly ferralitic, volcanic, as well as andosols.

2.2 Data Collection Procedure

To meet the objectives of this study, both biophysical and socioeconomic data was collected from secondary and primary sources.

2.2.1 Sampling procedure

A multi-stage sampling procedure was followed as reported in previous studies [4,12,35]. At the first stage, the study area (Mungo division) was purposively chosen owing to the presence of mainly cocoa-based agroforestry systems in the area. At the second stage, household surveys were undertaken with farmers involved in cocoa-based agroforestry systems. This was done with the help of agricultural extension agents working on the field. And the third stage involved direct field surveys on the farm plots of cocoa farmers. In these phase both tree and macro-fauna diversity and abundance were taken into consideration. Household and field surveys were complemented with focus group discussions, key informant interviews, as well as direct field measurements.

2.2.2 Secondary data

To realize the objectives of this work, secondary data was collected from the following sources: The Regional, Divisional and Sub-Divisional Delegations of Agriculture and Rural Development; Forestry and Wildlife, Environment and Nature Protection; and Economy and Regional Planning; and Municipal councils found in the Mungo Division in general and Melong sub-division in particular; libraries in the Faculty of Agronomy and Agricultural Sciences; scientific publications or articles, books and book chapters both online and offline; and different websites on the internet.

Secondary data enabled the verification and comparison of the contribution of soil macro-fauna in cocoa-based agroforestry systems to soil fertility status in the Mungo Division to that of other areas in Cameroon, Africa and the world.

2.2.3 Primary data collection

Primary data was collected through household surveys, direct field surveys as well as direct field observations.

2.2.3.1 Household surveys

Household surveys were conducted with farmers practicing cocoa-based agroforestry systems in order to ascertain their perceptions pertaining to the contribution of soil macro-fauna to soil fertility improvement. Semi-structured questionnaires were administered to 300 cocoa-based agroforestry practitioners. The selection of these farmers was done with the aid of agricultural extension officials working on the field in the Mungo Division. The household survey of 300 farmers was complemented with focus group discussions, and key informant interviews in order to ascertain the truthfulness of farmers' perceptions.

2.3 Data Analysis

Microsoft Excel 2007 and SPSS 17.0 software packages were used for descriptive and analytical statistical analysis. The main descriptive statistics were charts, graphs, tables as well as percentage indices, while analytical statistics included Spearman's correlation coefficient, chi-square test statistic, and logistic regression analysis. The analytical statistics were used based on the normality of the data obtained. Analytical statistics indicated the causal and non-causal relationship existing between tree diversity and density and soil macro-fauna diversity and density in the cocoa-based agroforestry systems in the littoral region of Cameroon.

3. RESULTS

3.1 Tree Diversity and Density in Cocoa-Based Agroforestry Systems

Cocoa (*Theobroma cacao*) farmers' perceptions of tree diversity and density in their cocoa-based agroforestry systems differed significantly (Fig. 1).

For tree diversity in cocoa-based agroforestry systems, most cocoa farmers perceived that tree diversity was either average, high or very high, with just few cocoa farmers perceiving that tree diversity was low or very low (Fig. 1).

With respect to tree density in cocoa-based agroforestry systems, most cocoa farmers perceived that tree density was either average or low (Fig. 1).

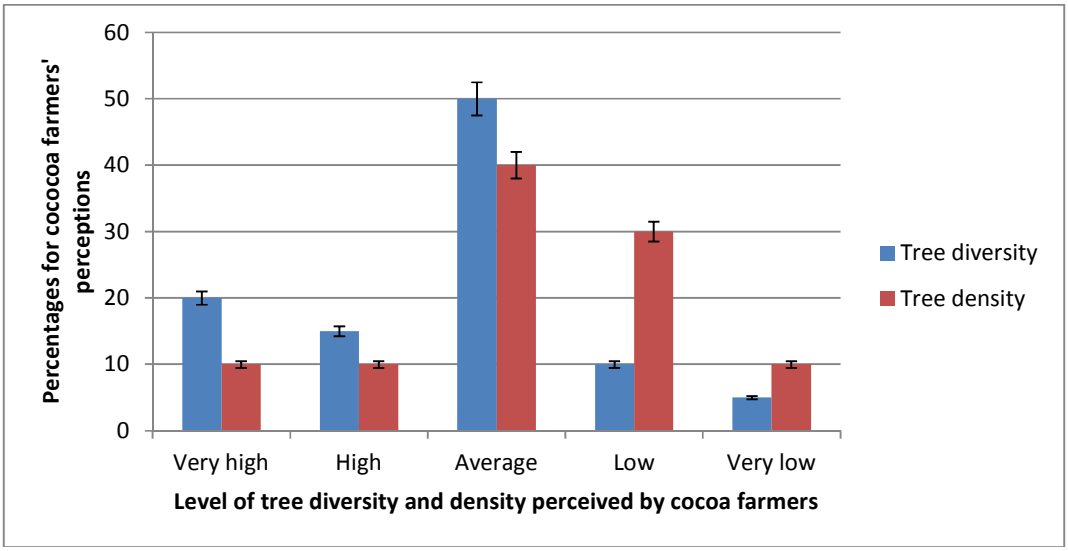

Fig. 1. Farmers' perception of tree diversity and density in cocoa-based agroforestry systems

3.2 Soil Macro-Fauna Diversity and Density in Cocoa-Based Agroforestry Systems

The perceptions of cocoa farmers differed significantly with respect to soil macro-fauna diversity and density in cocoa-based agroforestry systems (Fig. 2).

As seen on Fig. 2, concerning soil macro-fauna diversity in cocoa-based agroforestry systems, most of the cocoa farmers perceived that soil macro-fauna diversity was either average or high, with few cocoa farmers perceiving that soil macro-fauna diversity in cocoa-based agroforestry systems was very low.

Still on Fig. 2, it is noticed that, for soil macro-fauna density in cocoa-based agroforestry systems, most cocoa farmers perceived that soil macro-fauna density was either average, high or low.

3.3 Influence of Tree Diversity on Soil Macro-Fauna Diversity and Density in Cocoa-Based Agroforestry Systems

Correlation and regression analyses showed the existence of a direct non-cause-effect and cause-effect relationship between tree diversity and macro-fauna diversity and density in cocoa-based agroforestry systems (Table 1).

Table 1. Role played by tree diversity in soil macro-fauna diversity and density in cocoa-based agroforestry systems

Explanatory variable	Correlation coefficient (r)	p-level	Logistic regression coefficient (B)	p-level
Very high tree diversity	0.89*	0.000	3.62*	0.000
High tree diversity	0.93*	0.000	4.01*	0.000
Average tree diversity	0.54*	0.000	1.04*	0.037
Low tree diversity	0.62*	0.000	2.02*	0.000
Very low tree diversity	0.75*	0.000	2.84*	0.000
Likelihood Ratio X^2			150.28	0.000
Pseudo R^2			0.472	
Number of observations			300	

**, Significant at 5% probability level*

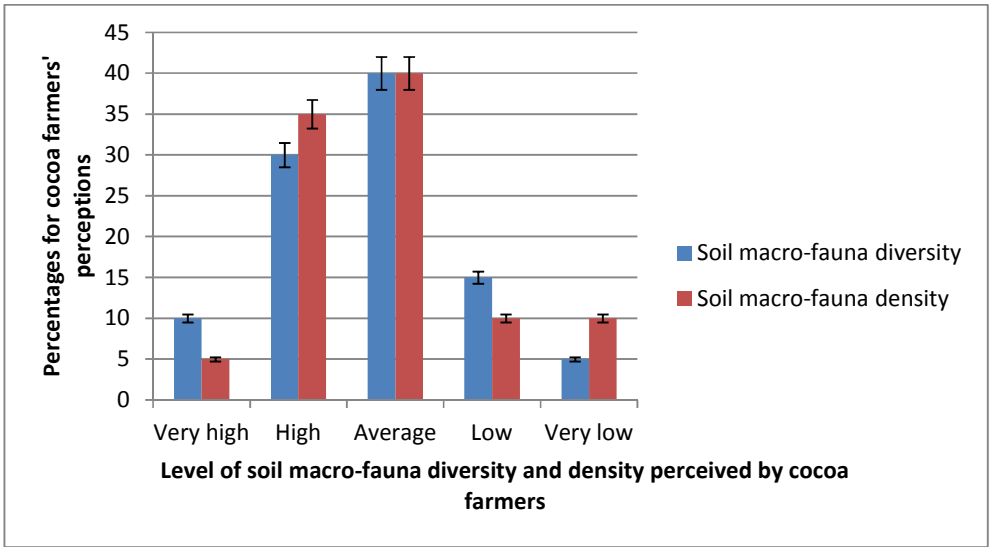

Fig. 2. Soil macro-fauna diversity and density perceived by farmers

From Table 1, it is found that a statistically significant ($p<0.05$) direct non-cause-effect and cause-effect relationship exists between the level of tree diversity in cocoa-based agroforestry systems (very high tree diversity, high tree diversity, average tree diversity, low tree diversity, very low tree diversity), and the level of soil macro-fauna diversity and density.

3.4 Influence of Tree Density on Soil Macro-Fauna Diversity and Density in Cocoa-Based Agroforestry Systems

From Spearman correlation and logistic regression analyses, it was found that a direct non-cause-effect and cause-effect relationship exist between tree density in cocoa-based agroforestry systems and soil macro-fauna diversity and density (Table 2).

Looking at Table 2, it is noticed that a statistically significant ($p<0.05$) direct non-cause-effect and cause-effect relationship exists between the level of tree density in cocoa-based agroforestry systems (very high tree density, high tree density, average tree density, low tree density and very low tree density), and soil macro-fauna diversity and density.

4. DISCUSSION

4.1 Tree Diversity and Density in Cocoa-Based Agroforestry Systems

Most cocoa farmers perceived that tree diversity was either average, high or very high, with just few cocoa farmers perceiving that tree diversity was low or very low**.** For tree density in cocoa-based agroforestry systems, most cocoa farmers perceived that tree density was either average or low.

Table 2. Role played by tree density in soil macro-fauna diversity and density in cocoa-based agroforestry systems

Explanatory variable	Correlation coefficient (r)	p-level	Logistic regression coefficient (B)	p-level
Very high tree density	0.98*	0.000	4.08*	0.000
High tree density	0.85*	0.000	3.84*	0.000
Average tree density	0.67*	0.000	2.09*	0.000
Low tree density	0.51*	0.000	1.02*	0.041
Very low tree density	0.59*	0.000	1.46*	0.013
Likelihood Ratio X^2			122.46	0.000
Pseudo R^2			0.274	
Number of observations			300	

**, significant at 5% probability level*

Farmers' perception of average to high tree diversity in cocoa-based agroforestry systems could be attributed to the fact that most cocoa farmers integrate diverse tree species into their cocoa farms, especially fruit trees like avocado, plums, oranges, mangoes, kola nuts, and others. Studies have generally found that farmers integrate diverse tree species in their agroforestry farm plots in order to obtain different services like fuelwood, shade, wind protection, erosion control, building materials [3,4,7,10,13,14,18,36]. However, in Cameroon where this study was carried out, just few studies (mainly biophysical) have estimated tree diversity in cocoa-based agroforestry systems [7,30–33,37].

Cocoa farmers' perception of average/low tree density in cocoa-based agroforestry systems could be attributed to the fact that, although farmers prefer greater tree diversity in their cocoa farms, they do not really like a high density of trees in their farms. This is because most cocoa farmers perceive that a higher tree density in their cocoa-agroforests will result in the spread of pests and diseases. Thus, most cocoa farmers prefer that the trees should be dotted and/or scanty in their cocoa farms. Studies undertaken in Cameroon by Sonwa et al. [7], Jagoret et al. [30], Jagoret et al. [31], Jagoret et al. [32], and Tankou [33] have shown that farmers integrate diverse tree species within their cocoa agroforests, but they tree density is limited to a manageable level.

4.2 Soil Macro-Fauna Diversity and Density in Cocoa-Based Agroforestry Systems

A cross section of the sampled cocoa farmers perceived that soil macro-fauna diversity was either average or high, with few cocoa farmers perceiving that soil macro-fauna diversity in cocoa-based agroforestry systems was very low. In the case of soil macro-fauna density in cocoa-based agroforestry systems, most cocoa farmers perceived that soil macro-fauna density was either average, high or low. Cocoa farmers' perception average to high soil macro-fauna diversity and density in cocoa agroforests could be attributed to the fact that farmers encounter these soil fauna on a daily basis while they go about their routine farming activities. There were however significant differences in farmers' perceptions of the level of soil macro-fauna diversity and density which could be attributed to differences in age of farmer, age of farm, farm experience, farm size, and level of education. Some studies carried out in different parts of the tropics [24,25,28,29,38,39,40,41] have shown that soil fauna diversity and density are relatively higher in agro-ecological farming systems. This could be attributed to the fact that agro-ecological farming systems like agroforestry make use of limited agro-chemicals which are harmful to soil organisms.

4.3 Influence of Tree Diversity and Density on Soil Macro-Fauna Diversity and Density in Cocoa-Based Agroforestry Systems

A significant direct non-cause-effect and cause-effect relationship was found to exist between tree diversity and density, and soil macro-fauna diversity and density in cocoa-based agroforestry systems. This implies that the more diverse and dense the tree species found in cocoa agroforests, the more diverse and dense the soil macro-fauna. This could be attributed to the fact that some tree species attract certain species of soil macro-fauna, which accounts for the great diversity and density of soil macro-fauna in cocoa agroforests characterized by more diversity and density. Studies carried out by Wartenberg et al. [42], Wartenberg et al. [43], Vanhove et al. [44], Villanueva-Lopez et al. [45], Awazi and Tchamba [4], Prayogo et al. [46], Rahman et al. [47] and Cardinael et al. [42] have generally shown that agro-ecological systems like agroforestry characterized by high tree diversity and density have more soil organisms diversity and density than monoculture systems. However, with few studies undertaken on cocoa-based agroforestry systems, this study is opening up a new research path, thus its originality.

5. CONCLUSION

Limited research had been done to assess the relationship between tree diversity and density in cocoa agroforests and soil macro-fauna diversity and density. From the findings of this study, most cocoa farmers perceived that tree diversity in cocoa agroforests was either average, high or very high. In the case of tree density, most farmers perceive that it was either average or low. Concerning soil macro-fauna diversity in cocoa-based agroforestry systems, most of the cocoa farmers perceived that soil macro-fauna diversity was either average or high. For soil macro-fauna density in cocoa agroforests, most cocoa farmers perceived that soil macro-fauna density was either average, high or low.

Correlation and regression analyses, revealed that a statistically significant direct non-cause-effect and cause-effect relationship existed between the level of tree diversity and density in cocoa-based agroforestry systems (very high tree diversity, high tree diversity, average tree diversity, low tree diversity, very low tree diversity), and the level of soil macro-fauna diversity and density. Based on these findings, it is recommended that policy makers take drastic measures to ensure greater tree diversity and density in cocoa agroforests in order to ensure higher soil macro-fauna diversity and density.

6. POLICY RECOMMENDATIONS

From the findings of this study, the following policy recommendations emerge:

Most cocoa farmers perceived that tree diversity in cocoa agroforests was either average, high or very high while tree density was perceived as either average or low. Thus, Measures should be taken by policy makers to either maintain this, or improve upon it.

Concerning soil macro-fauna diversity in cocoa-based agroforestry systems, most of the cocoa farmers perceived that soil macro-fauna diversity was either average or high while soil macro-fauna density was perceived as average, high or low. Thus, good policies should be put in place that will encourage cocoa farmers to maintain this standard.

A direct relationship existed between the level of tree diversity and density, and the level of soil macro-fauna diversity and density in cocoa-based agroforestry systems, implying that the higher the tree diversity and density, the higher the diversity and density of soil macro-fauna. Thus, policies geared towards increasing tree diversity and density in cocoa agroforests should be formulated and implemented which will go a long way to improve soil macro-fauna density and diversity.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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