



Assessing the determinants of soil fertility in cocoa-based (*Theobroma cacao*) agroforestry systems in the Littoral region of Cameroon

**Azembouh Roshinus Tsufac¹, Nyong Princely Awazi^{1*}
and Bernard Palmer Kfuban Yerima²**

¹*Department of Forestry, Faculty of Agronomy and Agricultural Sciences, P.O. Box 222, Dschang; University of Dschang, Cameroon.*

²*Department of Soil Sciences, Faculty of Agronomy and Agricultural Sciences, P.O. Box 222, Dschang; University of Dschang, Cameroon.*

Authors' contributions

This work was carried out in collaboration among all authors. All three authors took an active part in the conception, data collection, data analysis and write up. All three authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2020/v32i1730386

Editor(s):

(1) Dr. Muhammad Shehzad, The University of Poonch Rawalakot AJK, Pakistan.

Reviewers:

(1) Daniel Chukwuemeka Amaogu, University of Port Harcourt, Nigeria.

(2) Mohammad h Golabi, University of Guam Mangilao, USA.

Complete Peer review History: <http://www.sdiarticle4.com/review-history/64185>

Original Research Article

**Received 25 October 2020
Accepted 30 December 2020
Published 31 December 2020**

ABSTRACT

Soil fertility decline is a reality across the globe. Soil infertility has led to falling crop yields for both food and cash crops precipitating both poverty and food insecurity. Poor agricultural practices have often been blamed for declining levels of soil fertility. It was within this framework that this study was carried out to assess soil fertility levels in cocoa-based agroforestry systems in the Littoral region of Cameroon. Through the use of a mixed research approach and descriptive and inferential statistical analysis it was found that the most perceived indicators of soil fertility by cocoa farmers in cocoa-based agroforestry systems were cocoa yields (100%), soil colour (90%), indicator plant species (75%), presence of soil macro-organisms (80%), indicator weed species (65%), growth rate/vigour of the cocoa plant (70%), and level of compaction of the soil (50%). Chi-square test statistic ($X^2 = 15.92$, $p < 0.05$) revealed that there was a statistically significant difference in cocoa farmers' perceptions of soil fertility indicators in cocoa-based agroforestry systems. Most cocoa

*Corresponding author: E-mail: nyongprincely@gmail.com;

farmers perceived the level of soil fertility in cocoa-based agroforestry systems to be between average (29%) and low (43%). Very few cocoa farmers perceived that soil fertility level in cocoa-based agroforestry systems was very high (5.3%). Chi-square test statistic ($X^2 = 38.42$, $p < 0.05$), revealed the existence of a statistically significant difference in cocoa farmers' perception of the level of soil fertility in cocoa-based agroforestry systems. Correlation and regression analyses showed the existence of a direct and inverse non-causal and causal relationship respectively between several explanatory variables and soil fertility in cocoa-based agroforestry systems. It was noticed that explanatory variables such as fertilizer/manure application, diversity of tree species in the cocoa agroforests, diversity of soil macro-fauna in the cocoa agroforests, and density of soil macro-fauna in the cocoa agroforests, all had a statistically significant ($p < 0.05$) direct non-causal and causal relationship with soil fertility in cocoa-based agroforestry systems. Meanwhile, explanatory variables such as age of the cocoa farm, density of cocoa plants in the cocoa agroforests, and application of agrochemicals in the cocoa agroforests, all had a statistically significant ($p < 0.05$) non-causal and causal relationship with soil fertility in cocoa-based agroforestry systems. It is therefore recommended that there should be more organic fertilizer/manure application, more diversity of tree species in the cocoa agroforests, and measures to ensure the diversity and density of soil macro-fauna in cocoa-based agroforestry systems.

Keywords: Cocoa farmers; cocoa; soil fertility; soil; agroforestry; cocoa agroforests; Cameroon.

1. INTRODUCTION

Agroforestry being an agro-ecological, climate-smart, environmentally friendly, and sustainable practice, has many ecosystem services, one of which is soil fertility enhancement [1–8]. As defined by Nair [9] and Leakey [10], agroforestry is a landuse system where woody perennials and/or shrubs are deliberately integrated into croplands and pasture lands. The tree/shrub component which is omnipresent in all agroforestry systems plays a key role as far as soil fertility improvement is concerned – facilitates the nutrient cycling process.

Across sub-Saharan Africa, three (03) main agroforestry systems exist, characterized by several practices [5]. These agroforestry systems include agrosilvopastoral, silvopastoral, and agrisilvicultural systems [5]. These three main systems are characterized by several practices like home gardens with livestock, home gardens, trees on croplands, trees on grazing lands, coffee-based agroforestry, rubber-based agroforestry, oil palms-based agroforestry, entomoforestry, aquaforestry and many others [5]. All these practices provide a plethora of ecosystem services, one being soil fertility enhancement [6,11].

In Cameroon, all the aforementioned agroforestry systems and practices exist [8,12-14]. Cocoa-based agroforestry systems in particular are dominant especially in the humid southern part of the country characterized by high mean annual temperatures and high average annual rainfall

[15–26]. These cocoa-based agroforests are controlled by smallholder farmers who are mostly resource poor, and largely depend on the sale of cocoa for survival [27– 28]. Low cocoa yields and price fluctuations have pushed some of these smallholder cocoa farmers out of the cocoa sector [21]. Poor cocoa yields have been caused by poor soils and many other factors such as the lack of quality inputs (hybrid cocoa seedlings and quality fertilizers) and poor management of cocoa farms [21,25,28]. Most studies carried out on cocoa agroforests in Cameroon [17,22–26] have mainly focused on tree diversity and density within cocoa agroforests with limited focus on soil fertility. This study was therefore undertaken to fill this research gap through the examination of cocoa farmers' perceptions with respect to soil fertility in cocoa-based agroforestry systems. More specifically, the study was carried out to: (1) Identify the different soil fertility indicators perceived by farmers in cocoa-based agroforestry systems; (2) Assess the level of soil fertility perceived by farmers in cocoa-based agroforestry systems; (3) Examine the factors influencing soil fertility in cocoa-based agroforestry systems. Thus, this study will add to the limited body of literature regarding the factors affecting soil fertility in cocoa-based agroforestry systems.

2. MATERIALS AND METHODS

2.1 Location of the Study Area

The study was carried out in Melong administrative district, Mungo Division, littoral

region of Cameroon. It is located latitudinally and longitudinally between 4°22' to 6°20' N and 9°17' to 10°52' E respectively. Melong administrative district falls within one of the five agro-ecological zones of Cameroon – the Western Highlands. The Western Highlands of Cameroon is a vast area covering roughly 50,000 km² made up of the entire northwest and southwest regions as well as parts of the littoral and southwest regions of Cameroon. Agriculture is the main economic activity of the population resident in the Western Highlands making the region one of the major breadbaskets of Cameroon and the Central African sub-region [29].

Cocoa-based agroforestry systems being one of the predominant agricultural systems in Melong administrative district, the area was chosen purposively as the site for our study. Melong sub-division was created in 1962 by Decree No. 62/17 of 26/12/1962 [30]. It has a surface area of 497 Km² and a population of about 102,000 inhabitants living in rural and urban centres [30]. Melong sub-division shares territorial boundaries with different localities i.e. Santchou municipality to the north; Nguti municipality to the northwest; Bangem municipality to the west; Nkongsamba municipality to the southwest; Baré municipality to the southeast; the Nkam river and Kékem municipality to the east. The climate is humid tropical characterized by two main seasons i.e. a short rainy season and a long dry season. The vegetation type is dominated by degraded forest interspersed with patches of savannah grassland. Soils include andosols, ferrallitic and volcanic soils. Melong sub-division is characterized by a rolling topography made up of hills, plains and valleys. The hydrographical network is dense characterized by several rivers and streams. A diversity of flora and fauna species equally characterizes the locality of Melong.

2.2 Sampling Technique

To achieve the objectives of the study, biophysical and socio-economic data were collected from and secondary sources. For primary data collection in particular, the multi-stage sampling procedure was followed:

The multi-stage sampling technique was used as reported in previous studies [12,31,14]. At the first stage, the study area (Mungo division in general and Melong administrative district more specifically) was purposively chosen owing to the predominance of cocoa-based agroforestry

systems. At the second stage, focus group discussions and key informant interviews were carried out in order to get a general picture of cocoa farmers' and resource persons' perceptions with respect to the cocoa-based agroforestry system, soil fertility indicators, and levels of soil fertility in cocoa-based agroforestry systems. The third stage involved household surveys during which semi-structured questionnaires were administered to some 300 randomly selected cocoa farmers practicing the cocoa-based agroforestry system. The questionnaires were designed to obtain information regarding the socio-economic and demographic attributes of cocoa farmers, soil fertility indicators, levels of soil fertility in cocoa-based agroforestry systems and factors affecting soil fertility in cocoa-based agroforestry systems. The fourth stage involved direct field measurements on cocoa-based agroforestry farm plots of cocoa farmers. In this phase, soil bio-chemical parameters were taken for laboratory analysis. Agricultural extension agents were pivotal at each of these stages because of their better mastery of the study area.

2.3 Data Collection

Secondary data (on fauna and flora, soils, agricultural practices of cocoa farmers, etc) were collected from different administrative services including Divisional and Sub-Divisional Delegations of Forestry and Wildlife, Economy and Regional Planning, Agriculture and Rural Development, Environment and Nature Protection; Archives of Municipal Councils found in the Mungo Division in general and Melong sub-division in particular; The libraries of the Faculty of Agronomy and Agricultural Sciences as well as that of the Department of Soil Science as well as Forestry; Scientific articles, books and book chapters both offline and online; different internet websites. Secondary data were collected in order to verify and compare findings from elsewhere across Cameroon, Africa and the world to what obtains in Melong sub-division.

Primary data were collected through household surveys, direct field measurements as well as direct field observations. Household surveys were conducted through the administration of semi-structured questionnaires to 300 randomly chosen cocoa farmers involved in cocoa-based agroforestry systems. Questionnaires were designed in order to collect information relative to socio-economic and demographic characteristics of cocoa farmers, indicators of soil fertility, soil

fertility levels in cocoa-based agroforestry systems, as well as factors affecting soil fertility in cocoa-based agroforestry systems. Data collected from household surveys was triangulated with that collected through focus group discussions and key informant interviews in order to give the findings some credibility and scientific rigour.

2.4 Data Analysis

Data analysis was done on Microsoft Excel 2007 and SPSS 17.0 making use of descriptive and inferential statistics. Descriptive statistics computed were charts, graphs, tables as well as percentage indices, while analytical/inferential statistics computed were Spearman's correlation, chi-square test statistic, and logistic regression analyses. Mostly non-parametric tests like chi-square and discrete choice regressions like the logistic regression were used because the data were mainly qualitative. The inferential statistics were used to examine the non-cause-effect and cause-effect relationship existing between different independent variables and soil fertility in cocoa-based agroforestry systems.

3. RESULTS

3.1 Cocoa Farmers' Perceived Indicators of Soil Fertility in Cocoa-Based Agroforestry Systems

Cocoa farmers' perceptions of the indicators of soil fertility in cocoa-based agroforestry systems were varied (Table 1).

From Table 1, it seen that the most perceived indicators of soil fertility by cocoa farmers in cocoa-based agroforestry systems were cocoa yields (100%), soil colour (90%), indicator plant species (75%), presence of soil macro-organisms (80%), indicator weed species (65%), growth rate/vigour of the cocoa plant (70%), and level of compaction of the soil (50%). Chi-square test statistic ($X^2 = 15.92$, $p < 0.05$) revealed that there was a statistically significant difference in cocoa farmers' perceptions of soil fertility indicators in cocoa-based agroforestry systems.

3.2 Cocoa Farmers' Perceptions of Level of Soil Fertility in Cocoa-Based Agroforestry Systems

Cocoa farmers' perceptions of the level of soil fertility in cocoa-based agroforestry systems differed (Table 2).

Table 2 showed that most cocoa farmers perceived the level of soil fertility in cocoa-based agroforestry systems to be between average (29%) and low (43%). Very few cocoa farmers perceived that soil fertility level in cocoa-based agroforestry systems was very high (5.3%). Chi-square test statistic ($X^2 = 38.42$, $p < 0.05$), revealed the existence of a statistically significant difference in cocoa farmers' perception of the level of soil fertility in cocoa-based agroforestry systems.

3.3 Factors Influencing Soil Fertility in Cocoa-Based Agroforestry Systems

Correlation and regression analyses showed the existence of a direct and inverse non-causal and causal relationship respectively between several explanatory variables and soil fertility in cocoa-based agroforestry systems (Table 3).

From Table 3, it is noticed that explanatory variables such as fertilizer/manure application, diversity of tree species in the cocoa agroforests, diversity of soil macro-fauna in the cocoa agroforests, and density of soil macro-fauna in the cocoa agroforests, all had a statistically significant ($p < 0.05$) direct non-causal and causal relationship with soil fertility in cocoa-based agroforestry systems. Meanwhile, explanatory variables such as age of the cocoa farm, density of cocoa plants in the cocoa agroforests, and application of agrochemicals in the cocoa agroforests, all had a statistically significant ($p < 0.05$) non-causal and causal relationship with soil fertility in cocoa-based agroforestry systems.

4. DISCUSSION

4.1 Perceived Indicators of Soil Fertility by Cocoa Farmers in Cocoa-Based Agroforestry Systems

The most perceived indicators of soil fertility by cocoa farmers in cocoa-based agroforestry systems were cocoa yields, soil colour, indicator plant species, presence of soil macro-organisms, indicator weed species, growth rate/vigour of the cocoa plant, and level of compaction of the soil. This goes to show that these indicators are foolproof indicators that have been ingrained in the psyche of cocoa farmers from time immemorial. Studies carried out across Cameroon and other parts of Africa have shown that farmers perceived different indicators of soil

Table 1. Indicators of soil fertility in cocoa-based agroforestry systems

Soil fertility indicator	Frequency (n)	Percentage (%)	χ^2	p-level
Cocoa yield	300	100	15.92*	0.041
Soil colour	270	90		
Indicator weed species	195	65		
Indicator plant species	225	75		
Soil macro-organisms	240	80		
Soil texture	135	45		
Soil compaction	150	50		
Growth rate/vigour of cocoa plant	210	70		
Others (humus)	30	10		

* Significant at 5% probability level

Table 2. Level of soil fertility in cocoa-based agroforestry systems

Level of fertility	Frequency (n)	Percentage (%)	χ^2	p-level
Very high	16	5.3	38.42*	0.000
High	25	8.4		
Average	87	29		
Low	129	43		
Very low	43	14.3		
Total	300	100		

* Significant at 5% probability level

Table 3. Factors affecting soil fertility in cocoa-based agroforestry systems

Explanatory variable	Correlation coefficient (r)	p-level	Logistic regression coefficient (B)	p-level
Age of cocoa farm	-0.56*	0.000	-1.47*	0.019
Fertilizer/manure application	0.64*	0.000	2.01*	0.000
Diversity of tree species in the system	0.50*	0.000	1.22*	0.026
Density of tree species in the system	-0.79*	0.000	-2.55*	0.000
Density of cocoa plants	-0.73*	0.000	-2.31*	0.000
Application of agrochemicals	-0.51*	0.000	-1.24*	0.023
Diversity of soil macro-organisms	0.68*	0.000	2.04*	0.000
Density of soil macro-organisms	0.65*	0.000	2.01*	0.000
Likelihood ratio χ^2			113.52	0.000
Pseudo R^2			0.446	
Number of observations			300	

* Significant at 5% probability level

fertility [20,25,32–35]. However, most of these studies were carried out in other agricultural systems. This study by focusing on the cocoa-based agroforestry system has filled a research gap.

4.2 Cocoa Farmers' Perceptions of Level of Soil Fertility in Cocoa-Based Agroforestry Systems

Most cocoa farmers perceived the level of soil fertility in cocoa-based agroforestry systems to be between average and low. Very few cocoa farmers perceived that soil fertility level in cocoa-based agroforestry systems was very high. On

the basis of cocoa farmers' perception, there is clear evidence that soil fertility in cocoa agroforests has declined drastically. This could be attributed to poor agricultural practices like excessive application of agrochemicals which kill soil organisms – soil engineers contributing to soil fertility enhancement, as well as aging farms and poor management of cocoa farms. Although agroforestry systems provide many ecosystem services – one being soil fertility enhancement [1–2,5–6], the declining soil fertility levels in cocoa-based agroforestry systems could be attributed to poor management of the cocoa farms as well as poor agricultural practices taken up by most cocoa farmers.

4.3 Factors Influencing Soil Fertility in Cocoa-Based Agroforestry Systems

Correlation and regression analyses showed the existence of a direct and inverse non-causal and causal relationship respectively between several explanatory variables and soil fertility in cocoa-based agroforestry systems. It was noticed that explanatory variables such as fertilizer/manure application, diversity of tree species in the cocoa agroforests, diversity of soil macro-fauna in the cocoa agroforests, and density of soil macro-fauna in the cocoa agroforests, all had a statistically significant direct non-causal and causal relationship with soil fertility in cocoa-based agroforestry systems. This implies that an increase in fertilizer/manure application, diversity of tree species in the cocoa agroforests, diversity of soil macro-fauna in the cocoa agroforests, and density of soil macro-fauna in the cocoa agroforests, leads to an increase in soil fertility in cocoa-based agroforestry systems. This could be attributed to the fact that all these factors contribute towards adding more nutrients to the soil, which goes a long way to enhance the fertility of the soil. Studies carried out across Cameroon, Africa and other parts of the world, on different agricultural systems (cocoa-based agroforestry systems inclusive) have shown that soil fertility is enhanced by factors such as fertilizer/manure application, diversity of tree species in a farming system, diversity and density of soil macro-fauna in a farming system [4–5,16,20,33,36–41]. However, few of these studies were done in cocoa-based agroforestry systems, which was the research gap this study sought to fill.

Meanwhile, explanatory variables such as age of the cocoa farm, density of cocoa plants in the cocoa agroforests, and application of agrochemicals in the cocoa agroforests, all had a statistically significant non-causal and causal relationship with soil fertility in cocoa-based agroforestry systems. This implies that an increase in the age of the cocoa farm, density of cocoa plants in the cocoa agroforests, and application of agrochemicals in the cocoa agroforests leads to a decline in soil fertility in cocoa-based agroforestry systems. This could be attributed to the fact that as cocoa farms age, fertility declines naturally; while as density of cocoa plants increases, there is competition for nutrients which leads to a reduction in soil fertility; the excessive application of agrochemicals kills soil organisms which are the

engineers working to keep the soil fertile, hence a drop in soil fertility. Studies have shown that poor farm management and poor agricultural practices lead to a decline in soil fertility in all agricultural systems [27,42–45]. In cocoa-based agroforestry systems, little or nothing has been done so far to examine the factors affecting soil fertility. Thus, the findings of this paper are very timely as they come in to fill a research gap.

5. CONCLUSION

Soil fertility decline is a major palaver plaguing agriculture across the world. Soil infertility has led to falling crop yields for both food and cash crops precipitating both poverty and food insecurity. Poor agricultural practices have often been blamed for declining levels of soil fertility. It was within this framework that this study was carried out to assess soil fertility levels in cocoa-based agroforestry systems in the Littoral region of Cameroon. The study's findings revealed that the most perceived indicators of soil fertility by cocoa farmers in cocoa-based agroforestry systems were cocoa yields, soil colour, indicator plant species, presence of soil macro-organisms, indicator weed species, growth rate/vigour of the cocoa plant, and level of compaction of the soil. Most cocoa farmers perceived the level of soil fertility in cocoa-based agroforestry systems to be between average and low. It was noticed that fertilizer/manure application, diversity of tree species in the cocoa agroforests, diversity of soil macro-fauna in the cocoa agroforests, and density of soil macro-fauna in the cocoa agroforests influenced soil fertility positively, implying that an increase in these factors leads to an increase in soil fertility. Age of the cocoa farm, density of cocoa plants in the cocoa agroforests, and application of agrochemicals in the cocoa agroforests influenced soil fertility negatively, implying that an increase in these factors leads to a decline in soil fertility. Thus, it is recommended that there should be more organic fertilizer/manure application, more diversity of tree species in the cocoa agroforests, and more measures to ensure the diversity and density of soil macro-fauna in cocoa-based agroforestry systems.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Jose. Agroforestry for ecosystem services and environmental benefits: An overview. *Agrofor Syst.* 2009;76:1–10.
2. Nair PKR. Agroforestry systems and environmental quality: Introduction. *Journal of environmental quality.* 2011;40(3):784–790.
3. Jose S. Agroforestry for conserving and enhancing biodiversity. *Agroforestry Systems.* 2012;85:1–8.
4. Dollinger J, Jose S. Agroforestry for soil health. *Agroforestry Systems.* 2018; 92:213–219.
5. Awazi NP, Tchamba NM. Enhancing agricultural sustainability and productivity under changing climate conditions through improved agroforestry practices in smallholder farming systems in sub-Saharan Africa. *African Journal of Agricultural Research.* 2019;14(7):379–388.
6. Tsufac AR, Yerima BPK, Awazi NP Assessing the role of agroforestry in soil fertility improvement in Mbelenka-Lebialem, Southwest Cameroon. *International Journal of Global Sustainability.* 2019;3(1):115–135.
7. Munjeb NL, Yerima BPK, Avana TML Farmer's perception of soil and watershed degradation and the assessment of soil nutrients status under agroforestry systems in the western highlands of Cameroon: Case of Ako sub division. *Journal of Soil Science and Environmental Management.* 2018;9(8):119-126.
8. Awazi NP, Avana TML. Agroforestry as a sustainable means to farmer-grazier conflict mitigation in Cameroon. *Agroforestry Systems.* 2020;94(6):2147–2165. Available: <https://doi.org/10.1007/s10457-020-00537-y>
9. Nair PKR An introduction to agroforestry, Dordrecht, Netherlands: Kluwer academic publishers; 1993.
10. Leakey RRB. Definition of agroforestry revisited *Definitio of agroforestry revisited Agroforestry.* 1996;81:5-7. Available: <https://www.researchgate.net/publication/269407082>
11. Amare D, Wondie M, Mekuria W, Darr D. Agroforestry of smallholder farmers in Ethiopia: Practices and benefits. *Small-scale Forestry.* 2018;18(1): 39-56.
12. Awazi NP, Tchamba NM, Temgoua LF. Enhancement of resilience to climate variability and change through agroforestry practices in smallholder farming systems in Cameroon. *Agroforest Syst* 2020;94:687-705. Available: <https://doi.org/10.1007/s10457-019-00435-y>
13. Asaah EK, Tchoundjeu Z, Leakey RRB, Takoung B, Njong J, Edang I. Trees, agroforestry and multifunctional agriculture in Cameroon. *International Journal of Agricultural Sustainability.* 2011;9(1):110-119.
14. Awazi NP, Tchamba NM, Avana TML. Climate change resiliency choices of small-scale farmers in Cameroon: determinants and policy implications. *Journal of Environmental Management.* 2019;250:109560.
15. Nfinn T Cocoa production in Cameroon. AFTA 2005 conference proceedings. 2005; 5.
16. Laird SA, Awung GL, Lysinge RJ. Cocoa farms in the mount Cameroon region: Biological and cultural diversity in local livelihoods. *Biodiversity Conservation.* 2007;16:2401–2427.
17. Sonwa DJ, Nkongmeneck AB, Weise SF, Tchatat M, Adesina AA, Janssens MJ Diversity of plants in cocoa agroforests in the humid forest zone of southern Cameroon. *Biodivers Conserv.* 2007; 16:2385–2400.
18. Jagoret P, Michel-Dounais I, Malezieux E. Long term dynamics of cocoa agroforests: A case study in central Cameroon. *Agroforestry Systems.* 2011;81: 267–278.
19. Jagoret P, Michel-Dounias I, Snoeck D, Ngnogue HT, Malezieux E. Afforestation of savannah with cocoa agroforestry systems: a small-farmer innovation in central Cameroon. *Agroforestry Systems.* 2012;86:493–504.
20. Jagoret P, Kwesseu J, Messie C, Michel-Dounias I, Malezieux E. Farmers' assessment of the use value of agrobiodiversity in multispecies systems. An application to cocoa agroforests in Central Cameroon. *Agroforestry Systems.* 2014; 88:983–1000.
21. Tankou CM. The Cameroon cocoa story. The supply change – Make supermarkets fair project sponsored by the European Union; 2015
22. Alemagi D, Duguma L, Minang PA, Nkeumoe F, Feudjio M, Tchoundjeu Z.

- Intensification of cocoa agroforestry systems as a REDD+ strategy in Cameroon: Hurdles, motivations and challenges. *International Journal of Agricultural Sustainability*. 2015;13(3):187–203.
23. Mukete N, Li Z, Mukete B, Bobyeg P. Cocoa production in Cameroon: A socio-economic and technical efficiency perspective. *International Journal of Agricultural Economics*. 2018;3(1):1–8.
 24. Jagoret P, Snoeck D, Bouambi E, Ngnogue HT, Nyasse S, Saj S. Rehabilitation practices that shape cocoa agroforestry systems in Central Cameroon: Key management strategies for long term exploitation. *Agroforestry Systems*. 2018; 92:1185–1199.
 25. Essougong UPK, Slingerland M, Mathe S, Vanhove W, Ngome PIJ, Boudes P et al. Farmers' perceptions as a driver of agricultural practices: Understanding soil fertility management practices in cocoa agroforestry systems in Cameroon. *Human Ecology*. 2020;1–12.
 26. Temgoua LF, Momo SMC, Boucheke RK. Floristic diversity of woody species in cocoa-based agroforestry systems in the littoral region of Cameroon: Case of Ioum sub-division. *European Scientific Journal*. 2019;15(9):62–83.
 27. Kimengsi JN, Azibo BR. How prepared are Cameroon's cocoa farmers for climate insurance? Evidence from the south west region of Cameroon. *Procedia Environmental Sciences*. 2013;29:117-128.
 28. Kimengsi JN, Tosam JN. Climate variability and cocoa production in meme division of Cameroon: Agricultural development policy options. *Greener Journal of Agricultural Sciences*. 2013;3(8):606 – 617.
 29. Tankou CM, de Snoo GR, Persoon G, de longh HH. Evaluation of smallholder farming systems in the Western Highlands of Cameroon. *IOSR Journal of Engineering*. 2017;7(1):1–11.
 30. Plan Communal de Developpement – PCD Melong Melong Council Development Plan, Working Document. 2012;154.
 31. Awazi NP, Tchamba NM. Determinants of small-scale farmers' adaptation decision to climate variability and change in the north-west region of Cameroon. *African Journal of Agricultural Research*. 2018;13(12):534–543.
 32. Dawoe EK, Quashie-Sam J, Isaac ME, Oppong SK. Exploring farmers' local knowledge and perceptions of soil fertility and management in the Ashanti Region of Ghana. *Geoderma*. 2012;179:96–103.
 33. Rousseau L, Fonte SJ, Tellez O, Van der Hoek R, Lavelle P. Soil macro-fauna as indicators of soil quality and land use impacts in smallholder agro-ecosystems of western Nicaragua. *Ecological Indicators*. 2013;27:71–82.
 34. Bezabih B, Lemenih M, Regassa A. Farmers' perception on soil fertility status of small-scale farming systems in southwestern Ethiopia. *Journal of Soil Science and Environmental Management*. 2016;7(9):143–153.
 35. Omari RA, Bellingrath-Kimura SD, Addo ES, Oikawa Y, Fujii Y. Exploring farmers' indigenous knowledge of soil quality and fertility management practices in selected farming communities of the guinea savannah agro-ecological zone of Ghana. *Sustainability*. 2018;10(4):1034.
 36. Oliveira PHG, Gama-Rodrigues AC, Gama-Rodrigues EF, Sales MVS. Litter and soil-related variation in the functional group abundances in cocoa agroforests using structural equation modeling. *Ecological Indicators*. 2018;84:254–262.
 37. Tongkaemkaew U, Sukkul J, Sumkhan N, Panklang P, Brauman A, Ismail R. Litter, litter decomposition, soil macro-fauna and nutrient contents in rubber monoculture and rubber-based agroforestry plantations. *Forest and Society*. 2018;2:138–149.
 38. Suarez LR, Audor LCU, Salazar JCS. Formation of macroaggregates and organic carbon in cocoa agroforestry systems. *Florestae Ambiente*. 2019;26(3).
 39. Marsden C, Martin-Chave A, Cortet J, Hedde M, Capowiez Y. How agroforestry systems influence soil fauna and their functions – A review. *Plant and Soil*. 2020; 453:29–44.
 40. Sileshi GW, Mafongoya PL, Nath AJ. Agroforestry Systems for improving nutrient recycling and soil fertility on degraded lands. *Agroforestry for Degraded Landscapes*. 2020;225–253.
 41. Dahlsjo CAL, Stiblik P, Jaklova J, Zidek M, Huaycama WJ, Lojka B, Houska J. The local impact of macro-fauna and land use intensity on soil nutrient concentration and exchangeability in lowland tropical Peru. *Biotropica*. 2020;52(2):242–251.

42. Moco MKS, da Gama-Rodrigues EF, da Gama-Rodrigues AC, Machado RCR, Baligar VC. Soil and litter fauna of cacao agroforestry systems in Bahia, Brazil. *Agroforestry Systems*. 2009;76:127–138.
43. Moco MKS, Gama-Rodrigues EF, Gama-Rodrigues AC, Machado RCR, Baligar VC Relationships between invertebrate communities, litter quality and soil attributes under different cacao agroforestry systems in the south of Bahia, Brazil. *Applied Soil Ecology*. 2010;46:347–354.
44. Wartenberg AC, Blaser WJ, Gattinger A, Roshetko JM, Van Noordwijk M, Six J. Soil fertility and Theobroma cacao growth and productivity under commonly intercropped shade-tree species in Sulawesi, Indonesia. *Plant and Soil*. 2020; 453:87–104.
45. Wartenberg AC, Blaser WJ, Gattinger A, Roshetko JM, Van Noordwijk M, Six J. Does shade tree diversity increase soil fertility in cocoa plantations? *Agriculture, ecosystems and environment*. 2017; 248:190–199.

© 2020 Tsufac et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:

The peer review history for this paper can be accessed here:
<http://www.sdiarticle4.com/review-history/64185>