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Cocoa-agroforestry in Ghana: Practices, determinants and constraints faced by farmers

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To address the growing global demand for cocoa, sustainable intensification of its production in Ghana, the second largest producer, is considered crucial. This paper analyzes practices, determinants and constraints of agroforestry among cocoa farmers in Ghana to provide insights into challenges and drivers for agroforestry adoption, which will guide the formulation and prioritization of tailored policies to address them. We obtained data from 900 cocoa farmers from Bia West and Bibiani-Ahwiaso districts in the Western North region and Asunafo North and Tano South districts in the Ahafo region. We employed Probit Regression analysis to assess factors influencing adoption of agroforestry practices among cocoa farmers. The results indicated an association between agroforestry practice and the variety of tree planted ($\chi2$ = 81.71, P = 0.00), the type of planting ($\chi2$ = 8.2, P = 0.00) and frequency of pruning per year ($\chi2$ = 8.2, P = 0.00). The Probit Regression showed that at a significant level of 0.05, education (P = 0.04*), farming experience (P = 0.03), membership of farmer-based organization (P = 0.03), knowledge of climate change (P = 0.04), and received extension services on agroforestry (P = 0.03) were found to influence adoption of agroforestry practices by cocoa farmers. Our assessment of constraints revealed that the falling of trees, pests and diseases, trees competing with crops for water, excessive shade and trees competing with crops for nutrients were major constraints to cocoa farmers practicing agroforestry while lack of knowledge (ignorance), unavailability of tree seedling and fear of timber contractors are constraints to farmers not adopting agroforestry. This is an important finding as it re-emphasizes the importance of considering socioeconomic context in designing agroforestry and future evergreen agriculture technologies. We recommend collaboration between farmers and other stakeholders in the cocoa sector which focuses on educating farmers on the importance of shade trees, and by providing money and agro-inputs support to farmers as impetus for the adoption of cocoa agroforestry in Ghana.

Key words: Cocoa-agroforestry, climate change, adaptation, mitigation, agriculture.

INTRODUCTION

Due to the production, environmental, and socioeconomic benefits of agroforestry, it has recently received widespread recognition as an integrated strategy to sustainable land use (Toppo and Raj, 2018), which has

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led to an increase in research on the application of agroforestry technologies in the tropics. Much of this effort was motivated by an apparent discrepancy between the advancements in agroforestry research and the success of agroforestry-based development programs and projects (Mercer, 2004). To fully exploit the potential of cocoa-agroforestry, one must have a fundamental understanding of how and why cocoa farmers make long-term land-use decisions, as well as the potential drivers and constraints to the decision-making process.

As a method of sequestering carbon from the atmosphere, cocoa agroforestry is gaining popularity, collects and uses resources like sunlight, water, and nutrients more effectively by using a variety of plants and trees. Recent studies in this field have brought attention to this (Ramachandran Nair et al., 2009; Bidastuti, 2020).

Agroforestry should be based on four (4) fundamental elements: rivalry, complexity, profitability, and sustainability, according to Ramachandran Nair et al. (2009). How well farmers can control the rivalry between trees and crops for resources like light, water, and nutrients is what determines how effective cocoa-agroforestry systems are. In addition to maximizing resource use, cocoa-agroforestry also protects the soil's physical, chemical, and biological characteristics, particularly its nutrient content, creating healthy soil (Place et al., 2002; Dollinger and Jose, 2018).

However, with an increasing climate change manifesting extreme weather event, the cocoa value chain will not be spared due to the sector’s high dependence on rainfall (De Pinto et al., 2012; Asante and Amuakwa-Mensah, 2014; Denkyirah et al., 2017). This has implications on livelihoods, ecology, and national economy (Schroth et al., 2016).

The Ghanaian government has over the years established policies, strategies, projects, and programs on cocoa-agroforestry to improve afforestation and reforestation as part of efforts to strengthen the cocoa industry's resilience against climate change. To encourage sustainable land use in the nation, a national agroforestry strategy was created in 1986 (Dawoe et al., 2016). The National Climate Change Policy (NCCP) seeks to advance cocoa agroforestry in 2013 and encourage initiatives that protect trees alongside agricultural crops. A key component of the 2014 Wildlife Resources Management Bill's community-focused approach is the inclusion of cocoa farmers in the management of forests and other natural resources, as well as the establishment of Community Resource Management Areas. The National Climate-Smart Agriculture and Food Security Action Plan also seeks to develop climate-resilient food and agricultural systems in every agroecological zone. In 3.75 million hectares of agricultural landscapes, the Ghana Forest Plantation Strategy (GFPS) (2016-2041) seeks to encourage the incorporation of trees on farms. The Cocoa Sector Development Strategy also aims to promote the use of environmentally friendly cocoa growing practices while increasing production from 450 kg/ha to an average of 1,000 kg/ha.

There is a Cooperative System Program, which seeks to promote active efforts to maintain and restore forests in the cocoa landscape in collaboration with other cocoa sector players. The National Cocoa Rehabilitation Program, which was established in 2020, contains cocoa-agroforestry features in that it intends to build a cocoa-agroforestry strategy to diversifying cocoa farmers' revenue (Kongor et al., 2018).

In 2008, Ghana became a participant in the international REDD+ Readiness Program through the Forest Carbon Partnership Facility. The country's proposal for readiness preparation was approved in 2010. The program focuses on supporting improved cocoa planting methods, such as re-planting older cocoa farms while preserving shade trees, with the goal of maintaining 18-20 mature shade trees per hectare of recommended species (Acheampong et al., 2014). The program prioritizes implementation in designated hotspot areas, which include the two regions and four districts studied in this current study.

The practice of agroforestry can lead to various benefits for local communities, including income from carbon, wood energy, and improved soil fertility. It can also help to improve local climate conditions and reduce human impact on natural forests. Many of these benefits assist in local adaptation, while also contributing to global efforts to reduce greenhouse gas concentrations in the atmosphere (Mbow et al., 2014; Apuri et al., 2018).

Socioeconomic factors influence to a larger extent farmer’s decision to adopt agroforestry. Generally, socio-economic factors are the social and economic experiences and realities that shape one's personality, attitudes, and lifestyle. They constitute demographic characteristics such as income, level of education, age, gender, ethnic origin, and household size. Agro-based socio-economic factors such as farm size, land tenure, years of farming experience, proximity to a forest reserve and access to extension information also influence farmer’s decision to adopt agroforestry (Glover et al., 2013; Obeng and Weber, 2014).

Apart from the aforementioned factors, the design of the cocoa-agroforestry system by government and non-government organizations (NGOs) can be hindrance to successful farmers’ adoption (Cerda et al., 2019). Designing the agroforestry system can be tailored to meet the specific needs and goals of farmers, whether it be providing additional sources of income, improving food security, or increasing resilience to market and climate changes. In some cases, the system may also be designed to address environmental challenges such as vulnerability to climate change or managing the spread of disease. The chosen objective should be feasible given the resources and capacities of the farmer, market demand, the environmental context, and the availability of materials needed to implement the system. Therefore, the agroforestry system should be based on the specific needs and preferences of the farmer, and take into account the broader landscape factors (Apuri et al., 2018; Somarriba et al., 2018).

In Ghana, there are several challenges and issues related to cocoa-agroforestry systems, such as the destruction of crops due to the felling of timber, limited education on tree ownership, limited knowledge on logging procedures, insufficient supply of seeds/seedlings, occurrence of pests/diseases, inadequate marketing systems, low produce prices, lack of credit facilities, tree tenure, inadequate compensation from timber by contractors, etc. (Apuri et al., 2018). Understanding the socio-economic and biophysical dynamics or interaction that influence agro-based technology adoption among smallholder farmers helps to unravel key factors that influence decision making process (Baffoe-Asare et al., 2013; Obeng and Weber, 2014).

In the wake of growing efforts to curb greenhouse gas emission and put the earth on a sustainable path, attention has been shifted to considering sustainable cocoa production practices which delivers benefits to the environment and promote farmers livelihood. This study sort to investigate the practices, determinants and constraints of agroforestry among cocoa farmers in Ghana. Specifically, the study sought to identify on-going cocoa-agroforestry practices under taken by cocoa farmers, identify key determinants of cocoa-agroforestry practices among cocoa farmers, and determine constraints cocoa farmers have with cocoa-agroforestry.

MATERIALS AND METHODS

Description of the study areas

The Ahafo and Western North regions of Ghana each had two districts where the study was conducted (Figure 1). The districts that made up the Western North Region were Asunafo North (Goaso) and Tano South (Bechem), whereas the districts that made up the region were Bia West and Bibiani-Ahwiaso.

Climate

The Western North Region is primarily an evergreen rainforest area, while the region is a transitional forest. With a bimodal rainfall pattern that includes a minor and major peak, the region districts have a modified Tropical Continental or modified Wet Semi-equatorial climate. While the minor rainy season begins in late August and peaks in October/November, the major rainy season begins in March and peaks in June-July. The yearly rainfall averages between 1150 and 1250 mm. The average daily temperature is around 30°C in March and 24°C in August. The relative humidity is high, ranging from 90 to 95% during the rainy season. The Western North Region districts, on the other hand, are located in the tropical climate zone and have a double maxima rainfall pattern with an average annual rainfall of 1,600 mm. The two rainiest months, May through July and September through October, are also when the area experiences its two annual rainfall peaks. Due to the significant rainfall, the relative humidity is very high, averaging between 70 and 90% throughout the year. The average daily temperature in the area is around 29°C in March and 20°C in August (Atiah et al., 2019).

Soil

Types of soil in the Western North Region site comprise Gleyic arenosols (Brenyasi), Haplic arenosols (Beraku), Dystric fluvisols (Sene), Eutric gleysols (Kupela) and Xanthic ferralsols (Atuabo). Types of soil in the Region site comprise Dystric planosols (Gulo), Dystric fluvisols (Sene), Eutric gleysols (Kupela), Ferric lixisols (Murugu), Dystric leptosols (Bramin) and Plinthic lixisols (Kpelesawgu).

Vegetation

The region is classified as part of the Woody Savannah Zone, however, due to its unique characteristics, it does not display the typical characteristics of a savannah. The region is extensively forested, with trees that are taller than those in the northern savannah regions but shorter than those in the southern deciduous forest regions. The predominant tree species in the area include Dawadawa (*Parkia biglobosa*), Shea (*Vitellaria paradoxa*), Odum (*Milicia excelsa*), Wawa (*Triplochiton scleroxylon*), Mahogany (*Khaya seneqalensis*), etc. These trees are well-suited to the environment, but are not densely packed.

The Western North Region is characterized by its moist semi-deciduous rainforest. The area is heavily forested with dense woods containing very tall trees, unlike the site. The predominant vegetation in this region includes (*Cocos nucifera*), oil palm (*Elaeis Guineensis*) and rubber plantations (*Hevea brasiliensis*).

Sampling technique

A non-probabilistic purposive sampling strategy was used in this study to choose two (2) districts from the Ahafo region and Western North regions. In each district, three (3) communities where cocoa is widely/intensively cultivated were selected and questionnaire administered to 225 respondents from each cocoa district following sample size determination by Gockowski et al. (2013). The questionnaire was pre-tested and entails sections for data of the farmer, farm, tree health, pre-harvest, harvest and postharvest details. These are farmers with an average farm size of five (5) acres, planted with hybrid cocoa variety of average age of fifteen (15) years with a planting distance of 3 m × 3 m with economic trees incorporated (18-20 trees/ha) aged ten (10) years or more for shaded-cocoa and vice versa. Economic trees have been introduced through cocoa extension services with current policy support of seedlings supply for about 30 years by COCOBOD. 225 committed respondents were targeted per district because both quantitative and qualitative data were relevant for collection. Per CHED (COCOBOD) district, an extension agent to farmer ratio is 1: 300 farmers and average district have about 2000 cocoa farmers. 10% representation per Gockowski et al. (2013) is fair representation and for qualitative study, situation under study determines.

Data analysis

Quantitative data from questionnaire interviews were analyzed using IBM SPSS statistical software 22 (IBM Corp, 2016) to generate descriptive statistics for agroforestry practices, and Probit

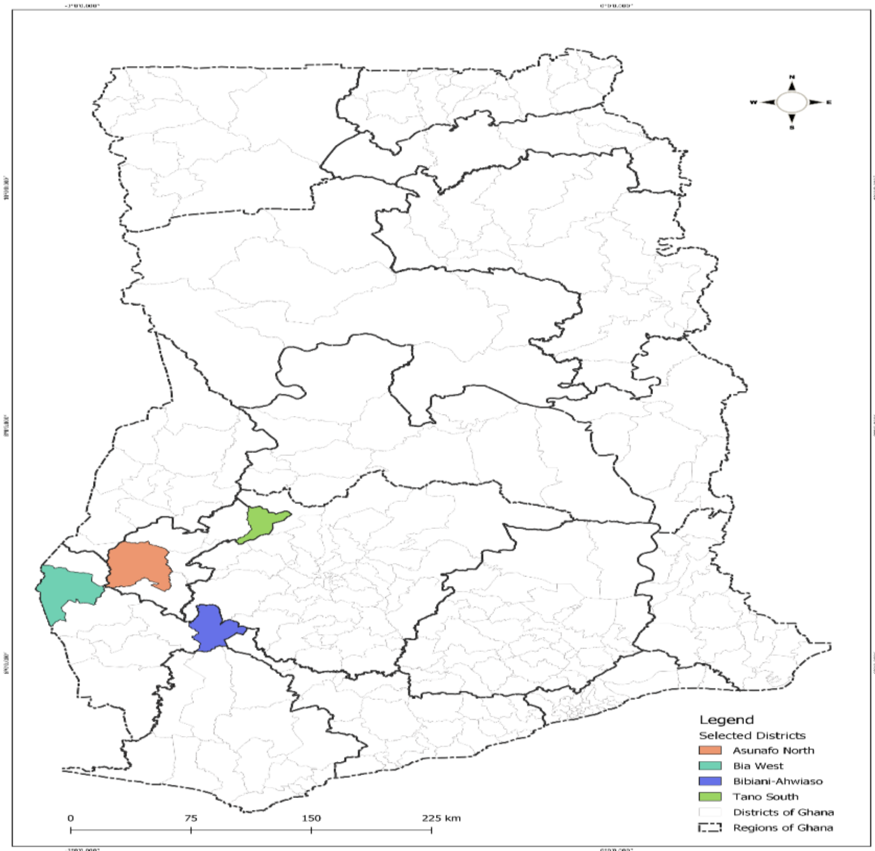

Figure 1. Map of the study area.

Regression Analysis for factors influencing adoption of agroforestry practices among cocoa farmers. The results are presented in tables and charts. The demographic factors taken into account for analysis include the income of farmers, their gender, education level, age, ethnicity, total number of households, and whether or not they have a second occupation.

RESULTS

Cocoa-agroforestry practices by farmers

Cocoa-agroforestry is the act and art of cultivation of selected cocoa varieties with incorporation of required number of approved economic trees species at recommended spacing to ensure desired micro climate and conservation of the cocoa environment for sustainable production and maximum economic gain.

The results indicate that only 38.89% (n=350) of participants are practicing coco-agroforestry, while the majority are not (61.11%, n = 550) (Figure 2), indicating the low adoption rate over three (3) decades of introduction in the cocoa sector. Table 1 presents a cross tabulation of agroforestry practices among participants who practice cocoa-agroforestry and those that do not. The results reveal that cultivating a hybrid variety and mix of varieties is dominant among both groups of farmers (practicing and not practicing agroforestry). 219 and 95 participants practicing cocoa-agroforestry adopt hybrid and mix of varieties, respectively. On the other hand, 184 farmers and 302 of participants not practicing cocoa-agroforestry adopt hybrid and mix of varieties, respectively. A Chi square test indicates that the variety of cocoa cultivated has association with the practice of cocoa-agroforestry ($\chi^2 = 81.71$, $P = 0.00$). This means that the two (2) variables (practice cocoa-agroforestry and cocoa variety cultivated) are not independent of each other, that is, farmers with hybrid varieties adopt cocoa-agroforestry because hybrid variety is associated with CHED (COCOBOD) extension farm package. In essence, the result shows that a participants' decision to apply cocoa-agroforestry is influenced by the type of cocoa variety he/she cultivates.

Participants were also asked about the type of planting they apply. The results as indicated in Table 1 show that the highest number of participants who practice cocoa-agroforestry also apply line planting (n = 275) while majority of farmers who do not practice cocoa-agroforestry apply random planting of seedling (n = 404). The Chi square test result also shows a correlation between the type of planting used and the cocoa

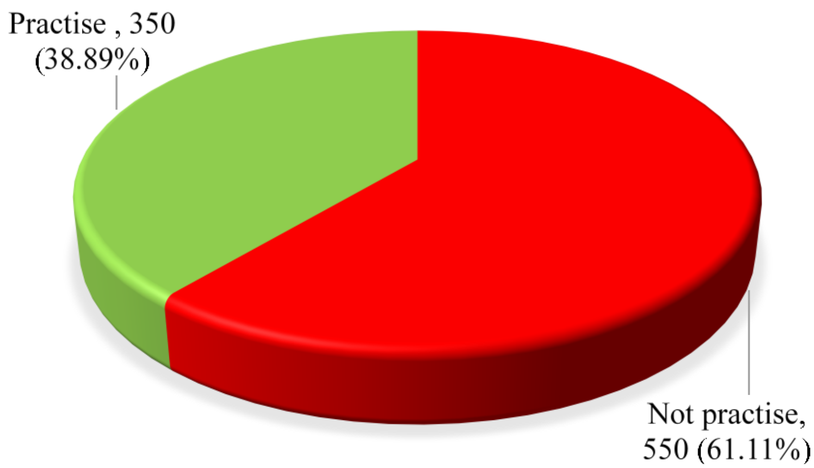

Figure 2. Proportions of cocoa farmers adopting cocoa-agroforestry practices.
Source: Field Survey, March (2016).

Table 1. Cross tabulation of practicing cocoa-agroforestry and cocoa varieties cultivated, method of planting and frequency of pruning by cocoa farmers.

Variable	Practice Cocoa-agroforestry[a]		Total	χ^2 (*P*)[b]
	Yes (38.98%)	No (61.1%)		
Variety				
Amelonado	0	6	6	81.71 (0.00)*
Amazona	36	58	94	
Hybrid	219	184	403	
Mix	95	302	397	
Type of planting				
Random Planting of seeds (Atodwe)	20	384	404	8.21 (0.04)*
Line planting of seeds	43	23	66	
Random planting of seedlings	12	14	26	
Line planting of seedlings	275	129	404	
Frequency of pruning per year				
Once	53	369	422	9.71 (0.01)*
Twice	269	180	449	
Thrice	28	1	29	

[a]Proportion of farmers practicing cocoa-agroforestry or otherwise and their respective percentages. [b]Chi-square value and value in parenthesis represents probability value. *Indicates significant association with practice of agroforestry or not.
Source: Field Survey, March (2016).

agroforestry approach (χ^2 = 8.2, *P* = 0.00) but not as strong as the one between the cocoa-agroforestry farmers and associated hybrid variety cultivated.

Regarding the frequency that participants prune their cocoa trees, the results (Table 1) reveal that the highest number of participants who practice agroforestry prune their cocoa plants twice a year (n=269) while the majority of participants who do not practice cocoa-agroforestry prune just once (n = 369). The Chi square analysis shows a significant association between the practice of cocoa-agroforestry and pruning (χ^2 = 8.2, *P* = 0.00).

The study further assesses the number of trees allowed on the farm, naturally occurring tree species and/or those planted by the farmer in his farm as well as the planting distances and sources of tree seedlings. This descriptive analysis only applies to participants who practice cocoa-agroforestry (n = 350). The results are presented in Table 1.

Table 2 shows that approximately half of the participants (49.70%) who practice agroforestry plant less than 7 trees per acre in their cocoa farms. This is followed by 44.60% of participants who plant between 8

Table 2. Trees and related features on cocoa farms of farmers who practice cocoa-agroforestry.

Variable	Frequency (n=350)	Percent
Number of trees		
< 7	174	49.70
8-10	156	44.60
> 10	20	5.70
Naturally occurring trees		
Terminalia superba (Ofram)	139	39.70
Milicia regia (Odum)	80	22.90
Ceiba pentandra (Onyina)	41	11.70
Terminalia ivorensis (Emire)	21	6.00
Entandraphragma cylindricum (Sapele)	14	4.00
Khaya ivorensis (Mahogany)	12	3.40
Mangifera indica (Mango)	8	2.30
Triplochiton scleroxylon (Wawa)	7	2.00
Bombax spp (Akonkodie)	7	2.00
Pycnanthus angolensis (Otie)	4	1.10
Antiaris toxicaria (Kyenkyen)	4	1.10
Cola gigantea (Wataapuo)	3	0.90
Pyrus communis (Pear)	2	0.60
Bombax spp (Akata)	2	0.60
Rauvolfia vomitoria (Kakapenpen)	2	0.60
Tectona grandis (Teak)	2	0.60
Citrus sinensis (Orange)	1	0.30
Cocos nucifera (Coconut)	1	0.30
Planted trees		
Terminalia ivorensis (Emire)	100	28.60
Terminalia superba (Ofram)	95	27.10
Khaya ivorensis (Mahogany)	35	10.00
Entandrophragma cylindricum (Sapele)	32	9.10
Ceiba pentandra (Ceiba)	30	8.60
Cocos nucifera (Coconut)	21	6.00
Citrus sinensis (Orange)	13	3.70
Pyrus communis (Pear)	9	2.60
Mangifera indica (Mango)	7	2.00
Cola gigantea (Wataapuo)	1	0.30
Planting distances		
21 m×21 m	227	64.90
Not well distributed	123	35.10
Sources of tree seedlings		
CHED (COCOBOD)	162	46.30
Forestry commission	79	22.60
Already on farm	56	16.00
Private sources	53	15.10

Source: Field Survey, March (2016).

and 10 trees per acre. Only 5.70% of participants plant more than 10 trees per acre.

Table 3. Factors influencing adoption of agroforestry practices among cocoa farmers by Probit regression analysis.

Variable	Coefficient	SE [a]	z [b]	*P*>|z|[c]	95 % CI [d]	
					Lower	Upper
Gender (X1)	-0.84	0.54	-1.57	0.12	-1.89	0.21
Age (X2)	0.25	0.45	0.56	0.58	-0.63	1.12
Education (X3)	0.14	0.56	0.25	0.04*	0.95	1.23
Marital status (X4)	-0.13	0.53	-0.25	0.81	-1.17	0.91
Family size (X5)	-0.03	0.54	-0.06	0.95	-1.10	1.03
Farming experience (X6)	0.86	0.57	1.50	0.03*	-0.27	1.99
Problem of land (X7)	-5.34	486.02	-0.01	0.99	-957.91	947.24
Residential status (X8)	-0.38	0.67	-0.57	0.57	-1.69	0.92
Member of FBO (X9)	0.50	0.53	0.93	0.03*	0.55	1.55
Knowledge of climate change (X10)	1.40	0.71	1.98	0.04*	0.01	2.79
Knowledge of agroforestry (X11)	16.28	643.38	0.03	0.98	-1244.71	1277.28
Trees registered (X12)	0.05	1.02	0.05	0.96	-1.95	2.06
Trained on agroforestry (X13)	0.71	0.76	0.94	0.35	-0.77	2.19
Incur cost on agroforestry (X14)	-6.70	421.57	-0.02	0.99	-832.96	819.55
Monetary assistance from government (X15)	0.47	0.69	0.68	0.50	-0.89	1.83
Assistance from NGOs (X16)	1.04	0.70	1.48	0.14	-0.33	2.41
Received extension services on agroforestry (X17)	0.45	0.57	0.79	0.03*	-0.67	1.58
Constant	-4.82	1.26	-3.83	0.00*	-7.29	-2.35

-2 Log likelihood: 59.12; Model Chi-square: 1183.28 ($P<0.00$); Pseudo R^2:0.9528. [a]Standard error. [b]z-score or probit index for a one-unit change in the predictor. [c]Probability of significance at 5% greater than z. [d]95% confidence interval. *Significant at $P≤0.05$.
Source: Field Survey, March (2016).

Table 2 reveals that the participants have at least one species of 18 trees species growing on their farm. Ofram is the highest naturally occurring tree species (39.70%) followed by Odum (22.90%), Ceiba (11.70%) and Emire (6.00%), Sapele (4.00%), Mahogany (3.40%) and Mango (2.30%). The rest of the tree species together constitute 10% of the total species observed on the farms.

Apart from the naturally occurring trees, participants who practice agroforestry do plant trees on their own. Emire is the highest planted tree species by participants (28.60%), closely followed by Ofram (27.10%), Mahogany (10.00%), Sapele (9.10%), Odum (8.60%), Ceiba (6.00%), Coconut (3.70%), and Orange (2.60%).

Most participants (64.90%) adopt a tree planting distance of 21 m × 21 m while 35.10% indicated that the planting is not well distributed.

Participants who obtained seedlings from CHED constituted 46.30% of the sample size. 22.60% obtained their seedlings from the Forestry Commission while participants already have the trees on their farm and those who obtained from private sources constitute 16.00 and 15.10%, respectively.

Factors influencing adoption of cocoa-agroforestry practices

The analysis's model was significant at 1%, indicating that it is appropriate for the analysis. Additionally, the Pseudo R^2 of the model was 0.95, meaning that the independent factors and the dependent variable's fluctuation together account for nearly 95% of the variation. At a significance level of 0.05, Education (*P* = 0.04*), Farming experience (*P* = 0.03), Member of FBO (*P* = 0.03), Knowledge of climate change (*P* = 0.04), and Received extension services on agroforestry (*P* = 0.03) were found to influence adoption of agroforestry practices by cocoa farmers (Table 3). They constitute significant predictors in the model.

Constraints of cocoa-agroforestry adoption

Figure 2 presents the results of participant's constraints to agroforestry. The results show that the constraints for participants who practice agroforestry and participants who do not differ. Majority of farmers who practice agroforestry indicated the destruction of crops due to falling of trees as the most pressing challenge (Figure 3A). This was followed by pests and diseases, trees competing with crops for water, excessive shade, trees competing with crops for nutrients. The major constraints among farmers who do not practice cocoa-agroforestry is that they accept they are ignorant of the practice (Figure 3B). This is followed by unavailability of tree seedlings and fear of timber contractors.

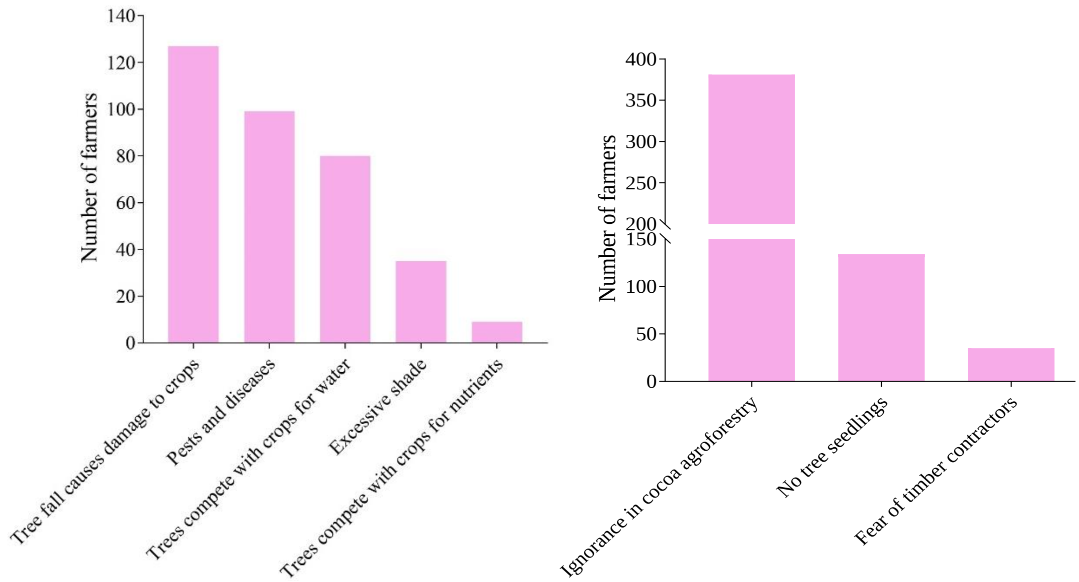

Figure 3. Constraints of cocoa farmers with regards to agroforestry. (A) Farmers who practice agroforestry. (B) Farmers who do not practice agroforestry.
Source: Field Survey, March (2016).

DISCUSSION

Adoption of cocoa-agroforestry by farmers

Although, government, NGOs and development partners' efforts on the adoption of cocoa-agroforestry (shaded-cocoa) among cocoa farmers have increased in recent years, farmers' adoption on the other hand has been slow as found by this study (Figure 2). This is consistent with studies by Abdallah (2017) and Yamoah and Kaba (2022). The results of this study have also iterated the fact that combination of factors come into play when it comes to adoption of cocoa-agroforestry by cocoa farmers (Abdallah, 2017).

This study first intended to understand how farmers' agro-based practices connect to their adoption of cocoa-agroforestry. The results showed varying association between various agro-based farming practices and cocoa-agroforestry. The association was very significant for practices such as variety selection. Most farmers who practice cocoa-agroforestry cultivate hybrid cocoa variety (Table 1). Variety of cocoa planted plays a role in cocoa-agroforestry because different varieties of cocoa respond differently to shade, competition, environmental stress (Williams, 2009). This means that a farmer must be certain of the resilience of his/her variety before introducing or allowing another species of tree.

Hybrid cocoa varieties were first introduced in 1984 through the government's Cocoa Rehabilitation Project (CRP). These hybrid varieties have been found to outperform older "Amazons" and "Amelonado" varieties in two ways: by producing fruit-bearing trees in three years, compared to at least five years for the older varieties, and by producing more pods per tree (Edwin and Masters, 2005; Asare et al., 2018). However, hybrid trees require optimal weather conditions and complementary farming practices such as the application of chemical inputs, new planting procedures, pruning, and spraying to perform well (Wongnaa et al., 2022). Cocoa-agroforestry (shaded-cocoa) could provide an advantage to hybrid cocoa by providing an optimal local weather, which may explain why a greater number of hybrid cocoa variety farmers also adopt agroforestry.

Lining and pegging

Line planting is an effective method for various production systems, including cocoa-agroforestry. In the study area, cocoa-agroforestry is commonly planted in lines (Table 1). Other crops such as coconut and rubber, as well as other shading plants, can be interspersed with the cocoa trees. In addition to cocoa pods, cocoa-agroforestry cultivation can provide a variety of agro-based products from incorporated trees. Co-products from coconut sap and raw latex are typical examples. The practice as well reduces the rate of use of agrochemicals.

Pruning

Farmers who practice cocoa-agroforestry (shaded-cocoa) prune more frequently than the counterparts who do not.

This is because cocoa-agroforestry farmers have association with technologically innovative partners (Table 1). However, pruning gave positive effects by reducing the costs from chemical fertilizer and pesticides applications which would have been needed to treat affected parts separated by pruning. For example, sanitation pruning (removal of diseased or pest-affected pods and branches) reduces the spread of black pod when done in conjunction with other disease management methods. Proper management of microclimate through pruning in cocoa-agroforestry (shaded-cocoa) systems help balance the trade-off between yield and shade cover with the boost of flowers from nutrients which otherwise would have gone to undesired parts.

Incorporation of economic trees

For a farm to be considered "cocoa-agroforestry" in the broadest sense, it must grow cocoa and include at least one other species of economically valuable tree for shade on the farm. In accordance with other standards, including the Rainforest Alliance/UTZ SAN Standard, each hectare must contain at least 5 native tree species. However, more than 90% of farmers who practice cocoa-agroforestry (shaded-cocoa) have less than 10 trees per acre on their farm. This is attributed to limited access to seedlings of desired economic tree spies and land tenure. Knowledge of number required per acre/planting distance was an issue. Other studies have also identified land size as a factor that influences farmers' decisions to adopt cocoa-agroforestry (shaded-cocoa) for fear of the trees taking spaces for their cocoa. The target density in a production model, however, depends not only on the area of the land but also on the variety and number of species present, as well as on the canopy's width, the distance from the sun's shade, and other technical elements that have an impact on the cocoa crop.

While the majority of farmers planted shade trees at various stages of setting up their cocoa farms, a lesser proportion did so with already-existing trees. The 2010 guideline of the Cocoa Research Institute of Ghana (CRIG), which calls for the planting of 16 to 18 shade trees, spaced 24 m apart and providing 30 to 40% shade coverage. The majority of farmers in this study used a spacing of 21 m × 21 m (70ft × 70ft) which is smaller than the recommendation from the CSIR-FRIG (Dumenu et al., 2014). This according to the farmers, well arrange tree spacing from four (4) tree plant interval square gives 3969 m^2 which is approximately an acre of land. This serves as a guide in planning cultural practices and estimation of their farm sizes. Well-spaced plants allow for less competition for resources such as space, sunlight, water and nutrients, resulting in healthier and more productive trees. Farmers who use closer spacing face difficulty when have difficulty with cultural practices.

Several factors have been identified in the literature as determining farmers' decisions to implement cocoa agroforestry (Obeng and Weber, 2014; Nunoo et al., 2015; Kaba et al., 2020; Yamoah et al., 2021). According to the Probit Regression Analysis, the primary factor influencing cocoa farmers' adoption of cocoa-agroforestry (shaded-cocoa) among the research participants include education, farming experience, FBO membership, understanding of climate change, and agroforestry extension services received (Table 3).

Education

Farmers who had completed their senior year of high school or above kept the required number of shade trees per hectare on their cocoa estates. However, lack of education and the desire for a high cocoa output were the main causes of shade tree removal on farms. Understanding the science behind cocoa-agroforestry could be useful in encouraging farmers to adopt it quickly. According to Nkamleu and Manyong (2005), the number of years spent in education is frequently directly related to how people make choices.

Extension services

It came out clear that receiving extension services on cocoa-agroforestry influences farmers’ adoption of cocoa-agroforestry. Most farmers with well shaded cocoa belonged to extension/farmer groups. Extension contact was seen to be a critical factor in building a favorable attitude among farmers toward technology adoption. This means that extension agents are critical in altering farmers' minds about adopting cocoa-agroforestry technologies. Regular communication with extension agents may encourage farmers to learn more about the technology through demonstration plots on their fields, improving the rate of adoption. This is in line with Matata et al. (2010)’s research, which maintains that extension contact is a crucial element in cultivating a positive attitude among farmers regarding the adoption of technology.

Farming experience

This study established a correlation between adopting cocoa-agroforestry practices and farmers' years of experience. The level of cocoa-agroforestry adoption is better, the longer the farming period. These farmers were aware of the importance of mixing different economic tree species to defend against pests, diseases, and the unique agronomic traits of each. The results are in line with those of Mignouna et al. (2011) and Kariyasa and Dewi (2013), who discovered that farmers become more adept at evaluating technical information over time as they gain knowledge and expertise via practice.

Membership of FBO

Farmers associated with FBOs better adopt and practiced with understanding cocoa-agroforestry. Collective action through FBOs provided a bridge to inclusive cocoa-agroforestry involvement for such farmers. There is much evidence that collective action assist farmers had access to loans, better inputs, skills, markets, or even social support networks. As a result, collective action is widely acknowledged as a possible road out of poverty for the rural poor. In recent times, government and development partners' programs are run through groups. Being a member of an FBO helps farmers to easily access seedlings or trainings to implement agroforestry.

Knowledge of climate change

Farmers' awareness of these issues is prompted to adopt mitigation and adaptation practices such as cocoa-agroforestry. Assessment of constraints to cocoa-agroforestry adoption revealed that felling of trees, pests and diseases, trees competing with crops for water, excessive shade and trees compete with crops for nutrients as major constraints to practicing cocoa-agroforestry (Figure 3A). On the contrary, farmers who do not practice agroforestry are constrained by the limited knowledge in cocoa-agroforestry, unavailability of tree seedling and fear of timber contractors (Figure 3B).

Conclusion

Farmers by their actions confirm as climate change progresses, cocoa-producing regions are expected to experience more extreme weather events. Drought and flooding are likely to have a significant impact on crop productivity and farmer food security. Climate change was seen to bring about other stressors such as rising temperatures, unpredictable precipitation, changes in seasonal patterns, and droughts. This is seen to affect other species present in cocoa-agroforestry systems, particularly cocoa pollinators, pests, and diseases, which have serious implications for farmers. In order to mitigate these hazards and supplement income during lean periods, farmers adopt climate-smart cocoa production practices such as cocoa-agroforestry. The government of Ghana and development partners have been implementing various programs in cocoa-growing areas to promote these practices.

Farmers who lack access to formal sources of farming knowledge often rely on information shared within their informal social networks. The social network of these farmers may not be able to provide educative information to each other on cocoa-agroforestry. In the absence of knowledge, farmers are comfortable with the normal practices.

The limited availability of economic tree seedlings is a barrier to the adoption of cocoa-agroforestry. The study found that when the Forestry Services Division (FSD) ceased providing free seedlings for planting to farmers, those who were interested in planting trees on their farms had no access to seedlings in the Asunafo District of the region.

Additionally, the felling of trees led to the destruction of farmers crops. This is caused by windy or unpredictable weather conditions or by logging contractors. This study's findings align with those of O'Sullivan et al. (2018) who noted that due to the destruction of crops caused by the felling of trees and the lack of adequate compensation for this damage during the logging of timber species by contractors, farmers are not motivated to engage in agroforestry practices.

Cocoa-agroforestry is recognized to minimize the spread of pests and diseases in cocoa farms, boosting farmer production, hence cocoa-agroforestry adoption should be encouraged. Agroforestry systems can impact the prevalence and population of pests in various ways, such as increasing the regulation of pests by natural predators and modifying factors like microclimate, soil nutrients, and water content. This can occur through both top-down and bottom-up mechanisms.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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