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Cocoa Agroforestry Systems and Yield Dynamics within the Offinso Municipality of Ghana

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Abstract

Cocoa production remains an important player in Ghana's economy. Over the years, there has been a shift from the traditional cocoa agroforestry system to full-sun cocoa production. Due to extreme exposure to high temperatures, sunlight and drought, the photosynthetic mechanism of cocoa is altered, reducing yield. Cocoa agroforestry provides economic, social, and ecological benefits and plays subsistence functions such food and fuelwood. The study was carried out to assess cocoa agroforestry systems based on shade and its effect on yield in the Offinso Municipality of Ghana. The study aimed to identify the types of cocoa agroforestry systems based on shade, determine the factors affecting cocoa agroforestry systems and assess the impact of shade regime on cocoa yield in the municipality. Purposively cocoa farmers were randomly and were administered with questionnaires. The study revealed that farmers in the Offinso Municipality practice all types of cocoa agroforestry systems (full sun, low shade, medium shade, and heavy shade). The cultivation of cocoa under medium shade (15–18 trees ha^{-1}) proved to be beneficial and essential for the long-term production of cocoa. The medium-shade cocoa recorded a higher average yield of 1576 kg ha^{-1}. Six common shade trees identified include *Terminalia superba* (ofram), *Ricinodendron heudelotii* (wawa) and *Chlorophora excelsa* (odum). Some challenges faced as a result of practicing the cocoa agroforestry system were pest infestation and diseases such as that of the black pod. Cocoa agroforestry still holds the key to sustainable future outputs in cocoa production as it drives the realization of SDG goal 13 (climate action). There is therefore the need to educate farmers on managing their farms with trees for optimum ecological and economic benefits.

Keywords: Cocoa agroforestry, cocoa, shade systems, cocoa yield, Ghana, shade trees

INTRODUCTION

Cocoa (*Theobroma cacao* L.) is an understorey tree, which explains why it is typically grown under the shade of deliberately reduced forests. Cocoa remains the most commonly grown cash crop in Ghana's rural households (Nimo *et al.,* 2021; Osman *et al.,* 2022). According to reports, Ghana is the world's second-largest cocoa producer (Boateng *et al.,* 2014; Afele *et al.,* 2021; Osman *et al.,* 2022), that explains why it is the primary source of income for 11% of Ghana's population (Gibson, 2007; Asante *et al.,* 2021; Yamoah *et al.,* 2021). A typical yield of 400 kg ha^{-1} is produced by Ghana's small-scale (2–3 ha) cocoa farms (Asare *et al.,* 2017; Afele *et al.,* 2021; Osman *et al*., 2022). Cocoa farming has remained in the hands of smallholder farmers despite a series of political and economic shifts (Mikell, 1992; Ameyaw *et al.,* 2018; Orozco-Aguilar *et al.,* 2021). About 800,000 cocoa households produce 75 percent of Ghana's cocoa (Maguire-Rajpaul *et al.,* 2020; Osman *et al.,* 2022). Carbon sequestration, nutrient cycling, soil organic matter accumulation, and biodiversity conservation are all aided by the forest shade trees that remain in cocoa systems. During dry seasons, shade trees increase evapotranspiration, which reduces soil moisture in cocoa farms (Afele *et al.,* 2021). Besides this, shade trees help to ensure the long-term viability of cocoa production (Kyereh, 2017).

Generally, cocoa farmers invade forests to establish new farms in Ghana's high forest zones (Afele *et al.,* 2022), taking advantage of the nutrient-rich forest soils' ability to boost cocoa harvests. In Ghana, the conversion rate of forest cover to cocoa farms is 1.6% every year; this is rapid and dominant in the western north region of the country, which doubles as a key front of the production system (Amooh, 2017). Many cocoa producers, on the other hand, consider leaving forest trees on existing farms to be an important and required part of the production environment (Atkins & Eastin, 2012; Asare *et al.,* 2019). There is inadequate information on cocoa agroforestry systems, shade intensities and yield with regards to the Offinso Municipality (Owusu & Frimpong, 2014; Afele *et al.,* 2021; Nimo *et al.,* 2021). Though several studies have established the shade regimes within cocoa farms generally in Ghana, there is evidence of the gap investigating cocoa farms shade regimes in the mentioned district. Each shade system has its effect on cocoa yield and its practice has associated problems (Afele *et al.,* 2021). It is therefore prudent to assess the cocoa agroforestry systems undertaken by farmers as well as its corresponding yield within the district. This will help make informed decisions and feed into policy formulations on the shade system to be adopted by farmers.

MATERIALS AND METHODS

Study Site Description

The study was conducted in four purposively selected communities; Samproso, Camp 31, Abrokyire, and Abofour in the Offinso Municipality (Figure 1) of the Ashanti Region of Ghana. It is located in the extreme northwestern part of the Ashanti Region and has Offinso as its capital town. The Municipality covers a land area of 585.7 km^2 which is 2.4% of the total land size of the Ashanti Region. It lies between longitudes 1^{0}50'W and 1^{0}45'E and latitudes 7^{0}20'N and 6^{0}50'S. The municipality shares common boundaries with Offinso North District in the north, Ejura Sekyedumase Municipality in the east, Sekyere South District in the south-east, Atwima Nwabiagya Municipality and Ahafo Ano South West District in the west. The population of the municipality according to the 2021 population and housing census stands at 137,272 with 66, 569 males and 70,703 females (GSS, 2021). The Offinso Municipal enjoys an agrarian economy with about 62% of the labor force engaged in agriculture. Food crops and livestock contribute 55% and 20% respectively to household income generation in the municipality (GSS, 2021). The district experiences a wet semi-equatorial type of climate characterized by moderate to heavy rainfall annually with temperatures ranging between 21 ^{0}C and 32 ^{0}C. The rainfall regime is double maxima with a mean annual rainfall of 953 mm. The major rainfall season occurs between May and June, followed by a dry spell between July and August. Minor rains occur between September and November followed by dry *harmattan* (a strong cool dry wind in Western Sahara) till February (Eric *et al.,* 2014). The natural vegetation of the municipality is semi-deciduous forest interspersed with thick vegetation cover. The land has three main underlying rock types upon which soil is formed. They

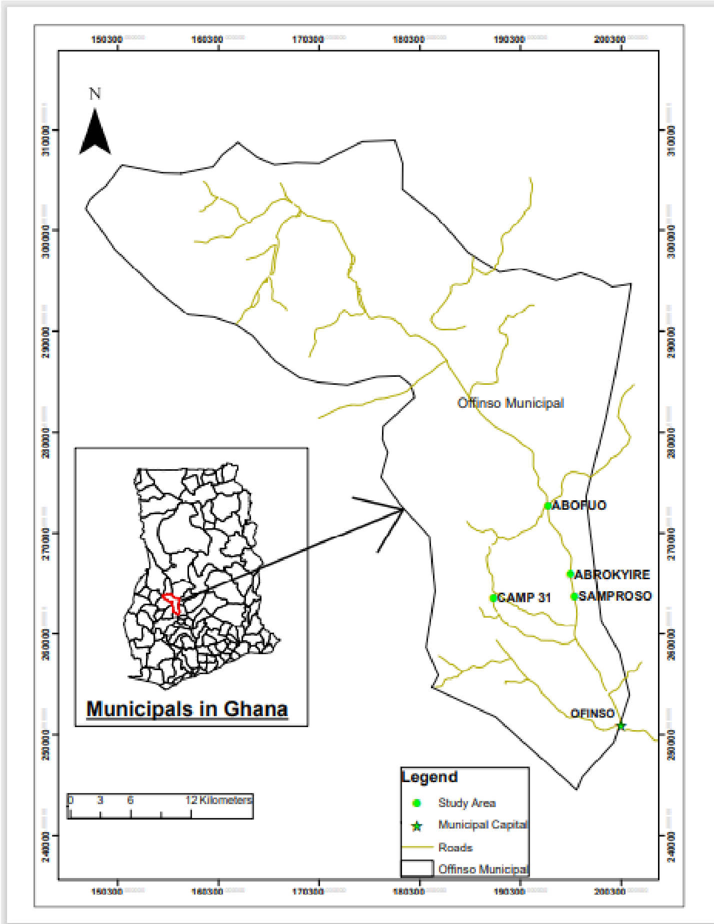

Figure 1. Map of Offinso Municipality showing study communities (Abofuor, Abrokyire, Samproso, and Camp 31) in Ghana

are voltain, birimian and the granite rock types. Soil in the municipality is generally rich in humus, well drained and good for the cultivation of a wide range of food crops such as plantain, cocoyam, cassava, maize and vegetables. The municipality has two main forest reserves namely Afram Head-waters and Opro Forest Reserves. Major food crops grown in the municipality are maize, cassava, yam, plantain, cowpea, and rice. Major tree crops in the municipality are cocoa, citrus, and oil palm. Sheep, goats, pigs, cattle, and poultry are raised in the municipality. However only a few people are in big-time commercial farming and this is concentrated on poultry (Eric *et al.,* 2014).

Research Design and Sampling

The district was selected in Ashanti Region based on the presence of different shade levels within cocoa farms as well as factors including, intensity of cocoa production, high temperatures affecting yield, reduction in yield over the past decade, presence of shade trees on cocoa farms and willingness of farmers to engage in the survey. Four (4) communities (Samproso, Abrokyire, Camp 31, and Abofuor) were purposively selected within the district based on similar conditions as described earlier. By use of Israels formula, $n = N/1+N(e)^2$, where n = sample size, N = total population, and e = error intensity, the total number of respondents were determined. Respondents from Samproso, Abrokyire, Camp 31, and Abofuor were identified using random sampling. In total, 85 cocoa farmers were interviewed. Of the 85 interviewed, 32 were from Samproso, 32 were from Abofour, 12 were from Abrokyire, and 9 were from Camp 31.

Data Collection and Analysis

Structured questionnaires with open and close-ended questions were used to collect the needed data with a prior briefing of respondents about the aim and objectives of the survey. Both quantitative and qualitative data were collected through face-to-face interviews and was supported with key informant interviews. Key informant interviews were in the form of free discussion. Survey questionnaire data obtained from the cocoa farmers were analysed using the Statistical Package for Social Sciences (Version 20). Regression and descriptive statistics were employed to analyse data. The results from the study were presented in figures and tables.

The types of cocoa agroforestry systems practiced in the district were identified and classified based on findings that the heavy-shade cocoa farms have about 22–30 forest trees ha^{-1} (STCP, 2002; Ofori-Frimpong *et al.,* 2007), medium-shade cocoa farms have 15–18 forest trees ha^{-1} (STCP, 2002; CRIG, 2010) and the low shade cocoa farms has 5–6 trees ha^{-1} (Ruf, 2011; UNDP, 2011) are the three existing cocoa agroforests. Furthermore, according to Uribe *et al.* (2001) there have been reports of cocoa farms with 0–2 shade trees in full-sun cocoa agroforests. Cocoa varieties cultivated include Tetteh Quarshie, Amazonia and Hybrid; on farms aged 1–40 years.

The average yield under each cocoa agroforestry type was estimated by finding the average of each total yield and its corresponding total hectarage. Under each cocoa agroforestry type, the individual bags of cocoa harvested by each farmer were converted to kilograms (kg) and the sum of all cocoa dry beans harvested by farmers in kilograms (kg) was then calculated.

RESULTS AND DISCUSSION

Demographic Characteristics

The demographic characteristics of farmers are presented in figure 1. More than half of the respondents (75.2%) were from Abofour and Samprososo (37.6% each) and about 14.1% were from Abrokyire. The majority of the respondents (67.1%) were males whiles the remaining 32.9% were females. This indicates that cocoa production is a male-dominated occupation. The findings agree with Nunoo *et al.* (2014), Afele *et al.* (2021) and Avane *et al.* (2022) that cocoa production is a male-dominated occupation as most of the activities associated with cocoa production requires physical energy and is labour intensive making it not well suited for females. Again, it was also reported that farmers make up the majority of the rural population in Ghana, and they are typically supported by their families (Osman *et al.,* 2022). The age group 51–70 years had 54.1% of respondents and the age group 18–30 years was the lowest (4.7%). This further tends to agree with findings of Afele *et al.* (2021), that most of the cocoa farmers in Ghana are old and above 50 years. The findings also support Kodom *et al.* (2022) that some youths may not show interest in cocoa farming because of the perception that cocoa farming is an activity for the aged and less lucrative. More than half of the respondents (57.6%) were married whiles 11.8% were divorced as shown in Figure 1. The native respondents were dominating with a percentage of 63.5% in the various communities. This is because natives have more access to lands in the communities. This agrees with a study

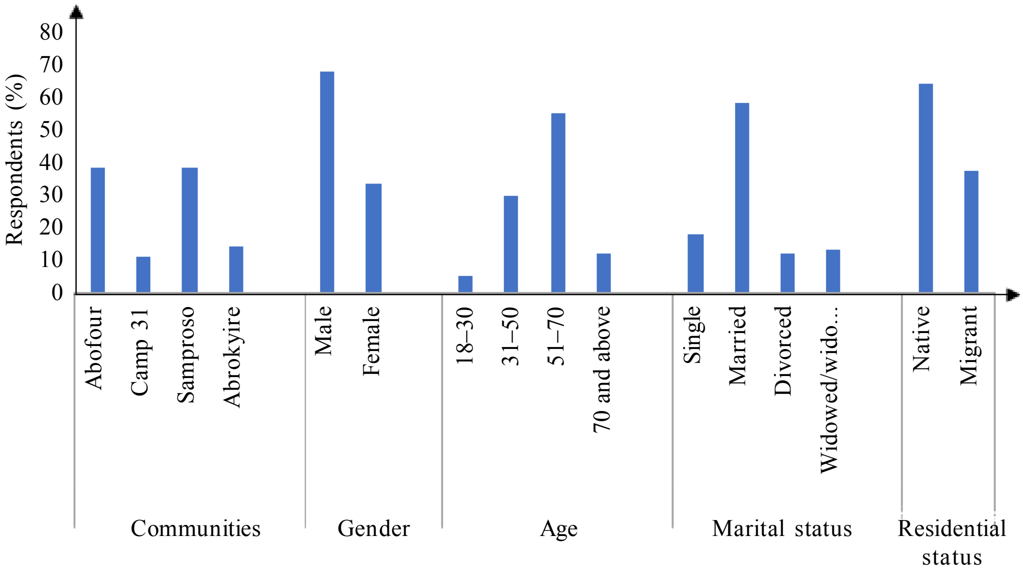

Figure 1. Demographic characteristics of cocoa farmers in the Offinso Municipality of Ghana

by Abu *et al.* (2014) that non-migrant households have greater access to land and kin relations than otherwise.

Farm Characteristics

Most of the respondents (30.6%) had farm sizes ranging between 5–6 acres, approximately 2 hectares. This supports research by Obiri *et al.* (2007) that found smallholder farmers with farms between 1–4 hectares in size are the majority of those engaged in cocoa production. Majority of the farmers (88.2%) keep shade trees on their cocoa farms, of which includes; *Terminalia superba* (Ofram), *Ricinodendron heudelotii* (Wawa), *Chlorophora excelsa* (Odum), *Antiaris toxricaria* (kyenkyen), *Cola gigantean* (Watapuo) and *Alstonia boonei* (Onyame dua) are the dominating tree species used by farmers (Table 1). Their reasons for keeping these trees are either for shade or as a source of wood for subsistence use. Again, results revealed that more than half of the respondents keep these trees to shade their cocoa farms. Others also keep *Mangifera indica* (mango), *Persea americana* (avocado pear), *Citrus sinensis* (orange), *Elaeis guineensis* (oil palm) or *Cola acuminata* (cola nut) on their cocoa farms mainly as a source of food. This confirms a study by Garen *et al.* (2011) that farmers preserve trees for a variety of reasons; ecological, environmental and subsistence. Gemechu *et al.* (2021) reported that trees provide homes with food, fuel, and insurance through generating money which is evident from results reported in this study where some trees such as *Mangifera indica* (mango), *Persea americana* (avocado pear), *Citrus sinensis* (orange), *Elaeis guineensis* (oil palm) are kept as sources of food for farmers subsistence use.

Majority (90.6%) of the respondents stated that tree species on their farms have no negative influence on their cocoa whiles 9.4% stated otherwise.

Cocoa Agroforestry Types and Constraints

Most of the respondents (37.6%) practice the heavy shade system (22–30 trees ha^{-1}), 34.1% medium shade (15–18 trees ha^{-1})

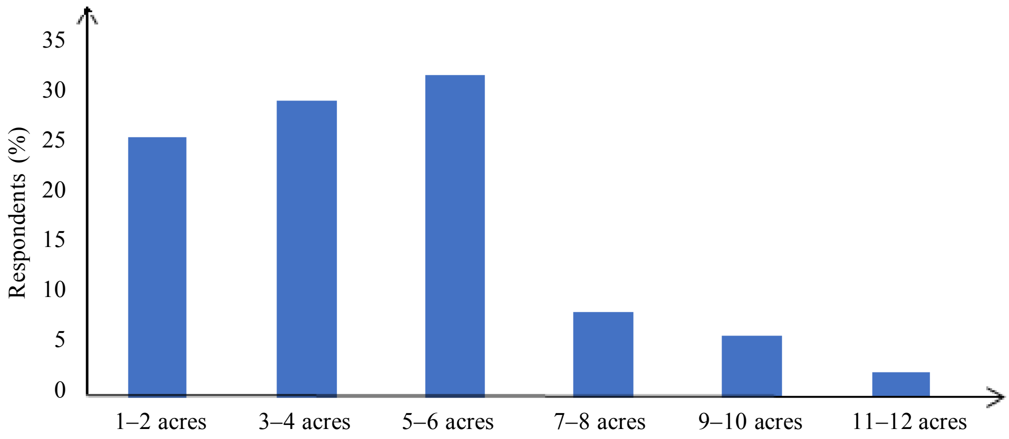

Figure 2. Sizes of cocoa farms in the Offinso Municipality of Ghana

Table 1. Common shade trees that exist on cocoa farms within the Offinso Municipality of Ghana

Scientific names	Local name
Terminalia superba	Ofram
Ricinodendron heudelotii	Wawa
Chlorophora excelsa	Odum
Khaya senegalensis	Mahogany
Terminalia ivorenisis	Emire
Alstonia boonei	Onyame dua
Albizia zygyia	Okoro
Pycnanthus angolensis	Otie
Antiaris toxricaria	Kyenkyen
Tectona grandis	Teak
Cola gigantean	Watapuo

Source: Author's compilation

whereas 15.3% of the total respondents practice low shade (5–6 trees ha^{-1}) cocoa agroforestry. A minimum of 12.9% of respondents practice the full sun cocoa agroforestry system (0–2 trees ha^{-1}) as seen in Figure 4.

Generally, majority (55.3%) of the cocoa farmers indicated they had no challenge with shade trees presence on farms. Constraints mentioned by farmers growing cocoa under shade include pest infestation (cocoa capsid) and diseases (black pod and swollen shoots diseases). About 21.2% of them had problems with pest infestation, 10.6% diseases, and 12.9% both pest infestation and diseases (Figure 5). Some farmers indicated that some shade tree species harbour insects like ants. A study by Asare (2005) confirms that tree species like *Terminalia superba* (ofram) and *Antiaris toxricaria* (kyenkyen) are self-prune whereas tree species like *Ceiba pentandra* (onyina) and *Cola gigantean* (watapuo) and *Cola acuminata* (cola nut) serve as hosts to virus of cocoa swollen shoots disease. Training must be intensified by extension officers to educate farmers on appropriate tree species to intercrop on their cocoa farms. Others include farmers' low fertility and lack of access to credit due to poor yield trends caused by shade trees and poor book keeping practices. Osman *et al.* (2022) revealed that all producers of cocoa received subsidy fertilizer from the government, but they still mentioned other difficulties in growing cocoa, such as low fertility, difficulty getting financing,

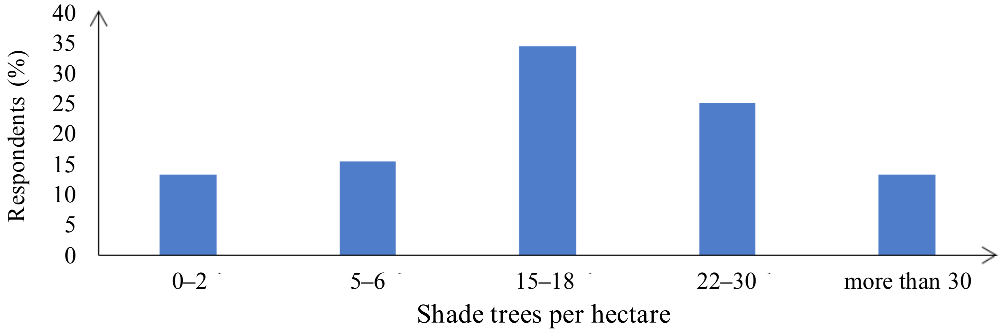

Figure 3. Shade trees per hectare in cocoa agroforestry systems in the Offinso Municipality of Ghana

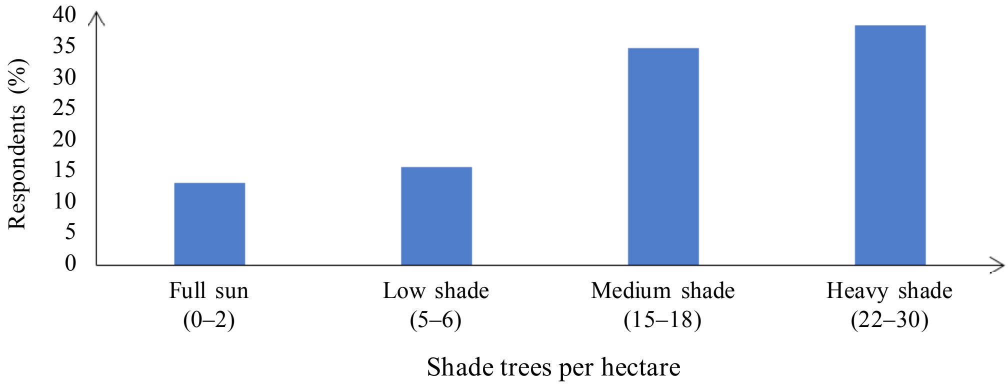

Figure 4. Types of cocoa agroforestry systems based on shade levels in the Offinso Municipality of Ghana

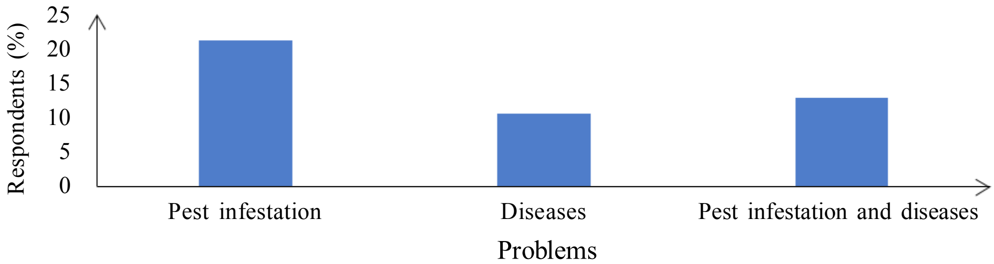

Figure 5. Constraints associated with growing cocoa under shade by farmers in Offinso Municipality of Ghana

and pest and disease infestation. Reduced light availability and wind speed, buffering temperatures, and higher relative humidity in cocoa agroforestry systems as opposed to monocultures may encourage the sporulation of diseases like black pod (Niether *et al.*, 2020).

Cocoa Yield Under Different Shade

A total of 48.2% of respondents, harvest between 1–5 bags per acre of cocoa which is equivalent to 160 kg–800 kg per hectare. This agrees with a study by Asare (2017), which states that the average productivity of dry cocoa beans in Ghana is reported to be in the range of 400–500 kg per hectare. Few respondents (1.2%) harvest above 10 bags (1600 kg per hectare) of cocoa. Out of the outstanding respondents, 31.8% stated that they had no idea about the number of bags they harvest (Figure 6). Under the different shade systems, most of the respondents (35.3%) harvested between 1–5 bags per acre which is equivalent to 160–800 kg per hectare in the 2021 major season. The average cocoa yield (kg ha^{-1}) under each shade intensity is presented in Table 2. Full sun, low shade, medium shade, and heavy shade recorded cocoa yields of 713, 1435, 1576, and 1196 kg ha^{-1} respectively. This supports a study by Kyereh (2017) that the medium-shade cocoa agroforestry system may be the most effective way of optimizing ecological, economic, and social outcomes to build organic bridges in cocoa production. As shade trees on cocoa farms maintain soil moisture, improve soil fertility, suppress weed growth, and improve biodiversity (Kyereh, 2017), the cocoa plantation should therefore maintain 10 to 15 trees per hectare to reduce some of the risks of disease and insect incidence brought on by a heavy shade system (Padi & Owusu, 2003). For a balanced financial and ecological benefit, the study recommends the medium shade regime cocoa agroforestry for farmers within the district. Figure 7 indicates a positive relationship between yield and shade intensity. The regression $R^2 = 0.9996$ and the equation $y = -275.59x^2 + 1537x - 545.49$ quantify the direction and strength of the relationship between the yield and shade types. Farmers generate income from shade trees on farm by selling tree products such as wood, food, timber, and fruits. This agrees with a study by Charles *et al.* (2013) that reported that agroforestry practices increase household income through the sale of wood, firewood, poles, fruits, and non-wood products. It can be deduced that yield increases as the shade level increases but drops slightly under the heavy shade regime. This confirms a study by Zuidema *et al.* (2005) who noted that heavy shade reduces seed yield. This is because the heavy shade system reduces the amount of sunlight reaching the cocoa causing low photosynthetic production (Alvim, 2013).

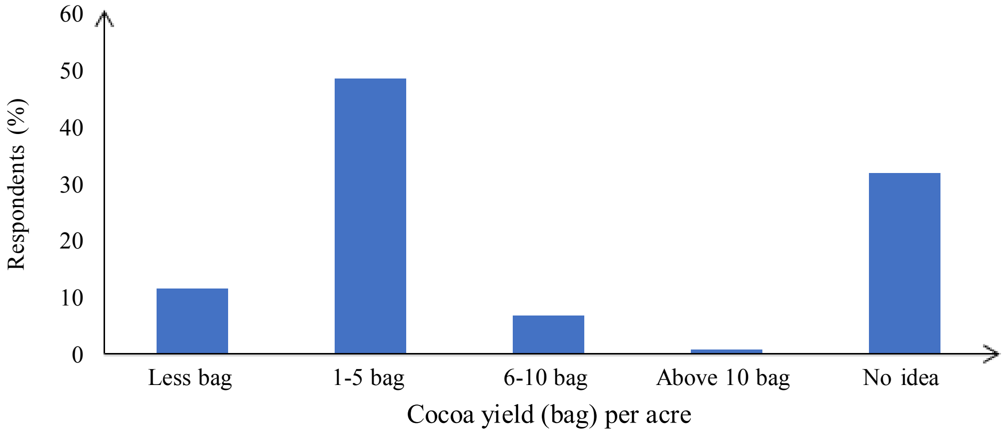

Figure 6. Cocoa yield (bags) per hectare by cocoa farmers in the Offinso Municipality

Table 2. Shade intensity and average cocoa yield (kg ha^{-1}) in the Offinso Municipality

Shade intensity	Total hectare (ha)	Total yield (kg)	Average yield (kg ha^{-1})
Full sun	19.6	13,975	713
Low shade	19.2	27,545	1435
Medium shade	46.8	73,778	1576
Heavy shade	52.8	63,133	1196

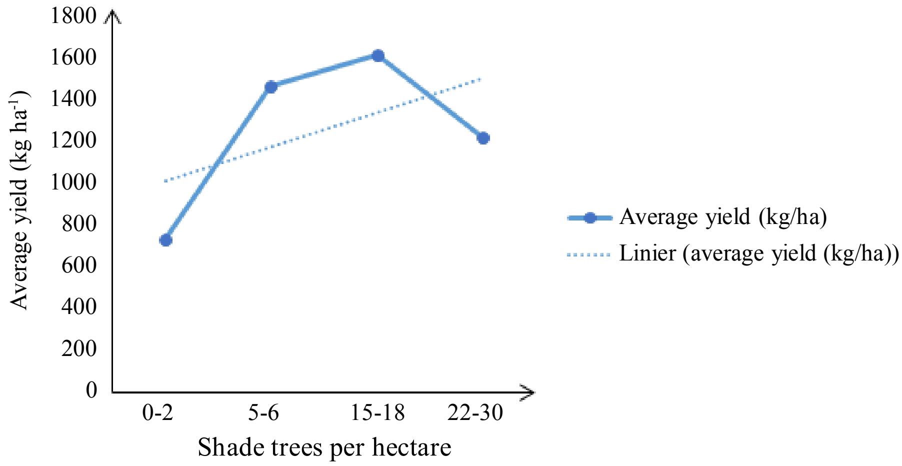

Figure 7. Relationship between yield and shade intensity of cocoa farms in Offinso Municipality

CONCLUSIONS

Amidst all changes, cocoa agroforestry is the most recommended practice recently, most cocoa farmers revealed that they faced problems such as pest and disease infestation, low yield, and lack of access to credit under this practice. Undesirable tree species such as *Ceiba pentandra* (Onyina), *Cola gigantean* (Watapuo), and *Cola acuminata* (Cola Nut) harbor pests and diseases. Again, farmers revealed that tree species like *Terminalia superba* (Ofram) and *Antiaris toxricaria* (kyenkyen) negatively affect the cocoa with their self-pruning ability which destroys other crops on the farm. Most farmers were found practicing the heavy shade system, but the medium shade system was the most effective way of increasing yield. The full potential of cocoa agroforestry can only be achieved if farmers are inspired and given the right incentives and support. Economic, and environmental advantages can result from properly planned and maintained cocoa agroforestry systems. Reducing high temperatures can also improve the microclimate of cocoa farms by boosting water availability and reducing the quantity of evapotranspiration into the atmosphere. In the end, cocoa agroforestry encourages the sustainable production of cocoa and enhances the quality and longevity of cocoa. It was reported that farmers in the Offinso Municipality practice all four cocoa agroforestry system types (full sun, low shade, medium shade, and heavy shade) with the heavy shade being practiced the most. The medium shade system should be the most adopted cocoa agroforestry type by farmers to help increase yield.

REFERENCES

Abu, M.; S.N.A. Cudjoe & J. Sward (2014). Climate change and internal migration intentions in the forest-savannah transition zone of Ghana. *Population and Environment*, 35(4), 341–364.

Afele, J.T.; E. Dawoe; A.A. Abunyewa; Afari-Sefa & R. Asare (2021). Carbon storage in cocoa growing systems across different agroecological zones in Ghana. *Pelita Perkebunan*, 37(1), 32–49.

Afele, J.T.; E. Nimo; B. Lawal & I.K. Afele (2022). Deforestation in Ghana: Evidence from selected forest reserves across six ecological zones. *International Journal of Forest, Animal and Fisheries Research*, 6(1), 7–17.

Alvim, P.D.T. & T.T. Kozlowski (Eds.) (2013). *Ecophysiology of Tropical Crops*. Elsevier.

Ameyaw, L.K.; G.J. Ettl; K. Leissle & G.J. Anim-Kwapong (2018). Cocoa and climate change: Insights from smallholder cocoa producers in Ghana regarding challenges in implementing climate change mitigation strategies. *Forests*, 9(12), 742.

Amooh, M.K. (2017). *Shade Management Options in Cocoa Agroforestry Systems in Two Ecological Zones in Ghana*. MPhil Thesis, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

Asante, W.A.; G. Ahoma; B.A. Gyampoh; B. Kyereh & R. Asare (2021). Upper canopy tree crown architecture and its implications for shade in cocoa agroforestry systems in the western region of Ghana. *Trees, Forests and People*, *5*, 100100.

Asare, R. (2005). Cocoa agroforests in West Africa: a look at activities on preferred trees in the farming systems. pp. 1–89. ***In:*** *The Danish Center for Forest. Landscape and Planning (KVL)*, Horsholm.

Asare, R. (2019). The nexus between cocoa production and deforestation. *Grain De Sel*, 78, 26–27.

Asare, R.; B. Markussen; R.A. Asare; G. Anim-Kwapong & A. Ræbild (2017). On-farm cocoa yields increase with canopy cover of shade trees in two agro-ecological zones in Ghana. *Climate and Development*, 11(5), 435–445.

Atkins, J.E. & I. Eastin (2012). Seeing the trees: farmer perceptions of indigenous forest trees within the cultivated cocoa landscape. *The Forestry Chronicle*, 88(5), 535–541.

Avane, A.; B. Amfo; R. Aidoo & J.O. Mensah (2022). Adoption of organic fertilizer for cocoa production in Ghana: Perceptions and determinants. *African Journal of Science, Technology, Innovation and Development*, 14(3), 718–729.

Boateng, D.O.; F.N.Y. Codjoe & J. Ofori (2014). Impact of illegal small-scale mining (Galamsey) on cocoa production in Atiwa district of Ghana. *International Journal of Advanced Agricultural Research*, 2, 89–99.

Charles, R.L; P.K.T. Munishi & E.F. Nzunda (2013). Agroforestry as an adaptation strategy under climate change in Mwanga District, Kilimanjaro, Tanzania. *International Journal of Environmental Protection*, 3(11), 29–38.

CRIG (2010). *Cocoa Manual, A Source Book for Sustainable Cocoa Production*. Cocoa Research Institute of Ghana. Accra, Ghana

Garen, E.J.; K. Saltonstall; M.S. Ashton; J.L. Slusser; S. Mathias & J.S. Hall (2011). The tree planting and protecting culture of cattle ranchers and small-scale agriculturalists in rural Panama: Opportunities for reforestation and land restoration. *Forest Ecology and Management*, 261(10), 1684–1695.

Gemechu, H.W.; D. Lemessa & D.B. Jiru (2021). A comparative analysis of indigenous and exotic tree species management practices in agricultural landscapes of southwest Ethiopia.*Trees, Forests and People*, 4, 100059.

Gibson, J. (2007). *Consistently Inconsistent: Addressing Income Volatility among Cocoa Producers in Ghana and Cote d'Ivoire*. International Institute for Sustainable Development, Winnipeg, Canada.

GSS (2021). *Ghana 2021 Population and Housing Census*. General Report. Volume 3A. Ghana Statistical Service, Accra, Ghana.

Kodom, M.; S.B. Azumah; N.A. Boateng; E.M. Tsekpo; K.B. Mensah & E. Boateng (2022). Changing the perceptions and attitudes of rural Ghanaian youth towards cocoa farming. *Development in Practice*, 1–10.

Kyereh, D. (2017). Shade trees in cocoa agroforestry systems in Ghana: Influence on water and light availability in dry seasons. *Journal of Agriculture and Ecology Research International*, 10, 1–7.

Maguire–Rajpaul, V.A; K. Khatun & A.M. Hiros (2020). Agriculture informations impact on the adaptive capacity of Ghana's smallholder cocoa farmers. *Frontiers in Sustainable Food Systems*, 4(28), 1–19.

Mattalia, G.; A. Wezel; P.; Costet; P. Jagoret; O. Deheuvels; P. Migliorini & C. David (2022). Contribution of cacao agroforestry versus mono-cropping systems for enhanced sustainability. A review with a focus on yield. *Agroforestry Systems*, 96(7), 1077–1089.

Mikell, G. (1992). *Cocoa and Chaos in Ghana*. Howard University Press, Washington, DC.

Niether, W; J. Jacobi; W.J. Blaser; C. Andres & L. Amengot (2020). Cocoa agroforestry systems versus monocultures: A multidimensional meta-analysis. *Environmental Research Letters*, 15(10), 104085.

Nimo, E.; E. Dawoe & J.T. Afele (2021). A comparative study of carbon storage in two shade-types of cocoa and a teak plantation in the moist semi-deciduous forest zone of Ghana. *Pelita Perkebunan*, 37(1), 50–61.

Nunoo, I.; V. Owusu & B. Darko Obiri (2014). Cocoa agroforestry a bridge for sustainable organic cocoa production. pp. 555–558. ***In:*** *Building Organic Bridges* (G. Rahmann & U. Oksay, Eds.). Johann Heinrich von Thünen-Institut, Braunschweig, Germany, Thuenen Report, no. 20.

Obiri, B.D.; G.A. Bright; M.A. McDonald; L.C.N. Anglaaere & J. Cobbina (2007). Financial analysis of shaded cocoa in Ghana. *Agroforestry Systems*, 71, 139–149.

Oduro-Ofori, E.; A.P. Aboagye & N.A.E. Acquaye (2014). Effects of education on the agricultural productivity of farmers in the Offinso Municipality. *International Journal of Development Research*, 4(9), 1951–1960.

Ofori-Frimpong, K.; A.A. Afrifa & A. Acquaye (2010). Impact of shade and cocoa plants density on soil organic carbon sequestration rates in a cocoa growing soil of Ghana. *African Journal of Environmental Science and Technology*, 4(9), 621–624.

Orozco-Aguilar, L.; A. López-Sampson; M.E. Leandro-Muñoz; V. Robiglio; M. Reyes; M. Bordeaux & E. Somarriba (2021). Elucidating pathways and discourses linking cocoa cultivation to deforestation, reforestation, and tree cover change in Nicaragua and Peru. *Frontiers in Sustainable Food Systems*, 5, 199.

Osman, N.; J.T. Afele; E. Nimo; D.O. Gorleku; L.A. Ofori & A.A. Abunyewa (2022). Assessing the impact of illegal small-scale mining (galamsey) on cocoa farming and farmer livelihood: A case study in the Amansie West District of Ghana. *Pelita Perkebunan*, 38 (1), 70–74

Owusu, V. & F.K. Frimpong (2014). Impact of cocoa agroforests on yield and household income: Evidence from Ghana. ***In:*** The 88th Annual Conference of the Agricultural Economics Society, AgroParisTech, Paris, France (No. 356-2016-18239).

Oy, I. (2002). *Increasing Timber Processing Utilization Efficiency and Reducing Waste.* Final Report. International Tropical Timber Organization. ITTO Pre-Project PPD 66/02 (I).

Padi, B. & G.K. Owusu (2003). Towards an integrated pest management for sustainable cocoa production in Ghana. ***In:*** A workshop held in Panama. Smithsonian Institution. Washington, D.C.

Ruf, R. & H. Zadi (1998). Cocoa: From deforestation to reforestation. ***In:*** *First International Workshop on Suitable Cocoa Growing.* Smithsonian Institute, Panama.

UNDP (2011). *Environmental Baseline Report on Cocoa in Ghana*. UNDP Ghana Consultancy Report. United Nations Development Programme. Accra.

Uribe, A.; H. Mendez & J. Mantilla (2001) Effect of Balanced fertilization on cocoa yield. *Better Crops International*, 15, 1–3.

Yamoah, F.A.; J.S. Kaba, D. Botchie & J. Amankwah-Amoah (2021). Working towards sustainable innovation for green waste benefits: the role of awareness of consequences in the adoption of shaded cocoa agroforestry in Ghana. *Sustainability*, 13(3), 1453.

Zuidema, P.A.; P.A. Leffelaar; W. Gerritsma; L. Mommer & N.P. Anten (2005). A physiological production model for cocoa (*Theobroma cacao*): Model presentation, validation and application. *Agricultural Systems*, 84(2), 195–225.

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