The prospect of biodiversity conservation in cocoa agroforestry landscape, Ghana

M. O. Ansah[1] , O. Pabi[1*], and J. S. Ayivor[1]

[1] *Institute for Environment and Sanitation Studies (IESS), University of Ghana, Accra, Ghana*

*Corresponding Author: *opabi@staff.ug.edu.gh*

Abstract

The adoption of cocoa agroforests in Ghana and other West African countries for biodiversity conservation has not been conclusive. Though constituting major landscapes, cocoa agroforests are not fully adopted for biodiversity conservation, despite the declining cover of protected forest areas that are considered as biodiversity hotspots. We assessed the biodiversity conservation potential of cocoa agroforest farms relative to a protected forest vegetation. Six plots were delineated in cocoa agroforest farms, and a plot in a protected forest. Trees with a diameter of, at least, 5 cm at breast height (1.3m) were identified and counted in the plots. Multiple quantitative general diversity measurements of species richness, Shannon index, Simpson index and Sorensen's plot similarity were estimated and compared among the plots. Though the protected forest recorded the highest (2.74) for the Shannon index, some cocoa farms recorded higher measurements as well (2.46 and 2.31). Three cocoa plots recorded higher values for Simpson index (0.92, 0.89 and 0.83) than the protected area (0.73). Dominance was higher in the protected forest (0.127) than one cocoa plot (0.098). The Sorensens's index showed a wide variation in similarity among the cocoa farms, indicating the possibility of management types. The finding indicates a potential for adopting cocoa agroforestry for biodiversity conservation, yet, given the variations in diversity measures among the farms, further studies to determine the management types and the mix of tree species diversity and abundance that yields the optimum sustainability benefits must be conducted.

Keywords: Protected forest, species richness, species count, Simpson index, Shannon index, Sorenson's coefficient, 'Kakum forest

Introduction

West African countries produce about 70% of the world's cocoa (FAO, 2019). Ghana produced about 1.1million metric tons of cocoa in the 2020/2021 cocoa season (GCB 2021). Cocoa production sustains cocoa businesses and rural households (Asamoah & Owusu-Ansah, 2017). Cocoa agroforestry is established in the forest regions of Ghana, which form part of the Guinean forests of West Africa, and noted for global significance in biodiversity of endemic species of flora and fauna (Norris et al., 2010). Traditional cocoa agroforest has been identified as hotspots of biodiversity (Norris et al 2010). However, these areas are also said to be experiencing deforestation, partly, due to cocoa production. In 2021, about 1.46 million ha of land was under cocoa production in Ghana (FAO, 2021). Protected forest areas have been used as a strategy for biodiversity conversation (Duran et al 2013). However, as the cover of protected forest and other forested areas reduce due to land use pressures, their potential and value for conserving biodiversity minimizes. Hence, cocoa agroforestry landscape has been recommended as alternative for conserving biodiversity (Suratman, 2018). Yet, their potential for sustainable biodiversity conservation has not been fully investigated.This study makes a contribution in this area.

Burgeoning human populations and intense land use exert immense pressure on forest resources that result in deforestation, forest degradation and biodiversity loss. Timber extraction and road construction in the forest are considered precursors for agricultural expansion. Ruf (2001), has observed that in Cote d'Ivoire, roads in timber concessionaires partly facilitated the influx of agricultural migrants that results in expansion, particularly, of cocoa and coffee, causing rapid deforestation. It has been observed that these activities lead to significant loss of forest species as vegetation structure becomes simplified (Norris et al., 2010). Between 2000 and 2013, the FAO (2019) observed that cocoa production made a large contribution to global deforestation, through forest conversion. Cocoa production contributes substantially to the economy of Ghana, contributing 7.3% of GDP (Afrane and Ntiamoah, 2011; Codjoe et al., 2013), and serves as a source of livelihood to many Ghanaians. In Ghana, cocoa production has been identified as the single most important commodity driver of deforestation in the cocoa mosaic landscape, contributing over a quarter (27%) of forest to agriculture conversion (Forestry Commission, 2017).

Contrary to the above claims, major cocoa production areas have been classified as biodiversity hotspots (Norris et al 2010; FAO,2011). It has been claimed that cocoa agroforest of native or exotic forest trees provides a multi-strata and multi-species system with a structure and function like the forest (FAO, 2002; Sonwa et al., 2014), mimicking a forest habitat and serving as faunal refuges (Griffith 2000). A recent study by Asigbaase et al (2019) in the Eastern Region of Ghana, observed high levels of diversity of shady trees: with higher levels in the organic cocoa farms (cocoa agroforest without agrochemical application) than the traditional cocoa agroforestry. They, however, did not compare the traditional cocoa farms with the natural forest. Besides, organic cocoa farms constitute a minor proportion of cocoa agroforestry in Ghana, hence would not be a major landscape for biodiversity conservation. Maintaining substantial proportions of shade trees in cocoa production systems is considered a sustainable land-use practice that complements the conservation of biodiversity within agricultural landscapes (Schroth et al. 2004; Asare, May 2006). Also, diverse trees on cocoa farms can be sold to supplement farm income to improve household welfare (Gockowski et al. 2006; Jagoret et al. 2014; Njini, 2021).

Given the inconclusiveness and contradictory observations, it is obvious that the understanding of the potential for the use of cocoa agroforestry as a biodiversity conservation strategy remains inconclusive. Therefore, the question of whether cocoa agroforest landscapes can host adequate species richness and abundance, to serve as biodiversity conservation landscapes is not fully answered. Deforestation reduces forest cover and transforms them into agro-ecosystems. Agricultural landscapes and forest land uses outside protected areas, are therefore, envisaged to become dominant areas for biodiversity conservation (Siebert, 2002; Putz et al. 2000; FAO, 2011). Thus, this study sought to evaluate the use of cocoa agroforestry for bio-diversity conservation.

The Kakum Forest and the adjoining non-forested landscape are important for both forest conservation and cocoa agroforestry. It is one of the areas for the implementation of the subnational REDD+ program dubbed 'Ghana Cocoa Forest REDD+ Program (GCFRP)'. The programme aims to reduce deforestation and forest degradation in the cocoa forest mosaic landscape by complementing cocoa production and forest management. Also, it seeks to make cocoa production resilient to climate change and at the same time, ensure livelihood enhancement of local farmers. It is envisaged that the findings of this study would provide knowledge to evaluate the potential and develop strategies for REDD+ interventions using cocoa agroforestry. Specifically, the study analyzed and made a comparison of tree count, richness, evenness, dominance and similarity on a protected forest reserve and cocoa farms of private owners. Quantitative diversity indices were used to estimate the diversity levels of both protected areas and cocoa agroforest landscapes. The rest of the paper reports on the methods, findings, discussions and conclusion.

Methodology

Study Area

The study area is in the Assin South district of the Central Region of Ghana (Fig 1). It occupies a total land area of 1100, 89650 km^2, representing about 11.4 percent of the region's total land area. It is bordered on the West by Twifo Hemang- Lower Denkyira District, Abura Asebu Kwamankese District on the South, Asikuma Odoben- Brakwa District and Ajumako Enyan Essiam District on the East and Assin North Municipal, in the North. Some of the cocoa growing communities were Assin Adiembra, Brahabebome and Assin Kruwa.

The area lies within the Evergreen and Semi-Deciduous Forest zones. It has a bimodal rainfall pattern, with the major season occurring from April to July, whereas the minor occurs between September and November. Annual rainfall averages between 1250 mm and 2000mm. Temperatures are generally high, with the highest average of about 30 ^{o}C occurring between March and April. The average humidity of the area is generally high: from 60 to 70 percent (GSS,,2014).

It has five protected forest reserves, namely, Ayensua, Krotoa, Apeminim, Atendansu and Kakum. Kakum also known as the Kakum Conservation Area (KCA) comprises the Assin Atandansu Resource Reserve (AARR) and the Kakum National Park (KNP) where exploitation of resources is prohibited. They are designated for scientific, educational, recreational, and aesthetic purposes (Pappoe, et al, 2010). Economic tree species like Wawa, Mahogany, Odum raffia and bamboo abound in the area (GSS, 2014). Many of the rural dwellers are dominantly farmers of cocoa and food crops.

Methods

Site selection and plots establishment

A reconnaissance survey was carried out to ascertain the type of cocoa production systems and the cocoa farm sizes in the study area. Matured farms with a mixture of cocoa and trees were the key candidates for the study. Three cocoa growing communities, namely: Adiembra, Brahabebome and Kruwa, all in the Assin South District, were purposively selected as they bordered the KCA ((Fig.1), hence presume to have the same ecological zone as the protected forest. The farmers also practice cocoa agroforestry. Cocoa farms of sizes greater than two hectares were selected with farmer consent. Assistance of local informants from the communities was sought. In all, six farms were purposely

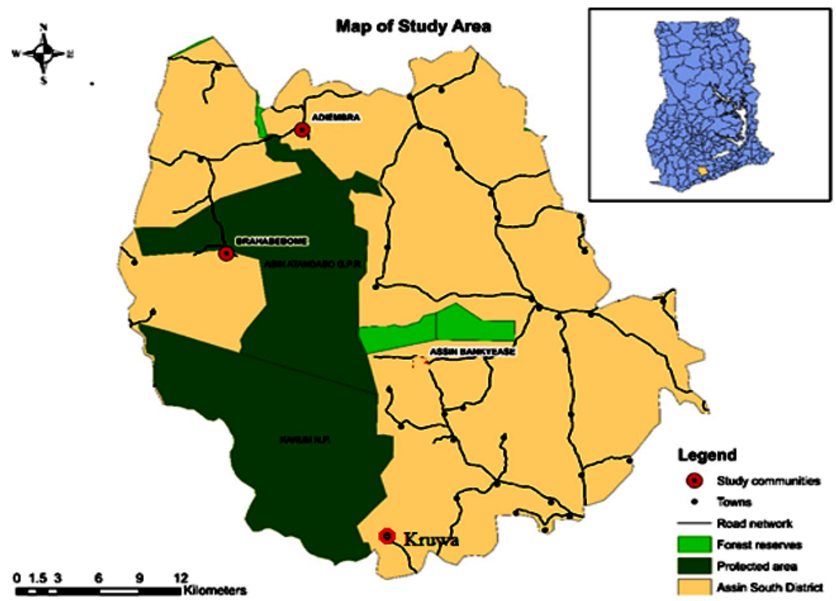

Figure 1 A map of Assin South District showing Adiembra, Brahabebome and Kruwa

selected based on the above selection criteria: two from each of the three communities.

A site was purposively selected from each farm. One site was also selected from the KCA for the comparative assessment. Thus, altogether, seven sites were selected for the study. For each site, a plot of 100m x 100m was demarcated, using a compass and a surveyor's tape. Wooden pegs were used in marking out the corners of the plots. Each plot was uniquely identified by their community's abbreviation and site number. The names used were as follows: Adiembra plot 1 (AP1), Adiembra Plot 2 (AP2), Brahabebome Plot 1 (BP1), Brahabebome Plot 2 (BP2), Kruwa Plot 1 (KP1), Kruwa Plot 2 (KP2) and KCA. Thus, a total of six plots of cocoa agroforest, and one.

Tree Identification and Enumeration

The diameter of all trees of, at least 5cm within the demarcated plots were measured at breast height (dbh) of 1.3m using a surveyor's tape and trees marked with white chalk for easy identification and counting. The enumeration team comprised a tree spotter and his assistant and a recorder. The Spotter identified the trees, measured the dbh and provided any useful information about it, while the recorder catalogued the species, dbh and any other information on a tally sheet. Trees were identified by the shape of their crowns, leaves, fruits, and bark texture. Trees that could not be identified on field were sent to the herbarium for identification (Hawthorne and Gyakari 2006).

Plant diversity and analysis

Multiple diversity measures were used to determine the general and different dimensions of plant diversity. Species richness was determined by species count (S) (Samways 1984; Krebs 1989). The Shannon diversity index (H) (Colwell and Huston 1991; Shannon and Weaver 1949) or equitability, was calculated as:

$$H_o = -\sum pi(\text{Ln } pi)$$

pi is ni/N,

where ni is the number of individuals per species i and N is the total number of individuals per study plot. Thus, pi is the proportion of individuals in species i. The Simpson's Index (D) (Simpson, 1949), was used to measure the probability that selecting two individuals will belong to the same species, with values ranging between 0-1. It is a measure of dominance, hence, high values indicates high dominance, whereas low probabilities indicate low dominance or high diversity (equitability). It was estimated using the formula:

$$1/D = 1/S[(n\ (n-1))/N(N-1)]$$

where n is the total count of individuals for a particular species in the sample and N is the total count of individuals in the sample. The Community/plot similarity was estimated by the Sorensen's coefficient (I) (Magurran, 2004), which is a measure of what the different communities have in common in terms of species. It gives a value between 0 and 1, where 1 is a complete community overlap and 0 is a complete or total community dissimilarity. The Sorensen's Coefficient equation is

$$CC = 2C/(S1+S2)$$

where: C represents the number of species the plots have in common, S1 is the total number of species in plot 1, S2 is the total number of species in plot 2.

Results

Tree species abundance, richness and family

A total of 699 individual trees comprising 65 different species and belonging to 30 families, were enumerated in all the 7 plots (Table 1). On average, a hectare of cocoa farm recorded 68 trees as compared to 293 on the natural forest. The six hectares of cocoa plots recorded 58% of the total tree counts, whereas a hectare of the natural forest plot alone recorded 42%. Cocoa farms in the northeastern (Brahabebome, 165) and Southern (Kruwa, 177) sections of the KCA recorded higher tree counts than the Northwest (Adiembra, 64). The six-hectare cocoa plots recorded 38 species belonging to 23 families, whereas the one hectare of protected forest (KCA) recorded 43 species,

TABLE 1
Species list and families

	Species		Family
	Local name	**Botanical name**	
1	Adwea	*Dacryodes klaineana*	*Burseraceae*
2	Afena	*Strombosia glaucescens*	*Olacaceae*
3	Akata	*Bombax buonopozense*	*Bombacaceae*
4	Akoua	*Antrocaryon micraster*	*Anacardiaceae*
5	Akyi	*Blighia sapida*	*Sapindaceae*
6	Asanfena	*Aningeria robusta*	*Sapotaceae*
7	Atabene	*Chrysophyllum perpulchrum*	*Sapotaceae*
8	Atoa	*Spondias mombin*	*Anacardiaceae*
9	Awiemfosaena	*Albizia ferruginea*	*Mimosaceae*
10	Baman	*Panda oleosa*	*Sapotaceae*
11	Bese	*Cola nitida*	*Sterculiaceae*
12	Besebuo	*Ivingia gabonensis*	*Sterculiaceae*
13	Cedar	*Entandrophragma candollei*	*Meliaceae*
14	Citrus	*Citrus spp*	*Rutaceae*
15	Danta	*Nesogordonia papaverifera*	*Sterculiaceae*
16	Dotodua		
17	Edubrafo	*Mareya micrantha*	*Euphorbiaceae*
18	Emire	*Terminalia ivorensis*	*Combretaceae*
19	Esa	*Malvaceae*	*Ulmaceae*
20	Esia	*Petersianthus macrocarpus*	*Lecythidaceae*
21	Esono nankroma	*Homalium letestui*	*Flacourtiaceae*
22	Esonoafe		
23	Fotie	*Hannoa klaineana*	*Simaroubaceae*
24	Foto	*Sterculia tragacantha*	*Sterculiaceae*
25	Fumtum	*Funtumia elastica*	*Apocynaceae*
26	Guava	*Psidium guajava*	*Myrtaceae*
27	Hyedua	*Daniellia ogea*	*Caesalpiniaceae*
28	Kakadukro	*Trichilia prieureana*	*Meliaceae*
29	Kakapenpen	*Rauvolfia vomitoria*	*Apocynaceae*
30	Konkroma	*Morinda Lucida*	*Rubiaceae*
31	Kosuoa	*Harungana madagascariensis*	*Guttiferae*
32	Kuakuabese	*Carapa procera*	*Meliaceae*
33	Kuakuanisuo	*Spathodea campanulata*	*Bignoniaceae*
34	Kumanini	*Lannea welwitschii*	*Anacardiaceae*
35	Kusia	*Nauclea diderrichii*	*Rubiaceae*
36	KyenKyen	*Antiaris toxicaria*	*Moraceae*
37	Mahogeny	*Khaya ivorensis*	*Meliaceae*
38	Mango	*Mangifera indica*	*Anacardiaceae*
39	Nyamedua	*Alstonia boone*	*Guttiferae*
40	Nyankomah	*Myrianthus libericus*	*Moraceae/Urticaceae*
41	Nyankyerene	*Ficus exasperata*	*Moraceae*
42	Obua	*Napoleonaea vogelii*	*Lecythidaceae*
43	Odoma	*Ficus capensis*	*Moraceae*

TABLE 1 *cont.*
Species list and families

	Species		Family
	Local name	Botanical name	
44	Odon	*Erytrophleum suaveolens*	*Fabaceae*
45	Odum	*Milicia excelsa*	*Moraceae*
46	Ofram	*Terminalia superba*	*Combretaceae*
47	Ohaa	*Sterculia oblonga*	*Sterculiaceae*
48	Okoro	*Albizia zygia*	*Mimosaceae*
49	Okuo	*Zanthoxylum gilletii*	*Rutaceae*
50	Okure	*Bosqueia angolensis*	*Cecropiaceae*
51	Omena	*Diospyros kamerunensis*	*Ebenaceae*
52	Onyina	*Ceiba pentandra*	*Malvaceae*
53	Opam kotokro	*Macaranga barteri*	*Euphorbiaceae*
54	Osran(yooyi)	*Dialium guineense*	*Fabaceae*
55	Otie	*Pycnanthus angolensis*	*Myristicaceae*
56	Ototim	*Treculia africana*	*Moraceae*
57	Pear	*Persea americana*	*Lauraceae*
58	Pepea	*Margaritaria discoidea*	*Euphorbiaceae*
59	Sese	*Holarrhena floribunda*	*Apocynaceae*
60	Sesemasa	*Newbouldia laevis*	*Apocynaceae*
61	Tanuro	*Trichilia monadelpha*	*Meliaceae*
62	Wama	*Ricinodendron heudelotti*	*Euphorbaceae*
63	Watapuo	*Cola gigantea*	*Sterculiaceae*
64	Wawa	*Triplochiton scleroxylon*	*Malvaceae*
65	Yaya	*Amphimas pterocarpoides*	*Caesalpiniaceae*

TABLE 2
Tree species abundance, richness and family of plots

ATTRIBUTES	AP1	AP2	BP1	BP2	KP1	KP2	KCA	TOTAL
Species Abundance	31	33	114	51	130	47	293	699
Species Richness	10	15	21	16	14	4	43	65
Family	9	13	15	16	7	4	24	30

belonging to 24 families (Table 2).

Tree abundance varied widely among the cocoa, with Kruwa Plot 1 (KP1) recording the highest of 130 trees per hectare, followed by Brahabebome Plot 1 (BP1) with 114. The natural forest recorded 293 trees per hectare. The total and average tree species count per hectare was 80 and 13 for the cocoa farms. The standard deviation of tree count for all the cocoa farms was 43, whereas the species count standard deviation was about 6.

Generally, species richness increased with abundance, with the exception of KP1 and KP2 as depicted (Table 2). The highest richness for the cocoa plots was BP1, which recorded 32% of the tree species, followed by BP2 (24%) with KP2 recording only 6% of the tree species. Plots KP1 and KP2 had few species, namely, *Morinda lucida* (69) representing more than half (53%), *Rauvolfia vomitoria* (23), representing 18%, *Albizia zygia* (14) representing 11% and the remaining 13 species contributed 18% of the tree count.

All the 699 tree species recorded belonged to 30 families. Plot KCA recorded highest

TABLE 3
Tree diversity measurements

	2.06	2.49	2.16	2.31	1.62	0.67	2.74
	7.8	12.06	8.67	10.07	5.05	1.94	15.49
	0.89	0.92	0.71	0.83	0.62	0.49	0.73
	0.159	0.098	0.223	0.144	0.328	0.669	0.127
1-D	0.841	0.902	0.777	0.856	0.672	0.331	0.873

number of families, constituting 80%. This was followed by BP2 (53%), BP1 with 50%, AP2 with 43%, AP1 with 30%, KP1 with 23% and KP2 with 13%. The richest families were Sterculiaceae and Moraceae, with six species each, followed by Meliaceae with 5 spp., and Anacardiaceae and Apocynaceae with four spp. each.

The Shannon diversity index measurements ranged between 0.67 and 2.49 for the cocoa farms (Table 3). The average estimate was 1.90, with the standard deviation being 0.66. The highest value was (2.49) for AP2, with the lowest, 0.67, recorded for KP2. Thus, of the cocoa farms, the AP2 recorded the highest diversity or equitability, very similar to the protected forest area. The protected forest recorded 2.74, which was the highest of all seven plots. The exponentiated values followed the same pattern (Table 3). The relatively very low exponentiated value of KP2 of less than two is indicative of very few species and with low abundance,

The Evenness index recorded measurements from 0.49 to 0.92, for the cocoa farms (Table 3). The equitability for the protected forest was 0.73. Evenness measurements among cocoa agroforestry farms, including AP1, AP2 and BP2, were higher than the protected forest. Hence, dominance was higher for the protected forest than the cocoa agroforest (Table 3). The Simpson's index ranged between 0.098 and 0.669 for the cocoa agroforestry farms. The highest was recorded for KP2 (0.669), which was about sevenfold the lowest recorded for AP2, 0.098. The KCA recorded 0.127, which was lower in diversity than AP2.

The Sorensen's similarity index measurement between the cocoa agroforestry farms and the natural forest obtained was 0.19 or 19%. However, the cocoa were more similar, with a value of 0.425 (42.5%). Specifically, plot KP2 and KCA were the most dissimilar (4.34%) among all the plots. The similarity between the BP1 and the protected forest was the highest (33.8%): it was more than the similarity between any cocoa agroforestry farm and a forest reserve. Tree species that were common in the area were *Celtis mildbraedii*, *Diospyros sanza-minika*, *Carapa procera*, *Cola gigantea*, *Dacryodes klaineana*, *Funtumia elastica*, and *Nesogordonia papaverifera*. These were known forest trees present in the Kakum conservation area.

Discussion

Tree abundance, richness and families

Generally, tree abundance on cocoa farms was higher than the 18 per hectare recommended for cocoa agroforestry farms by the Cocoa Research Institute of Ghana (CRIG) (Anim-Kwapong, 2006). Though KP1 and KP2 recorded the highest tree count for cocoa farms (Table 2), they recorded lower species richness as few tree species, namely, *Morinda lucida*, *Rauvolfia vomitoria* and *Albizia zygia* recorded high tree count. The predominance of *Morinda lucida* on cocoa farms has been associated with their use in traditional medicine. This confirms the assertion that, farmer's preference of shade trees revolve around their importance to the farmers and their favorable interactions with cocoa trees (Asare and Asare 2008; Smith Dumont et al 2014). In a study conducted by Asigbaase et al. (2019), they recorded 454 trees/ha belonging to 41 species and 18 families on organic cocoa systems.

Kpakpo et al., (2010) have recorded 73 per 2.2 plots in the Kakum area. In another forest area of Ghana, a much higher richness of 80 species per ha was recorded (Vordzogbe, et al., 2005). Earlier studies in other parts of West Africa's tropical high forests recorded 60 and 70 species per hectare (Lawson, 1985). In contrast, others have recorded lower species richness Ghana: 37 species/ha by Anning, et al,(2008) and 28 species/ha by Addo-Fordjour et al, 2009). Although the species richness of the KCA plot is lower than those recorded in other parts of West Africa, it is comparable to what was recorded by Anning, et al., (2008) and Pappoe et al., (2010) in a disturbed semi-deciduous forest of Ghana.

Plots like AP2, with relatively lower tree counts (33/ha) but high richness (15 spp./ha) and low species dominance meets the criteria espoused by some researchers. According to them maintaining substantial proportions of shade trees in a diverse cocoa production systems is a sustainable land-use practice that complements the conservation of biodiversity within agricultural landscapes (Schroth et al. 2004; Asare, May 2006). They hold the view that such farms stand a great chance of conserving biodiversity than those with numerous trees with high species dominance.

The richest tree families observed on the cocoa farms, ie, Sterculiaceae (6), Moraceae (6), Meliaceae (5), Anacardiaceae (4) and Apocynaceae (4), were also found by Asigbaase et al., (2019), who recorded Moraceae and Apocynaceae as the richest families on a traditional cocoa farms. Some tree species of the families Sterculiaceae, Moraceae and Fabaceae, such as Albizia ferruginea, *Albizia zygia*, *Amphimas pterocarpoides*, *Ficus exasperata*, *Antiaris toxicaria*, and *Melicia excelsa* are known to improve soil nutrients through nitrogen fixation, provides good shade which keeps soil cool and moist, are a good source of local construction material and commercial timber (Asare et al, 2014; Asase et al, 2009; Dawoe et al, 2016 & Anglaaere et al, 2011). Other research have made similar findings, where farmers prefer tree species that are medicinal, provides construction materials, timber, improves soil fertility and are shady (Tondoh et al, 2015; Asare et al, 2014; Tscharntke et al, 2011 & Asase et al, 2009).

Tree diversity in cocoa farms and forest

The forest landscape recorded the highest tree diversity compared to the average diversity on the cocoa farm, except for two plots AP2 and BP2. The Shannon index score was highest for plot AP2 (2.47), since many tree species had high and almost equal representations. This is an indication of minimal dominance, which compares favorably with findings in Cameroon by Jagoret et al. (2014), who obtained values of 2.42 for the Shannon index, and 2.6 by Asase and Teteh (2010) for same index in Ghana. In a recent study in Cameroon, the the Shannon index values reported for the cocoa agroforestry plots range between 2.95 to 3.43 (Njini, 2021), an indication of a higher tree diversity than what was recorded in this study. This cocoa plots AP2 and BP2 can serve as a farm management type that are better at conserving biodiversity than KP2, which scored highest in abundance but lowest in diversity. However, given the high tree abundance of plot KP2, it may have a high capacity and value for carbon sequestration and climate change mitigation, and thus serving to achieve the objective of REDD+.

The sample plot from the forest recorded the highest diversity value of 2.74, was higher than cocoa agroforestry farms (figure 2). Cocoa agroforest, although, ecologically friendlier than other agriculture land use types in the area, were not the same as protected forests (Donald, 2004). However, the equitability index of the forest was lower than two plots from the cocoa farms. This implies that tree species found on the farms are evenly represented in abundance than the forest. This agrees with the finding that farmers, especially, those from developing countries are responsible for high biodiversity in agro-ecosystem landscapes since they are critical sources of food security, nutrition, and sustenance of their livelihoods

(Sundar, 2011). They may have decided which tree species and numbers to nurture or thin out based on economic, medicinal or food benefits and its good interaction with the cocoa.

Plots KP1 and KP2, which scored lowest for species diversity, scored highest for dominance based on the Simpsons Index (Table 3). The two farms are more of a monoculture cocoa plantation, hence makes limited contribution to biodiversity conservation. Consequently, cocoa on these farms may lack the benefits enjoyed by cocoa agroforestry such as suppression of weeds, pest control, nutrient enrichment, provision of shade, creation of microclimate etc. They many have followed the practice of the low shade cocoa farming in the area.

Similarities

Species such as *Blighia sapida*, *Nesogordonia papaverifera*, *Aningeria robusta* (*Asanfena*), *Albizia ferruginea*, *Triplochiton scleroxylon*, and *Amphimas pterocarpoides* were found in both the forest and cocoa farms. Others like *Cola gigantea*, *Ceiba petandra*, *Carapa procera* though present in the forest were absent in the cocoa farms. Wiafe (2016), in his study of the Kakum Conservation Area, counted about the same species on one of his sample plots in Adiembra. These are known forest trees present in the Kakum conservation area. Pappoe et al. (2010), found Sterculiaceae and Meliaceae as the most common families in a study of the Kakum Conservation area. They found species such as *Carapa procera*, *Entandrophragma candollei*, *Khaya ivorensis*, *Trichilia monadelpha*, *Trichilia prieureana*, *Cola gigantea*, *Cola nitida*, *Ivingia gabonensis*, *Nesogordonia papaverifera* and *Sterculia oblonga* as some of the most common trees.

According to the Sorensen's index of similarity, averagely, the cocoa plots were much dissimilar to the forest (19%). However, the similarity between the forest and BP1 was relatively high (33.8%), an indication of BP1being a candidate farm that may be further studies for sustainable cocoa production. In contrast, KP2 and the forest were the most dissimilar (4.3%). These wide variations may be due to the history of managing the different agroforestry farms. The extreme cases may be studied for their socio-economic and environmental benefits. It has been indicated that a composition with a mixture of cocoa, native or exotic forest trees provides a multi-strata and multi-species systems that function like the forest (FAO, 2002; Sonwa et al., 2008), mimicking a forest habitat and serving as faunal refuges (Griffith, 2000).

Conclusion

The study evaluated the potential of using cocoa agroforestry for the conservation of biodiversity, by comparing tree species count and abundance, diversity, evenness, dominance and similarity using quantitative measurement of cocoa agroforestry farms and a protected forest. For species count and abundance, there were substantial variations among the cocoa farms. There should be further investigation of the management types that resulted in the variability. The forest recorded higher values of species count and abundance than all the cocoa farms. However, some cocoa farms recorded almost half the abundance and species count of the forest species.

Though the protected forest recorded the highest measurement for the Shannon index, some cocoa agroforest recorded values that were quite similar. For dominance by the Simpson index, however, some cocoa farms recorded higher values than the protected area (see AP1, AP2 and BP2 in table 3), indicating a relatively high dominance in the protected area. This implies that though higher abundance of trees was found in the protected forest, hence may be good for carbon sequestration capacity, they are not necessary the same for biodiversity conservation. This indicates a high potential for using the cocoa agroforestry farms for biodiversity protection since there is a good representation of the different species present. Obviously, the study provides indication of the potential for the use of cocoa agroforestry for plant biodiversity conservation. Yet, given the high variations in the tree biodiversity indicator values for the cocoa farms, it will be important to do further studies for a cost benefit analysis to identify the mix of tree species counts and abundance that yields the optimum sustainability benefits.

Acknowledgement

We acknowledge the assistance of all who supported the field sampling activities and the communities for their corporation.

References

Afrane, G. and Ntiamoah, A. (2011). Comparative life cycle assessment of charcoal, biogas, and liquefied petroleum gas as cooking fuels in Ghana. *Journal of Industrial Ecology*, **15(4)**:539-549.

Anglaaere, L. C. N., Cobbina, J., Sinclair, F. L. and McDonald, M. A. (2011). The effect of land use systems on tree diversity: farmer preference and species composition of cocoa-based agroecosystems in Ghana. *Agroforestry Systems*, **81**:249–265.

Anim-Kwapong, G. J. (2006). Potential of planted and natural tree fallows for rehabilitation of degraded cocoa farmlands in Ghana. Paper presented at the conference on extending cacao for biodiversity conservation, Kumasi, Ghana

Asare, R. (2006). A review on cocoa agroforestry as a means for biodiversity conservation. Paper Presented at the World Cocoa Foundation Partnership Conference, Brussels, Ball GH, Hall

Asigbaase, M. Sjogersten. S., Lomax. B. H. and Dawoe, E. (2019) Tree diversity and its ecological importance value in organic and conventional cocoa agroforests in Ghana. *PLoS ONE* **14(1)**: e0210557. https://doi.org/10.1371/journal. pone.0210557

Asare, R. & Asare, R. A. (2008). A participatory approach for tree diversification in cocoa farms: Ghanaian farmers experience. Technical Report https://biblio1.iita.org/handle/20.500.12478/3525

Asare, R., Afari-Sefa, V., Osei-Owusu, Y. and Pabi. O. (2014). Cocoa agroforestry for increasing forest connectivity in a fragmented landscape in Ghana. *Agroforestry Systems*, **88**:1143–1156.

Asase, A., Ofori-Frimpong K. and Ekpe, K. (2009). Impact of cocoa farming on vegetation in an agricultural landscape in Ghana. *A. Journal Ecology*, **48**:338–346.

Asigbaase, M., Sjogersten, S., Lomax, B. H. and Dawoe, E. (2019a). Tree diversity and its ecological importance value in organic and conventional cocoa agroforests in Ghana. *PLoS ONE*, **14(1)**:1–19. https://doi.org/10.1371/journal.pone.0210557

Boateng, D. O., Cudjoe, F. N. Y. and Ofori, J. (2014). Impact of illegal small scale mining (Galamsey) on cocoa production in Atiwa district of Ghana. *International Journal of Advance Agricuture Research*, **2**: 89–99.

Codjoe, F. N. Y., Ocansey, C. K., Boateng, D. O. and Ofori, J. (2013b). Climate change awareness and coping strategies of cocoa farmers in rural Ghana. *Journal of Biology, Agriculture and Healthcare*. **3(11)**:19–29.

Dawoe, E., Asante, W., Acheampong, E., and Bosu, P. (2016). Shade tree diversity and aboveground carbon stocks in Theobroma cacao agroforestry systems: implications for REDD+ implementation in a West African cacao landscape. *Carbon balance and management*, **11**, 1-13.

Durán, A. P., Casalegno, S., Marquet, P. A., and Gaston, K. J. (2013). Representation of ecosystem services by terrestrial protected areas: Chile as a case study. *PLoS one*, **8(12)**, e82643.

FAO. (2002). Forestry Laws & Regulations. http://www.fcghana.com/publications/ laws/index.htm

FAO. (2011). The state of the world's forests. *Food and Agricultural Organization*. Rome, Italy, 179 pp.

FAO. (2019). FAOSTAT. Available online: http://www.fao.org/faostat/en/#data/QCL

Forestry Commission. (2017). The Ghana Cocoa Forest REDD+ Program

GCB. (2022). *Sector Industry Analysis-Cocoa Sector Report 2022*. Ghana Commercial

Bank Strategy & Research Dept, Ghana.

Ghana Statistical Service. (2014). 2010 Population and Housing Census. *District Analytical Report*. *Ghana Statistical Service*, 1–109. https://doi.org/10.1371/journal. pone.0104053

Gockowski, J., Tchatat, M., Dondjang, J. P., Hietet, G. and Fouda, T. (2006). The Value of Biodiversity in the Beti Cocoa Agroforests of Southern Cameroon. Paper presented at the International Society of Tropical Foresters Conference on Conservation and The Agricultural Frontier, Yale University, School of Forestry and Environmental Science, New Haven, CT., April 7, 2006.

Griffith, D. M. (2000). Agroforestry: a refuge for tropical biodiversity after fire. *Conservation Biology* **14**: 325-326

Hawthorne, W. D. (1989). The flora and vegetation of Ghana's forests. In: Ghana forest inventory pro- ceedings. *Overseas Development Agency/Ghana Forestry Department*, *Accra*, 8–13.

Hawthorne, W. and Gyakari, N. (2006). Photoguide for the forest trees of Ghana: tree–spotters guide for identifying the largest trees. Oxford Forestry Institute, UK.

Krebs, C. J. (1985). Ecology—the experimental analysis of distribution and abundance, 3rd edition. Harper & Row Publishers, New York.

Magurran, A. (2004). Measuring biological diversity. Blackwell Publishing; Oxford, UK.

Moguel, P. and Toledo, V. M. (1999). Biodiversity conservation in traditional coffee systems in Mexico. *Conservation Biology*, **13**:11–22.

Njini, L. M., Marie-Louise, A. T., Yerima, B. K. P. and Roger, K. E. (2021). Cocoa-based agroforestry systems and its potential for tree resource conservation around the Dja Biosphere Reserve Southeastern Cameroon. *Journal of Ecology and The Natural Environment*, **13(3)**:73-82.

Norris, K., Asase, A., Collen, B., Gockowski, J., Mason, J., Phalan, B. and Wade, A. (2010). Biodiversity in a forest-agriculture mosaic–The changing face of West African rainforests. *Biological conservation*, **143(10)**:2341-2350.

Pappoe, A. N., Armah, F. A., Quaye, E.C. and Kwakye, P.K. B. (2010). Composition and stand structure of a tropical moist semi-deciduous forest in Ghana. *International Research Journal of Plant Science*, **1(4)**:95–106. http://www.interesjournals.org/irjps/october-2010-vol-1-issue-4.

Putz, F. E., Redford, K. H., Robinson, J. G., Fimbel, R. and Blate, G. M. (2000). *Biodiversity conservation in the context of tropical forest management*. World Bank Environmental Department, New York.

Ruf, F. (2001). Tree crops as deforestation and reforestation agents: the case of cocoa in Côte d'Ivoire and Sulawesi. In *Agricultural technologies and tropical deforestation* (pp. 291-315). Wallingford UK: CAB International.

Schroth, G., Da Fonseca, G. A., Harvey, C. A., Gascon, C., Vasconcelos, H. L., Izac, A. M. N., ... and Wilkie, D. S. (2004). Conclusion: agroforestry and biodiversity conservation in tropical landscapes. *About Island Press*, Washington.

Siebert, S. F. (2002). From shade- to sun-grown perennial crops in Sulawesi, Indonesia: implication for biodiversity conservation and soil fertility. *Biodiversity and Conservation*, **11**:1889–1902.

Smith Dumont, E., Gnahoua, G.M., Ohuo L, Sinclair, F. L. and Vaast, P. (2014). Farmers in Côte d'Ivoire value integrating tree diversity in cocoa for the provision of ecosystem services. *Agroforestry Systems*, **88**:1047–1067.

Sonwa, D. J., Weise, S. F., Schroth, G., Janssens, M. J., & Shapiro, H. Y. (2014). Plant diversity management in cocoa agroforestry systems in West and Central Africa—effects of markets and household needs. *Agroforestry systems*, **88**, 1021-103

Sundar, I. (2011). Food security through biodiversity conservation. Int. Conf. Asia Agric. Anim., *IPCBEE*, **13**:131.

Suratman, M. N. (2018). Introductory Chapter: Conserving Biodiversity in Protected Areas. National Parks -

Management and Conservation. doi: 10.5772/intechopen.73566

Tondoh, J. E., Kouamé, F. N. G., Guéi, A. M., Sey, B., Koné, A. W., and Gnessougou, N. (2015). Ecological changes induced by full-sun cocoa farming in Côte d'Ivoire. *Global Ecology and Conservation*, **3**:575-595.

Tscharntke, T., Clough, Y., Bhagwat, S. A., Buchori, D., Faust, H., Hertel, D., ... and Wanger, T. C. (2011). Multifunctional shade-tree management in tropical agroforestry landscapes–a review. *Journal of Applied Ecology*, **48(3)**:619-629.