Research Article

Journal of Agricultural, Earth and Environmental Sciences

Plant Diversity in Cocoa, Coffee and Cashew Agroforest in Southern Ghana

Daniel Ako Tetteh[1*] and Gadafi Iddrisu Balali[2]

[1]Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Department of Environmental Health and Sanitation Education, Ashanti Mampong, Ghana
[2]Department of science, SDA College of Education, Agona Ashanti region, Ghana

[*]Corresponding author: Daniel Ako Tetteh, Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Department of Environmental Health and Sanitation Education, Ashanti Mampong, Ghana.

Submitted: 22 May 2024 **Accepted:** 25 May 2024 **Published:** 07 June 2024

Citation: *Daniel Ako Tetteh, Gadafi Iddrisu Balali (2024) Plant Diversity in Cocoa, Coffee and Cashew Agroforest in Southern Ghana. J of Agri Earth & Environmental Sciences 3(3), 01-06.*

Abstract
Understanding the importance of cocoa, coffee, and cashew agroforestry systems in preserving biodiversity and ecosystem services remains limited in tropical and humid regions globally. This study seeks to evaluate plant species diversity within cocoa, coffee, and cashew agroforestry systems in comparison to natural forests, addressing a critical knowledge gap in these regions.

The forest reserve hosted the majority of shade trees, demonstrating greater density and basal area of native forest trees compared to cashew agroforest land. These findings underscore the significance of implementing sustainable management practices in tropical agricultural landscapes and contribute to ongoing biodiversity conservation efforts within agricultural contexts.

Keywords: Tree, Diversity, Conservation, Agroforest Ecosystems.

Introduction

Rainforests, covering merely 7% of the Earth's land area, are invaluable reservoirs of biodiversity, housing a staggering one-third of global species diversity [1]. However, the relentless encroachment of deforestation and degradation presents a looming threat to this ecological wealth, endangering both agricultural productivity and biodiversity preservation [2]. In response, agroforestry emerges as a beacon of hope amid the environmental crisis. While existing research extensively examines the adverse impacts of cocoa cultivation on land use and biodiversity agroforestry, integrating trees with crops and/or livestock, garners attention as a sustainable alternative [3-8]. Yet, significant knowledge gaps persist regarding the specific relevance of different agroforestry systems to biodiversity conservation. Notably, quantitative data on plant species diversity in various agroforestry systems compared to natural forests are scarce, particularly in monoculture- dominated agricultural landscapes [9]. Thus, this study aims to bridge this gap by investigating the contribution of coffee, cocoa, and cashew agroforestry systems to plant diversity conservation.

In Ghana, cocoa agroforestry prevails, with farmers strategically preserving shade trees to nurture young cocoa seedlings [10]. This approach, combining cocoa with high-value tree species and other crops, enhances ecological sustainability and improves farmers' livelihoods. Despite shaded cocoa agroforestry systems gaining attention for their biodiversity conservation potential, similar scrutiny has not been extended to coffee and cashew agroforestry practices.

Recent studies highlight the conservation value of coffee agroforests, rivalling natural forests in humid tropical landscapes [11, 12].

However, the comprehensive understanding of tree species diversity and its conservation significance in coffee, cocoa, and cashew agroforestry systems compared to natural forests remains unexplored. This study provides critical insights into the impact of different farming systems on plant diversity. Furthermore, by transcending traditional monoculture farming, this research explores the capacity of agroforestry systems to sustain diverse plant communities while maintaining agricultural productivity.

This holistic perspective advances our understanding of sustainable land management practices and offers practical guidance to policymakers, farmers, and conservationists striving to promote biodiversity conservation in agricultural landscapes. Our hypothesis posits that plant species diversity is higher in natural forests than in agroforestry systems. Thus, our study aims to quantify tree species diversity and evaluate its conservation implications across different agroforestry systems, shedding light on their potential role in biodiversity conservation and sustainable land management.

Materials and Methods

Study Area

The study was conducted on degraded and abandoned farmland near Ashanti Mampong campus of the Aketen Appiah-Menka University of Skills Training and Entrepreneurial Development. The study covered various agricultural sectors, including cocoa, coffee, and cashew farms, as well as the adjacent degraded natural forest (Tetteh and Amos, 2024a). The study area is positioned between longitudes 0°05' and 1°30'W and latitudes 6°55' and 7°30'N. The site experiences a double maximum rainfall pattern with peak rainfall periods in May-June and September-October and dry periods between November-February. The climate is typically tropical, with total annual rainfall between 1200 - 1500mm with an average rainfall of 1270 mm. The average annual temperature of the area was 27°C, with mean monthly temperatures ranging from 22 to 30°C. The potential evapotranspiration is estimated at 1450 mm per annum. The average humidity during the wet season is typically high at 86% and falls to about 57% in the dry period (GMET, 2006). The soil at the study site is classified as Chromic Luvisol (FAO-UNESCO, 1990) or Udic Rhodustalf (USDA, 1999) and locally referred to as Peduase series (Asiamah, 1998). The study area falls within the wet semi-equatorial forest zone with reforested mixture of Acacia angustissima (Acacia), Leucaena leucocephala (Leucaena), and Cassia siamea (Cassia). Although all the tree species used were exotic, they are well adapted to many climatic environments in sub-humid and semi-arid zone of West Africa and are fast growing with high biomass production potential. The most dominant grasses of the area include Imperata cylindrical (Imperata), Panicum maximum (Panicum) and sedges such as Cyperus spp(nut grass)

Methods

Field Survey

The study was conducted between December 2022 to March 2023, employing the line transect method to investigate various agroforest farmlands and natural forest reserves. Transect lengths ranged from 450 to 1000 meters and were positioned at least 200 meters apart for each land use category. Following the methodology outlined by Tetteh and, sampling plots measuring 20 meters by 20 meters were delineated at 50-meter intervals within the plots [13, 14]. The geographical coordinates of each plot were determined using a handheld Global Positioning System (GPS) device, with pegs placed at the corners to mark their boundaries.

Fifteen plots were established for each land use type, totaling 60 plots across cocoa, cashew, and coffee farms, as well as the natural forest. Tree diversity assessment followed the protocol described by Valencia et al., within each plot, all trees with a diameter at breast height (DBH) of ≥ 5cm (measured at 1.3 meters above ground level) were individually identified to the species level, and their DBH was recorded. Tree species identification was conducted in the field by experienced tree observers and verified through comparison with voucher specimens at the Forest Service Department, Ashanti Mampong Municipality [15].

Determination of Vegetation Parameters

The data on vegetation parameters such as relative density, relative dominance, relative frequency, and important value index of the most common tree species were determined using the following methods using the following formula [16]:

Relative density = Number of individual species x 100

Total number of individuals Relative frequency = Frequency of species x 100
The sum of the frequency of all species Relative dominance = Dominance of species x 100
The dominance of all species

Data Analysis

The research assessed shade tree diversity across various land-use types by employing the Shannon-Wiener diversity index (H) and the Jaccard similarity index. These calculations were conducted using EstimateS software (version 9.1.0) Additionally, the basal area of trees was determined using the formula πd2/4, where 'd' represents the diameter of the trees [17].

Statistical analyses, including ANOVA, were performed to identify statistically significant differences in the mean diameter at breast height (DBH), density, and basal area of trees among the three land-use types.

Results

Plant Composition, Diversity and Structural Characteristics

In total, 461 individual shade trees belonging to 62 species in 26 families were identified in this study (Table 1). Families with the greatest number of species were Leguminosae (16 specie), Meliaceae (9 species), Sterculiaceae (9 species), Apocynaceae (7 species), Euphorbiaceae (7 species) and Sapotaceae (6 species). Total number of shade tree species was 263 in the forest reserve, 85 in the cocoa agroforest, 74 in the coffee agroforest and 39 in the cashew agroforest (Fig 1). Of the species of trees identified ten (10) of them, namely, Alstoniaboonei, Albizia ferruginea, Azadirachta indica, Ficus exasperata, Funtumia africana, Khaya ivorensis, Lannea welwitschia, Luceana leocophala, Parkia biglobosa, and Terminalia superba were found in all the land-use types. With exception of Elaeis guinensis, Carica papaya and Musa sapientum Musa paradisica all the trees encountered were native forest trees species.

About (50.1%) of shade trees were observed in the forest reserve, 22.5% in the cocoa agroforest, 20.2% in the coffee agroforest, and 7.2% were recorded in the cashew agroforest respectively.

The non-crop tree species composition similarity was highest between cocoa and coffee agroforests and between the cocoa and cashew agroforest. The β-diversity statistics showed that non-crop tree species community in the cocoa and coffee agroforest are most similar (Jaccard index = 0.33) followed by that between the cocoa and cashew agroforest (Jaccard index = 0.12). The least non-crop tree species composition similarity was found between the natural forest and cashew agroforest (Jaccard index = 0.04).

Average density of native forest trees was higher in the forest reserve (17.40 ± 1.21 ha-1) and lower (2.07 ± 0.85 ha-1) in the cashew agroforest (Table 2). The density of native forest trees varied significantly across the land use types ($p < 0.001$). There was significant difference in mean density of native forest trees between the cocoa agroforest (Tukey HSD, $p < 0.0001$) and between the forest reserves and coffee agroforest (Tukey HSD, $p < 0.0001$). Average basal area was high (43.70 ± 5.34) in the forest reserve and low (15.56 ± 3.21) in the cashew agroforest basal area of forest trees differed significantly across land use types ($p < 0.001$). There were significant differences in tree basal area between forest reserve and cocoa agroforest (Tukey HSD, $p < 0.001$), and between forest reserve and coffee agroforest (Tukey HSD, $p < 0.001$).

Table 1: Tree Species Composition and Distribution in the Different Land use Types

Species	Family	Cocoa agroforest	Coffee agroforest	Cashew agroforest	Forest reserve
Acacia suberiana	Leguminosae	-	-	-	+
Albizia ferruginea Benth	Leguminosae	+	-	-	+
Albizia zygia J.F.Macbr	Leguminosae	+	+	-	+
Alstonia boonei De Wild	Leguminosae	+	+	+	+
Artocarpus comminus	Leguminosae	-	-	-	+
Azadirachta indica	Leguminosae	+	+	+	+
Bombax brevicuspe Sprague	Leguminosae	-	-	-	+
Bombax buonopozense	Leguminosae	-	-	-	+
Bridelia grandis	Leguminosae	-	-	-	+
Bridelia atroviridis Müll.Arg.	Leguminosae	-	-	-	+
Blighia welwitschii Hiern(Radlk)	Leguminosae	-	-	-	+
Ceiba pentandra Gaertn	Leguminosae	+	+	+	+
Carica papaya L	Caricaceae	+	+	-	-
Celtis malbraedii Engl	Ulmaceae	+	-	-	+
Celtis zenkeri Engl	Ulmaceae	-	-	-	+
Cedrela odorata Blanco	Meliaceae	-	-	-	+
Daniella olivieri Benn	Leguminosae	-	-	-	+
Dialium aubrevillei Pellegr	Caesalpinaceae	-	-	-	+
Dacryodes klaineana (Pierre) H.J.Lam	Burseraceae	-	-	-	+
Daniella olivieri Benn	Leguminosae	-	-	-	+
Diospyros gabunensis	Leguminosae	-	-	-	+
Elaeis guineensis Jacq	Palmae	+	-	-	+
Erythrina senegalensis A.DC.	Leguminosae	-	-	-	+
Ficus exasperata Vahl	Moraceae	+	+	+	+
Ficus sur Forssk	Moraceae	-	-	-	+
Funtumia africana (Benth.) Stapf	Apocynaceae	+	+	+	+
Funtumia elastica (Preuss)Stapf	Apocynaceae	-	-	-	+
Gliricidia sepium	Leguminosae	-	-	-	+
Gilbertiodenron preussii Harms	Leguminosae	-	-	-	+
Holarrhena floribunda (G.Don) T.Durand& Schinz	Apocynaceae	-	-	-	+
Khaya ivorensis A.Chev	Meliaceae	+	+	+	+
Lannea keristingii	Anacardiaceae	+	+	+	+
Lannea welwitschii (Hiern) Engl.	Anacardiaceae	+	+	+	+
Leucaena eococephala	Leguminosae	+	+	+	+

Table 1. 2: cont'd

Species	Family	Cocoa agroforest	Coffee agroforest	Cashew agroforest	Forest reserve
Macaranga barterii Müll.Arg	Euphorbiaceae	+	+	-	+
Mareya micrantha (Benth.) Müll.Arg	Euphorbiaceae	+	+	-	+
Morinda lucida	Rubiaceae	+	-	-	+

Parkia biglobosa	Leguminosae	+	+	+	+
Pappea capensis	Sapindaceae	+	-	+	-
Pycnanthus angolensis	Myristicaceae	+	+	-	+
Rhodagnaphalon brevicuspe (Sprague) Roberty	Bombacaceae	-	-	-	+
Ricinodendron heudelotii Perre ex Pax	Euphorbiaceae	-	-	-	+
Rinorea oblongifolia C. Marquand	Violaceae	-	-	-	+
Rinorea prasina	Violaceae	-	-	-	+
Rinorea sp Aubl	Violaceae	-	-	-	+
Rothmania hispida	Violaceae	+	-		+
Rothmania longiflora	Violaceae	+	-	-	+
Rothmania whitfieldii (Lindl.) Dandy	Violaceae				+
Sapium aubrevillei Leandri	Euphorbiaceae	+	+	+	-
Teatona grandis	Verbenaceae	+	-	-	+
Terminalia ivorensis	Combretaceae	+	+	+	+
Terminalia superba	Combretaceae	+	+	+	+
Trema orientalis Blume	Ulmaceae	-	-	-	+
Tricalysia discolor A. Juss	Rubiaceae	-	-	-	+
Tricalysia sp A. Rich.ex. DC	Rubiaceae	-	-	-	+
Trichilia monadelpha L.	Meliaceae	-	-	-	+
Trichilia prieureana P. Browne	Meliaceae	-	-	-	+
Trichilia tessmannii Harms	Meliaceae	-	-	-	+
Trilepesium madagascariensis DC	Moraceae	-	-	-	+
Xylopia zilosa	Annonaceae	-	-	-	+
Zanthoxylum gilletii L	Rubiaceae	-	-	-	+
Gliricidia sepium	Leguminosae	-	-	-	+
Gilbertiodenron preussii Harms	Leguminosae	-	-	-	+
Holarrhena floribunda (G.Don) T.Durand& Schinz	Apocynaceae	-	-	-	+
Khaya ivorensis A.Chev	Meliaceae	+	+	+	+
Lannea keristingii	Anacardiaceae	+	+	+	+
Lannea welwitschii (Hiern) Engl.	Anacardiaceae	+	+	+	+
Leucaena eococephala	Leguminosae	+	+	+	+

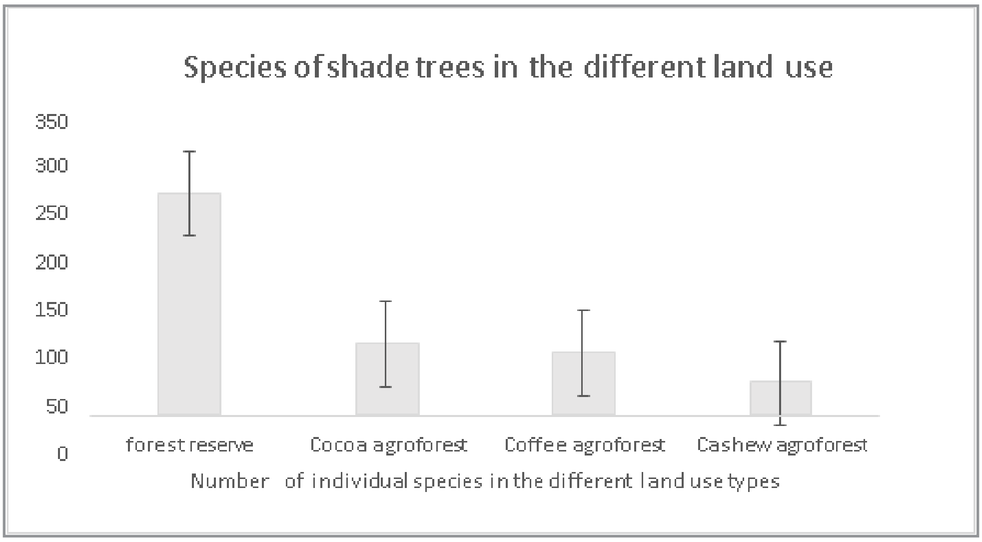

Figure 1: Number of Individual Shade trees in the Different land use Types

Table 2: Floristic and Structural Characteristics of Shade Trees in The Different Land Use Types

Parameters	Forest reserve	Cocoa agroforest	Coffee agroforest	Cashew agroforest
Number of individual trees	263	85	74	39
Number of tree species	58	25	17	13
Shannon-Weinner index	0.82	0.65	0.61	0.42
Mean stem density (m2/ha)	17.40	6.45	2.46	2.07
Mean basal area (m2/ ha)	43.72	24.97	20.14	15.56

Relative Frequency and Successional Stage of the Most Common Tree Species

It was observed that Khaya ivorensis recorded the highest (3.25) relative frequency, followed by the coffee farmlands (0.75) while the least (0.25) was observed in the cashew agroforest (Table 2). Among the common tree species found, Parkia biglobosa was found to have the lowest relative frequency in all the land use types. Except for Azadirachta indica, Ficus exasperata, and Parkia biglobosa all the other common species were pioneer species (Table 2).

Table 3: Relative frequency and successional stage of the most common trees in the different land use types

Species	family's	Relative frequency (% tree)				Successional Stage
		Cocoa farms	Coffee farms	Cashew farms	Forest	
Albizia ferrugineaBenth	Leguminosae	1.25	2.25	0.75	2.0	Pioneer
Alstonia boonei De Wild	Apocynaceae	0.25	0.75	1.0	2.25	Pioneer
Azadirachta indica	Meliaceae	1.25	1.75	0.5	3.0	Non-Pioneer
Ficus exasperata Vahl	Moraceae	0.75	0.25	0.5	2.0	Non-pioneer
Funtumia africana Stap f.	Apocynaceae	1.0	0.25	0.25	2.25	Pioneer
Khaya ivorensis A.Chev	Meliaceae	0.5	0.75	0.25	3.25	Pioneer
Lannea welwitschii Hiern	Anacardiaceae	0.5	0.75	0.5	1.75	Pioneer
Engl. Luceana leococephala	Leguminosae	1.5	1.25	1.0	1.25	Pioneer
Parkia biglobosa A.Chev	Leguminosae	0.5	0.5	0.25	1.0	Non-Pioneer
Terminalia ivorensis A. Chev	Combretaceae	1.0	0.5	0.5	2.75	Pioneer
Terminalia superba Engl.& Diels	Combretaceae	0.75	0.5	0.25	1.75	Pioneer

Discussions

In this investigation, a notable decrease in diversity of native forest tree species was observed within cocoa, coffee, and cashew agroforest farmlands. This decline aligns with earlier findings, highlighting the role of trees in providing shade for shade tree crops and fostering biodiversity [18, 19]. The gradual transition of natural forest into agroforest ecosystems underscores the urgency for effective management strategies to curb further deforestation. Diminished forest tree presence in food crop farmlands not only diminishes biological diversity but also disrupts ecosystem functions and environmental services [19]. The tree species richness and abundance within cocoa, coffee, and cashew farms were comparable to findings in Ghana and elsewhere [9, 20]. Notably, the Shannon-Weiner index for natural forests exceeded values observed in agroforest farms, resembling findings in a coffee-based agroforestry system in Southern Ethiopia [2]. Variations in tree species among food crop farms may be attributed to differing management practices and farm histories.

Our results reveal that the average density of shade tree species in natural forests was lower compared to coffee, cocoa, and cashew farmlands. While these farms necessitate some degree of shade for optimal yields, the ideal number of shade trees in coffee or cocoa plantations remains uncertain. Although consensus suggests that excessive shade diminishes yields, moderate shade may prove more beneficial than none at all [21-23]. This observation aligns with reports of lower tree densities in coffee farms in Eastern Uganda [20, 24]. The reduced tree count in our study may be attributed to the high density of oil palm plants within coffee and cocoa farms. The relative frequency and successional stage of the most prevalent tree species in agroforestry farms illustrate farmers' conscious efforts in managing specific shade trees, potentially for medicinal or other related benefits.

Conclusion

In summary, the significant decline in tree species diversity within cocoa, coffee, and cashew farmlands has led to notable reductions in stem density and basal area. The dominance of only a select few shade tree species in these farmlands, as indicated by the importance value index, underscores the need for sustainable management practices in tropical agricultural production landscapes. These findings carry profound implications for both the management of agricultural ecosystems and the conservation of biodiversity within agricultural landscapes. Policy interventions aimed at promoting agroforestry practices, preserving native tree species diversity, and incentivizing sustainable land management strategies are crucial steps toward mitigating further declines in tree diversity and fostering long-term environmental sustainability in agricultural settings.

Acknowledgement

We extend our sincere appreciation to the final year students for their invaluable assistance during the data collection process. We are especially grateful to farm manager for his unwavering support and cooperation throughout the fieldwork endeavor.

References

1. Tetteh DA, Asase A, Ofori-Frimpong K, Attuquayefio D (2018) Effect of cocoa farming intensification on biodiversity and ecosystem properties in southern Ghana. Journal of Ecology and The Natural Environment 10: 172-181.
2. Tesfay HM, Negash M, Oettel J, Lapin K (2023) Plant Diversity and Conservation Role of Three Indigenous Agroforestry Systems of Southeastern Rift–Valley Landscapes, Ethiopia. Diversity 16: 64.
3. Kelley LC (2018) The politics of uneven smallholder cacao expansion: a critical physical geography of agricultural transformation in Southeast Sulawesi, Indonesia. Geoforum 97: 22-34.
4. Torralba M, Fagerholm N, Burgess PJ, Moreno G, Plieninger T (2016) Do European agroforestry systems enhance biodiversity and ecosystem services? A meta-analysis. Agric Ecosyst Environ 230: 150-161.
5. Arosa ML, Bastos R, Cabral JA, Freitas H, Costa S R, et al. (2017) Long-term sustainability of cork oak agro-forests in the Iberian Peninsula: a model-based approach aimed at supporting the best management options for the montado conservation. Ecol Model 343: 68-79.
6. Den Herder M, Moreno G, Mosquera-Losada RM, Palma JH, Sidiropoulou A, et al. (2017) Current extent and stratification of agroforestry in the European Union. Agric. Ecosyst Environ 241: 121-132.
7. de Jalón SG, Graves A, Palma JH, Williams A, Upson M, et al. (2018) Modelling and valuing the environmental impacts of arable, forestry and agroforestry systems: a case study. Agrofor Syst 92: 1059-1073.
8. Moreno G, Aviron S, Berg S, Crous-Duran J, Franca A, et al. (2018) Agroforestry systems of high nature and cultural value in Europe: provision of commercial goods and other ecosystem services. Agrofor Syst 92: 877-891.
9. Asase A, Tetteh D (2010) The role of complex agroforestry systems in the conservation of forest tree diversity and structure in southeastern Ghana. Agroforestry Systems 79: 355-368.
10. Essouma FM, Isabelle M, Mala WA, Levang P, Ambang Z, et al. (2020) Cocoa-based agroforestry system dynamics and trends in the Akongo subregion of central Cameroon Franc. Agroforestry Systems 1-12.
11. Bhagwat SA, Willis KJ, Birks HJB, Whittaker RJ (2008) Agroforestry: a refuge for tropical biodiversity? Trends in ecology and evolution 23: 261-67.
12. McNeely JA, Schroth G (2006) Agroforestry and biodiversity conservation-traditional practices, present dynamics and lessons for the future. Biodivers Conserv 15: 549-554.
13. Tetteh DA, Amos I (2024) Effect of land use on soil macrofauna in Southern Ghana. Biodiversity. https://doi.org/10.1080/14888386.2024.2342311.
14. Manaye A, Negash M, Alebachew M (2019) Effect of degraded land rehabilitation on carbon stocks and biodiversity in semi-arid region of Northern Ethiopia. Forest Science and Technology 70-79.
15. Valencia V, García-Barrios L, West P, Sterling EJ, Naeem S (2014) The role of coffee agroforestry in the conservation of tree diversity and community composition of native forests in a Biosphere Reserve. Agriculture, Ecosystems & Environment 189: 154-163.
16. Abdulrasyid T, Hasna A, Sintje L (2019) The Composition and Important Value Index of Trees for Wildlife Feed in Bacan Island, South Halmahera. International Conference on Life Sciences and Technology. doi:10.1088/1755-1315/276/1/012037.
17. Colwell RK (2019) EstimateS 9.1.0 Software. https://www.robertkcolwell.org/pages/estimates.
18. Tetteh DA (2009) Agroforestry, ecosystem, biodiversity conservation: A case study in the Eastern Region of Ghana. Unpublished Mphil Thesis Dissertation
19. Oliveira W, Cruz-Neto S, Marcelo T, Leonardo G, Carlos AP, et al. (2023) Markedly declining reproductive functional diversity of food plants in the world's largest tropical country despite rapid cropland expansion. Agriculture, Ecosystems & Environment.
20. Correia M, Diabaté M, Beavogui P, Guilavogui K, Lamanda N, et al. (2010) Conserving forest tree diversity in Guinée Forestière (Guinea, West Africa): the role of coffee-based agroforests. Biodiversity and Conservation 19: 1725-1747.
21. Meylan L, Christian G, Clémentine A, Jorge O, Louise J, et al. (2017) Evaluating the effect of shade trees on provision of ecosystem services in intensively managed coffee plantations. Agriculture, Ecosystems & Environment 245: 32-42.
22. Muschler RG (2001) Shade improves coffee quality in a sub-optimal coffee-zone of Costa Rica. Agroforestry Systems 51: 131-139.
23. Ruf FO (2011) The Myth of complex cocoa agroforest. The Case of Ghana. Human Ecology 39: 373-388.
24. López-Gómez AM, Williams-Linera G, Manson RH (2008) Tree species diversity and vegetation structure in shade coffee farms in Veracruz, Mexico. Agriculture Ecosystems & Environment 124: 160-117.