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Forest Trees and their Perceived Negative Impacts on Cocoa Plantations in Southern Nigeria

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Abstract

Cocoa (*Theobroma cacao*) is a key agricultural crop in Southern Nigeria, contributing significantly to the livelihoods of rural populations and the nation's economy. However, forest trees within cocoa plantations are often perceived by farmers to negatively affect cocoa production through resource competition, excessive shade and the promotion of pests and diseases. This study investigates farmers' perception of these negative effects and examines the socio-economic factors influencing cocoa farming in Southern Nigeria. Field data were collected from 138 cocoa farmers in Ondo, Osun, and Oyo states using a multistage random sampling technique. The results showed that 66.0% of the farmers believe that forest trees, particularly *Cola gigantea* and *Spondias mombin*, reduce cocoa yield. The results further reveal that fifty-five percent of the farmers (55.0%) are middle-aged men with secondary education (51.0%), and hired labour (75.0%) is commonly used. Chi-square analysis indicated significant relationships between cocoa yield, farmers' socio-economic characteristics, and the perceived negative impacts of forest trees. Specifically, factors like age and educational status of the farmers significantly influenced the perception of farmers on the effect of forest trees on cocoa production. This study concludes that forest trees reduce cocoa yield but may be detrimental to cocoa or any other crop. It is recommended that while forest trees offer ecological benefits, their management must be well carried out. Also, selective tree retention for improved shade management practices is recommended to maximize cocoa productivity and maintain environmental sustainability.

Introduction

Theobroma cacao (cacao) belongs to the Malvaceae family (alternatively Sterculiaceae). It is an economically important perennial crop and one of the world's most valuable crops, cultivated on 8.2 million hectares globally. It plays a significant role in the social and economic life of over 5 million households and impacts 25 million people in poor rural areas (National Agricultural Advisory Services, 2023). Cocoa is grown in fifty-eight countries and contributes more than US$4 billion annually to the world economy (International Cocoa Organization (ICCO), no date). Nigeria ranks as the fourth largest cocoa producer globally, following Ivory Coast, Ghana, and Indonesia, accounting for approximately 12.0% of the total world production (World Cocoa Foundation, 2014). Cocoa is Nigeria's primary export crop in terms of production and export capacities (Nwachukwu et al., 2012).

In West Africa, cocoa plays a significant role, contributing around 70.0% of the global cocoa production (Kehinde, 2021) and it is mainly grown by smallholders who traditionally plant their cocoa at random under thinned forest shade. Nigeria, ranked as the third-largest cocoa producer in West Africa, features a predominantly small-scale farming sector, crucial for the livelihoods of rural populations in cocoa-

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producing states in Nigeria like Ondo, Oyo, Osun, Ogun, and Ekiti states. The cultivation methods range from inherited fields to share cropping systems, with the latter entailing two-thirds of the produce going to the landowner, who also contributes to farming input costs (Kehinde, 2021). Historically, cocoa was a primary source of foreign exchange in Nigeria between 1950 and 1960, but the discovery of oil in 1970 shifted the economic landscape, relegating cocoa to the second position in foreign exchange earnings. Nevertheless, cocoa remains a vital crop, contributing significantly to the country's foreign exchange earnings within the agricultural commodity export sector (Ajayi and Oyejide, 1974; Afolayan, 2020). Despite Nigeria's annual production of 300-350 metric tons of cocoa, majority is exported, accounting for approximately 96.0% of the total cocoa output. (International Cocoa Organization, 2023).

Cocoa production is a vital agricultural and economic activity in Southern Nigeria, contributing significantly to the livelihood of many rural farmers. However, the interaction or coexistence of forest trees within or near cocoa plantations has been a subject of concern due to the perceived negative impacts they may have on cocoa growth and yield. The most frequently reported negative impact of forest trees is a reduction in cocoa yield. Farmers attribute this to the competition between forest trees and cocoa plants for essential resources such as sunlight, nutrients and water. Forest trees with dense canopies create significant shading which can lower the amount of sunlight reaching the cocoa plants hindering photosynthesis and reducing overall productivity. While some shade is beneficial for cocoa, excessive shading caused by large or numerous forest trees can disrupt optimal growing conditions leading to lower yields. Most farmers often attribute reduced cocoa yields to excessive shading caused by forest trees. According to Ahenkorah *et al.* (1974), although moderate shade (30–50%) is beneficial for young cocoa plants, excessive shading can limit photosynthesis leading to lower pod production. Similarly, Ruf (2011) noted that forest trees with dense canopies reduce sunlight penetration which is critical for optimal cocoa yield.

Water and nutrient competition is a recurring concern among cocoa farmers. Forest trees with their expansive root systems, draw significant amounts of water and nutrients from the soil, leaving less available for cocoa plants. According to Duguma *et al.* (2001), the competition for soil resources in cocoa-agroforestry systems often leads to reduced cocoa growth and yield particularly in areas with poor soil fertility. Similarly, findings by Tscharntke *et al.* (2011) emphasized that resource competition is a critical factor limiting cocoa productivity in mixed cropping systems. The shedding of leaves from forest trees was also reported by farmers as a factor affecting cocoa growth. Decomposing leaves can alter the PH of the soil or release allelopathic substances harmful to cocoa plants. Findings by Ofori-Frimpong *et al.*, (2010) revealed that certain non-cocoa tree species produce leaf litter that temporarily lowers soil nutrient availability particularly nitrogen. This nutrient imbalance can negatively impact cocoa growth. Forest trees often serve as reservoirs for pests and pathogens, increasing the risk of infestation and disease in cocoa plantations. Leaf litters may create a breeding ground for pests as confirmed by Dzahini-Obiatey *et al.* (2010) who linked leaf litter accumulation with increased black pod disease incidence in cocoa farms. Ambele *et al.* (2018) highlighted that forest trees harbour mealybugs, which are vectors for the cocoa swollen shoot virus (CSSV). The proximity of forest trees complicates pest management, as their dense foliage provides a haven for pests that are challenging to control. Similarly, Opoku *et al.* (2007) reported higher incidences of black pod disease in cocoa farms surrounded by dense forest cover attributing this to increased humidity levels caused by shaded environments.

The presence of forest trees has also been linked to the death of cocoa plants through resource competition and allelopathy. A study by Isaac *et al.* (2005) demonstrated that forest trees with extensive root systems outcompete cocoa plants for water and nutrients particularly in resource-scarce environments. Furthermore, certain forest tree species release allelopathic chemicals that inhibit the growth of surrounding vegetation including cocoa plants. This was corroborated by the findings of Kébé *et al.* (2009), who identified chemical interactions between forest trees and crops as a significant factor in agroforestry systems.

Balancing the presence of forest trees with cocoa cultivation requires careful management to mitigate the challenges while harnessing the benefits they provide. Forest trees contribute positively by regulating microclimates, conserving soil and enhancing biodiversity which are crucial for sustainable agricultural systems. However, to address their negative impacts without losing these advantages, researchers advocate for the adoption of integrated management practices. One of such a practice is selective tree management which involves retaining beneficial shade trees that support cocoa growth while removing species known to have harmful effects (Asare, 2006). Another approach is optimizing agroforestry systems by designing tree-crop arrangements that reduce competition for resources and maximize ecological synergies (Snoeck *et al.,* 2010). Additionally, the implementation of integrated pest management (IPM) is essential to monitor and control the spread of pathogens from forest trees to cocoa plants ensuring the health and productivity of the plantation (Schroth *et al.,* 2000). These strategies offer a balanced solution to managing forest trees in cocoa cultivation systems.

In Southern Nigeria, cocoa plays a crucial role as a key agricultural crop, supporting rural livelihoods and contributing significantly to the nation's economy. However, the presence of forest trees in cocoa plantations has often been linked to various adverse effects on cocoa production. This has led farmers to either manage or remove these trees in order to maximize yields. Some of the perceived negative impacts of forest trees on cocoa plantations include issues with shade management, competition for resources, the creation of habitats for pests and diseases, economic considerations, and regulation of soil moisture and temperature. This study aimed to investigate the perceived negative effects of forest trees on cocoa plantations in Southern Nigeria, with the overall objective of assessing cocoa farmers' perceptions of these effects in the study area.

Materials and Methods

Study area

The study was conducted in Southern Nigeria. The study employed a multistage random sampling procedure to select cocoa farmers in the study area. The first stage involved a selection of three cocoa-producing states from Southern Nigeria, these were Ondo, Osun and Oyo states. The second stage also involved a selection of three Local Government Areas (LGAs) from Ondo state namely Akure South, Idanre and Ondo East; two LGAs from Osun state (Ayedaade and Isokan) and one LGA from Oyo state (Ona Ara) giving a total of six (6) LGAs from Ondo, Osun and Oyo states altogether. The selection was due to the prominence of cocoa-related activities in the local government areas and communities. Well-structured questionnaires were used to elicit information from the respondents. Seventy-five farmers were selected from Ondo state, forty-five from Osun state and forty farmers from Oyo state making a total of one hundred and sixty farmers from the three states. However, information from one hundred and thirty-eight cocoa farmers was used for the analysis as some questionnaires were incomplete and therefore excluded from the study. Data were analyzed using descriptive statistics (frequency distribution, percentages, means, and standard deviation) and Chi-square analysis.

Geographical location

Fig. 1 below illustrates the distribution of respondents in Ondo, Osun, and Oyo states. A total of 138 respondents information were included in the analysis. In Ondo state, Paadi recorded the highest number of respondents, with 38 farmers (27.54%). Mokere in Osun state followed with 20 farmers (14.49%), while Oyewo in Oyo state accounted for 10 farmers (7.25%). Respondents from other towns were sparsely distributed.

Results and Discussion

Socio-economic characteristics of respondents

Table 1 below presents the socio-economic characteristics of cocoa farmers in the study area. The table shows that (55.1 %) of the farmers in the study area are between ages 30 and 50, 15.9 % are less than 30 years of age while 29.0 % are more than 50 years. This implies that middle aged people dominated production of cocoa in the study area(s). The mean age and standard deviation are approximately 43 and 11.8

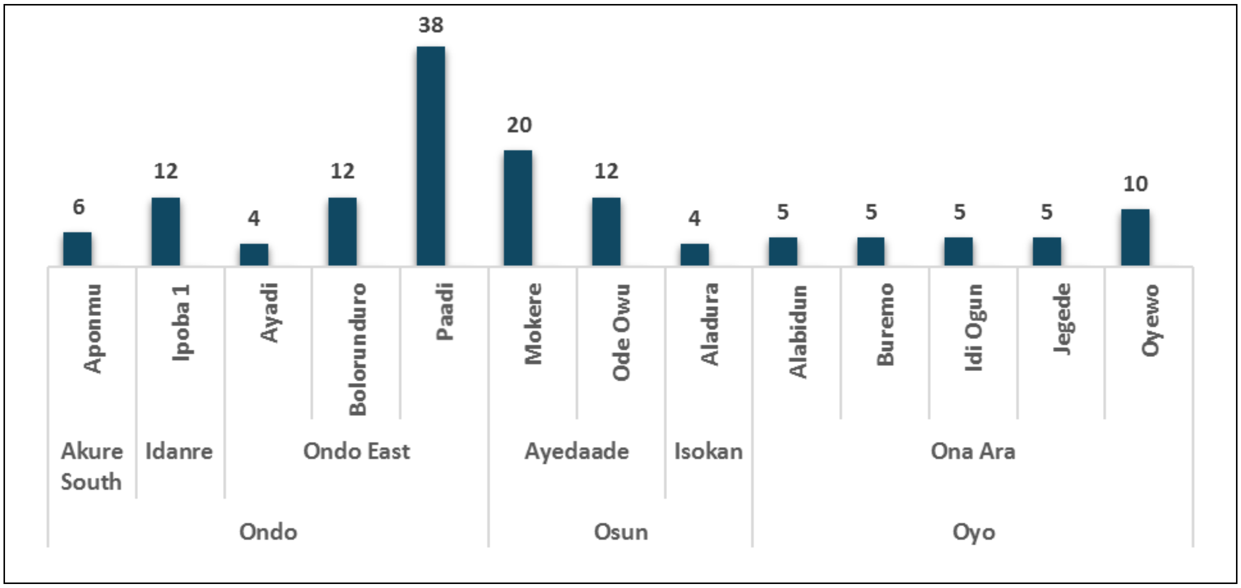


Fig. 1: Diagram showing communities and distribution of respondents across the selected LGAs

Table 1: Socio-Economic Characteristics of Cocoa Farmers in Southern Nigeria

Variable	Frequency	Percentage (%)	Mean	Standard Deviation
Age (Years)			43	11.84
Less than 30	22	15.9		
30-50	76	55.1		
Above 50	40	29.0		
Gender				
Male	108	78.3		
Female	30	21.7		
Educational Level (Years)				
No Formal Education	10.1	14		
Primary Education	25	18.1		
Secondary Education	70	50.7		
Tertiary Education	27	19.6		
Adult Education	1.4	2		
Type of Farm Labour				
Family	10.1	14		
Hired	103	74.6		
Self	21	15.2		
Farming Experience (Years)			29.31	8.45
Less than 30	105	71.6		
30-50	28	20.3		
51 and above	5	3.6		

Source: Field Survey, 2024

years respectively. This suggests that the group is generally middle-aged and it is skewed towards the 30-50 age group, which had the highest percentage. The standard deviation measures the spread or variability of ages around the mean. A standard deviation of 11.8 years indicates a moderate spread of the ages around the mean. The gender of the farmers showed that about seventy-eight percent are male while about twenty-two percent are female. This shows that both the male and female gender are involved in cocoa production though the male gender is dominant in the study area. Also, according to table 1, the largest percentage (50.7%) of the farmers had secondary education while 10.1% had no formal education. This corroborates *a priori* expectation of the fact that education is a vital tool needed to enhance production, marketing and modern practices of farming (Smith and Doe, 2023). It can be clearly deduced that greater part of the farmers are educated. It therefore suggests that the education could improve farmer's access to information and knowledge which could be a positive impact on cocoa production efficiency. Furthermore, table 1 indicates that 74.6% of the respondents used hired labour. This result suggests that family members are not committed to cocoa farming as an economic venture from which income can be generated to sustain the family. The table also shows that 76.1% of the respondents have less than thirty years of farming experience with 20.3% having between thirty to fifty years of farming experience. This indicates that the average farming experience is approximately 29.3 years**,** with a relatively small variation or standard deviation of 8.45 `

Status of cocoa farmers

Figs. 2a and 2b show the status of cocoa farmers in the study areas. Majority of them, (93.0 %) are full-time cocoa farmers and (84.0 %) are sole owners of their cocoa farms, indicating a strong commitment to cocoa farming as their primary livelihood and also a high degree of individual control and responsibility over production. This high level of full-time involvement and farm ownership affirms the importance of cocoa farming to the local economy. It also points out the need for targeted support in areas such as training, finance, and farm management to enhance productivity and sustainability.

Fig. 3 shows that 68.0 % of cocoa farmers in the study area(s) are members of cooperatives or associations while Fig. 4 reveals the size of the farm owned by individual farmers. It shows that 77.0 % of the farmers have farm size of less than 5 hectares, (8.0 %) have between 5 and 10 hectares. Only 15.0 % have land sizes of 11 hectares or more. This shows that most cocoa farmers (68.0 %) are members of cooperatives, which can enhance access to resources and market opportunities. However, 77.0 % of the farmers have small farms (less than 5 hectares), limiting production capacity. Only 15.0 % have larger farms, suggesting challenges in scaling up. Hence, the need for better land access, resources and support for small-scale farmers to increase productivity and expand operations. This suggests that while cooperatives can support small farmers, there is a need for greater access to land, resources, and technology to help farmers scale up production and improve efficiency. Policies targeting land access and supporting cooperative development could enhance cocoa farming outcomes in the study area.

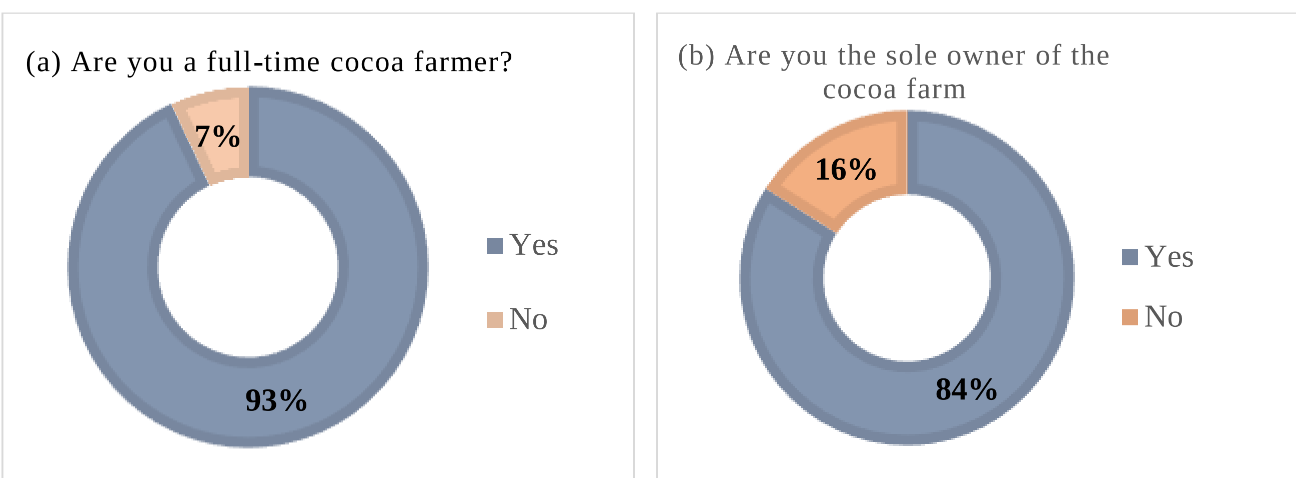


Fig. 2. Status of cocoa farmers. (*Source: Field Survey, 2024*)

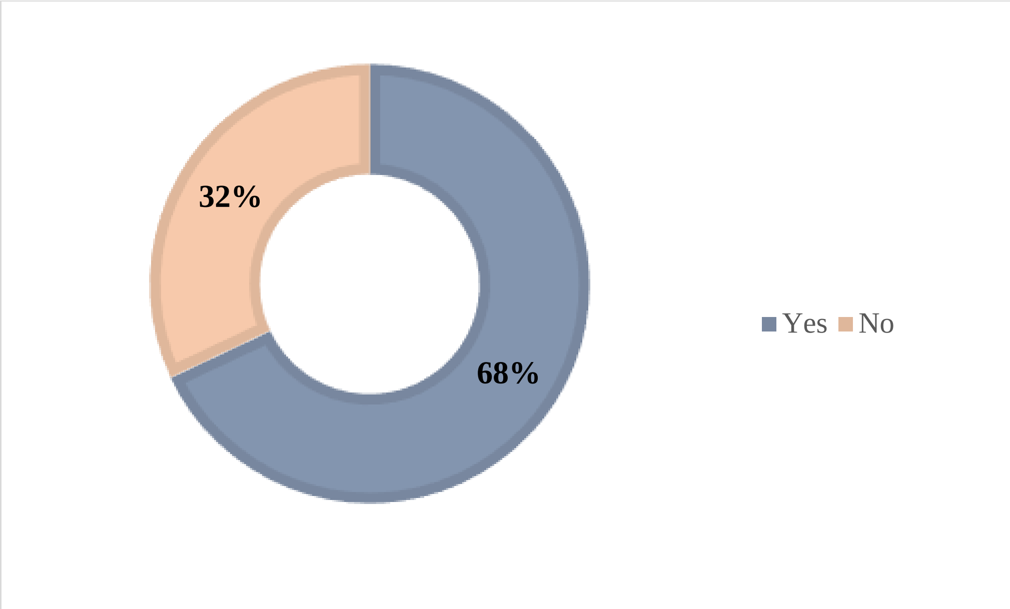


Fig. 3: Membership of any cocoa farmers' cooperative or association

Source: Field Survey, 2024

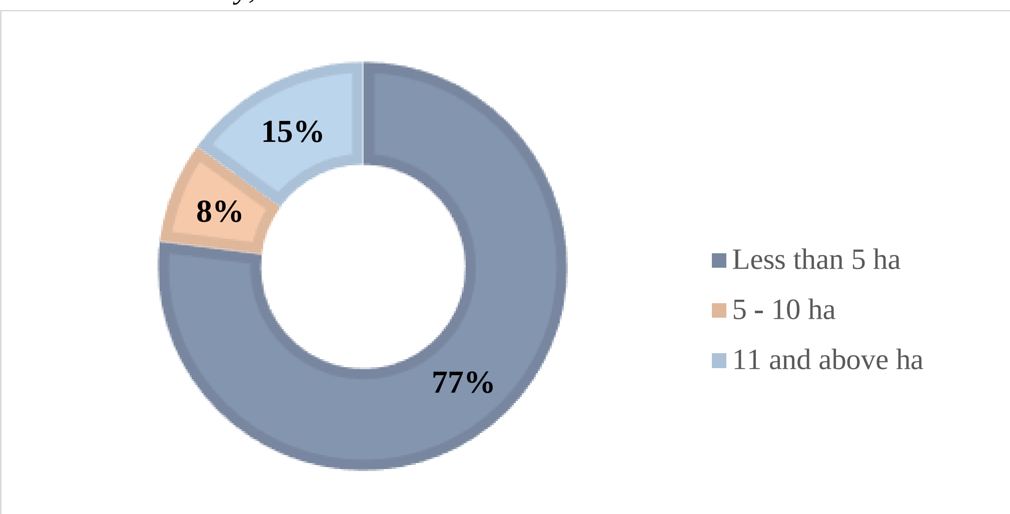


Fig. 4: Cocoa farm size (hectare)

Source: Field Survey, 2024

Cocoa varieties grown by farmers

Fig. 5 shows the varieties of cocoa cultivated in the selected areas. The findings indicate that the Amelonado and F3 Amazon hybrid combination is the most popular cocoa variety among farmers, suggesting its widespread cultivation and potential advantages in terms of adaptability, yield, or market demand. On the other hand, the least cultivated varieties are the F3 Amazon and TC Series combinations, as well as the TC Series alone, indicating lower farmer preference or suitability. Cocoa farmers in the study area prioritize varieties that perform well under their specific conditions to meet market requirements. Promoting less common varieties may require addressing factors such as productivity, resilience, or economic viability to encourage adoption. The significant number of "none/unknown" entries in the diagram suggests that farmers in this category either grow mixed or unidentified cocoa varieties due to limited knowledge or access to certified planting materials. This gap highlights the need for improved farmer education and support to enhance awareness, data accuracy, and adoption of high-yield, quality cocoa varieties.

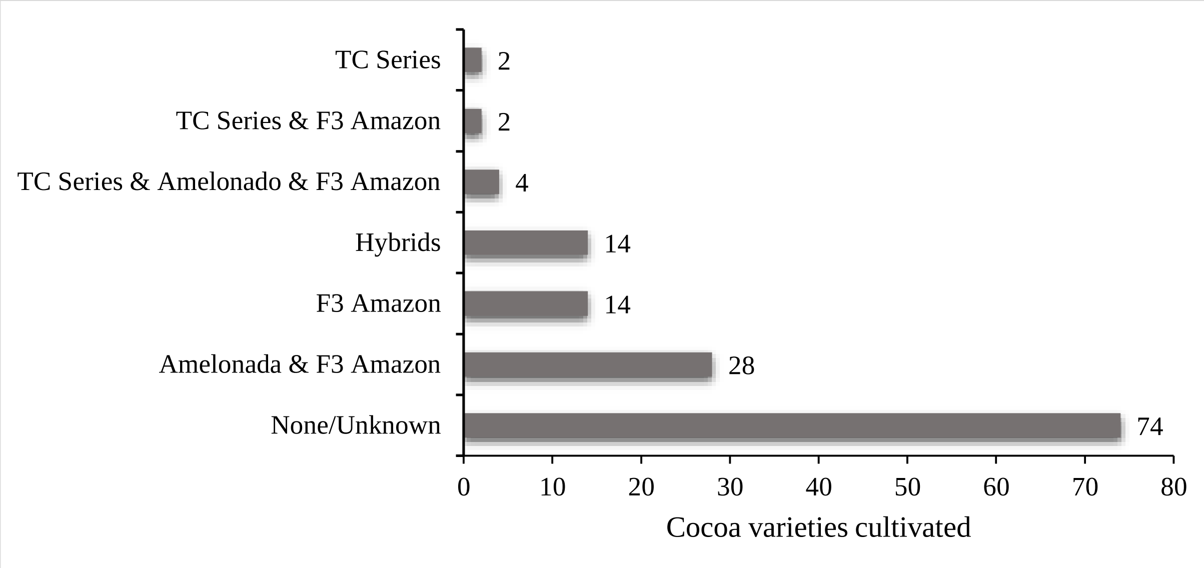


Fig. 5: Distribution of cocoa varieties cultivated
Source: Field Survey, 2024

Source of planting materials

The sources of cocoa materials planted by farmers are shown in Fig. 6. A significant percentage of respondents (29.0 %) stated that they either do not source planting materials or are unclear about the source. The most frequently cited sources are "Other Farmers" and "Own Farm" contributing approximately 20.0 % and 21.0 % respectively. The results showed that 29% of the farmers do not actively source planting materials, while 20.0 % rely on other farmers and 21.0 % on their own farms. Institutional sources like Cocoa Research Institute of Nigeria (CRIN) account for 21.0 %. This highlights limited adoption of scientifically improved planting materials. Hence, institutions like CRIN need to intensify sensitization and training on the benefits of improved planting materials to boost adoption rates, enhance productivity, and ensure sustainable farming practices.

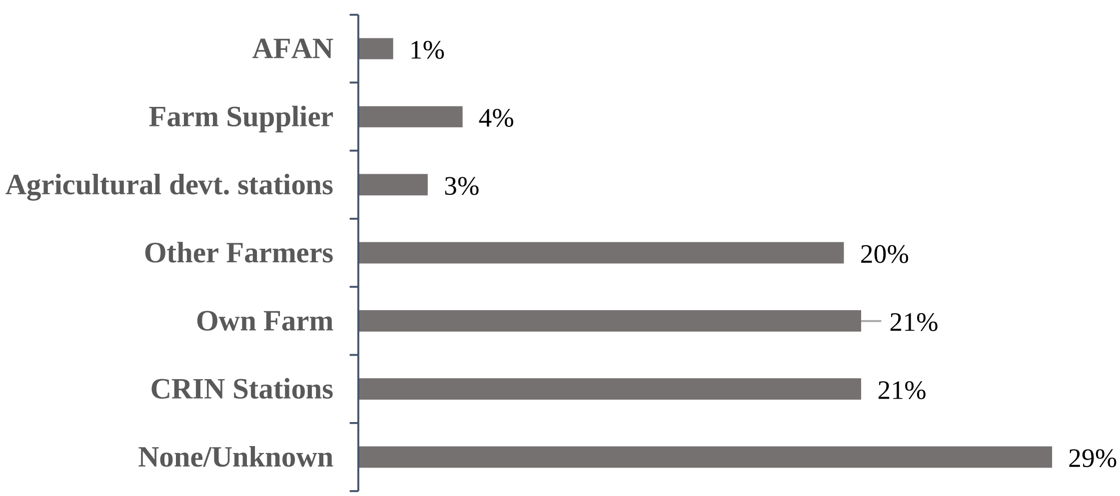


Fig. 6: Source of materials. (*Source: Field Survey, 2024*)

Normal harvesting period for cocoa

Fig. 7 shows the harvesting period within the year by cocoa farmers. A higher percentage of the farmers (47.0 %) harvest cocoa throughout the entire year. Harvesting is highest in October, which accounts for 40.0 %. While April to June and July to September are 26.0 % and 19.0 % respectively. The results show that 47.0 % of farmers harvest cocoa year-round, ensuring a steady supply. October is the peak harvest month (40.0 %), which is ideal for large-scale buyers, while April–June (26%) and July–September (19.0 %) represent secondary harvests. This information will help farmers optimize resources, buyers plan sourcing and policymakers will also be able to support key harvesting periods to enhance production and reduce losses.

Negative effect of forest trees on cocoa trees

The distribution of the perspectives of farmers to the harmful effect of forest trees to cocoa trees are shown in Fig. 8. It was observed that sixty-six percent (66.0 %) of the cocoa farmers perceived that forest trees on their farm harmed cocoa trees. Table 2 shows that *Cola gigantea* [Igbere-oko (ogunun)] of 48 had a higher percentage (52.7%), followed by *Spondias mombin* (Iyeye) with 23 (25.3%). Other forest trees such as *Terminalia superba* (African whitewood or Limba; Afara), *Alstonia boonei* (Stoolwood or Patterned African Whitewood; Ahun), *Parkia biglobosa* (Locust Bean; Iru), *Dacryodes edulis* (Pear) and *Cola nitida* or *Cola acuminata* (Kolanut) trees were also identified and classified as other forest trees that harmed cocoa trees.

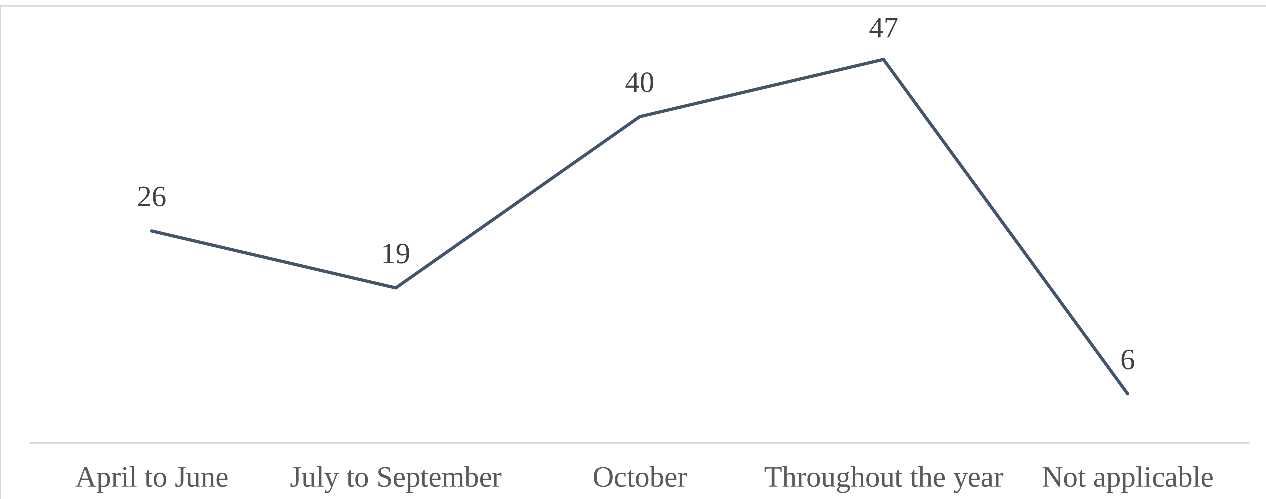


Fig. 7: Period of cocoa harvesting farmers across the area (*Source: Field Survey, 2024***)**

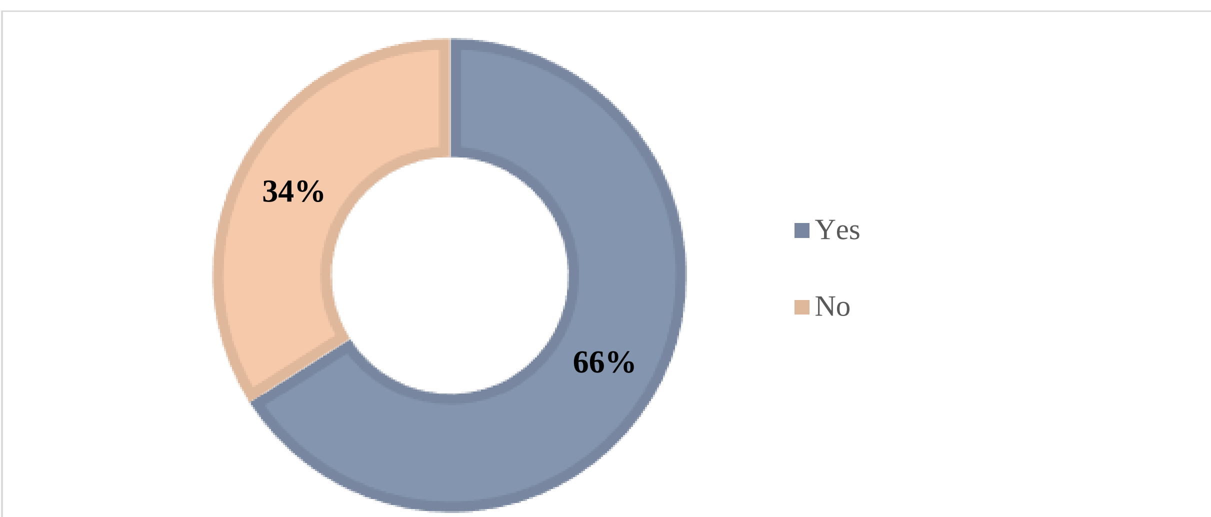


Fig. 8: Farmers' perspectives of the adverse effects of forest trees to cocoa trees. (*Source: Field Survey, 2024*)

Table 2: Distribution of categories of forest trees with negative effects on cocoa plantation

	Spondias mombin (Iyeye)	*Cola gigantea* [Igbere-oko (ogunun)]	Others	Total
Respondent	23	48	20	91
Percentage	(25.3%)	(52.7%)	(22.0%)	(100.0%)

Source: Field Survey, 2024

Having observed that about 47.0 % of the respondents noticed changes in cocoa yield when forest trees grow near cocoa plants, the negative effects that forest trees had on cocoa growth and yield were shown in Fig. 9. The most significant perceived negative effect reported by farmers is a reduction in cocoa yield (37.0 %). Additionally, 28.0 % farmers indicated that leaf shedding from forest trees negatively impacted their cocoa plants while 18.0 % of the farmers reported that forest trees contributed to the death of cocoa trees. Meanwhile, Figs. 10a and b show the period at which the forest trees has negative effects and the types of effects on cocoa yield. As shown in Fig. 10a, 42.0 % of the respondents believed that forest trees primarily affect cocoa during their mature stage, 21.0 % indicated a range of unspecified stages while 20.0 % of the cocoa farmers indicated that the cocoa trees die as the forest trees die. Also, 17.0 % of the farmers reported that forest trees affect cocoa at the seedling/young stage of development (Fig. 10).

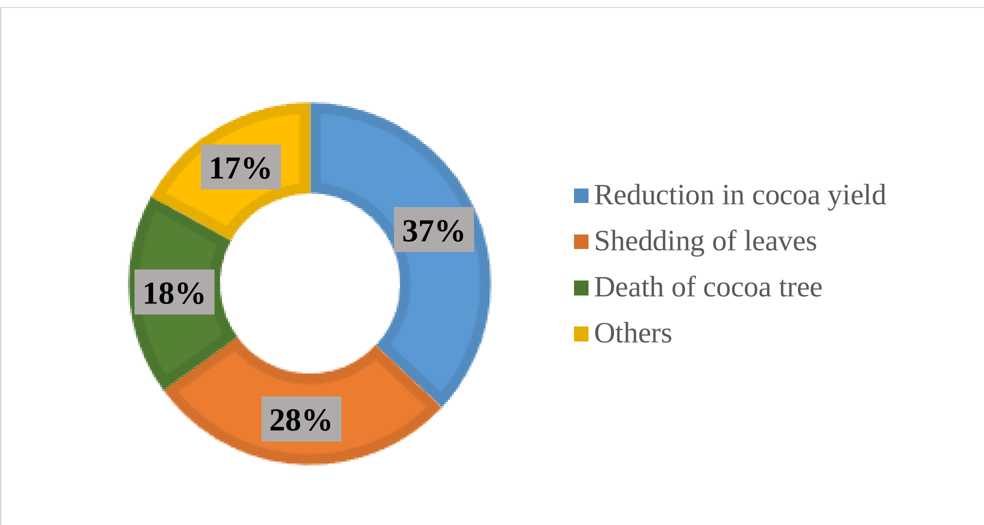
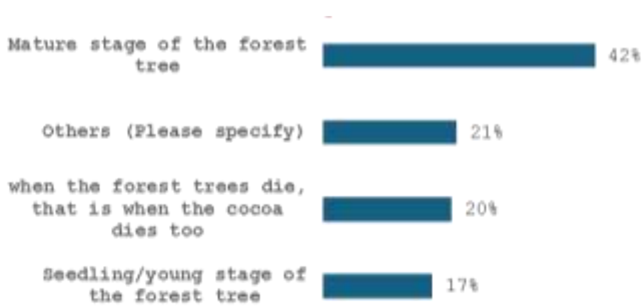


Fig. 9: The negative effects of forest trees on cocoa. *(Source: Field Survey, 2024)*



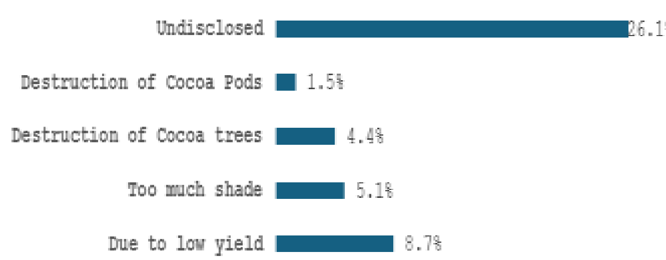


Fig. 10a: Stage at which forest trees affect cocoa **Fig. 10b: Effects of forest trees on cocoa yield**

Source: Field Survey, 2024

Chi-square analysis

The chi-square (χ^2) analysis in Table 3 shows the distribution of cocoa yield (kg/ha) across the states, sexes, age groups and educational backgrounds in 2023. Yield distribution was not statistically significant across the states since the p value (0.228) is greater than 0.05 with most production concentrated in Ondo state (52.2% of total yield). There was positive and significant difference in cocoa yield based on age groups (χ^2=29.687, $p < 0.05$) at 5% level of significance. The low p-value (0.000) showed a strong association of age with yield with the majority (55.1%) of farmers aged 30-50, and higher yields among younger farmers. Yield was also significantly associated with gender (χ^2=13.012, p = 0.005), with males contributing 78.3% of total yield. Educational background was also significant (χ^2= 30.026, p = 0.003), with secondary education dominating (50.7%) but better yields observed among those with formal education.

Chi-Square Analysis on the Perception of Farmers about the Negative Effect of Forest Trees on cocoa plants

The result in Table 4 shows the Chi-Square (χ^2) analysis on the relationship between socioeconomic characteristics of cocoa farmers in the three states and the perceived negative effects of forest trees on cocoa plants. There was positive and significant difference in the negative effects based on age groups (χ^2=10.630, $p < 0.05$) and educational background (χ^2=11.116, $p < 0.05$) at 5% level of significance in the study area. The low p-values (0.005, 0.025) indicates a strong association between age, educational background and the perceived negative effects of forest trees on cocoa plants in the study area.

Table 3: Chi-square analysis of the estimated cocoa yield (kg/ha) in 2023

		Yield (kg/ha)						
		Less than 1000	2000 - 4000	4000 - 6000	6000 & above	Total	Chi-square Value	P-value
State	Oyo	29	1	0	0	30	8.146	0.228
		21.00%	0.70%	0.00%	0.00%	21.70%		
	Ondo	62	4	4	2	72		
		44.90%	2.90%	2.90%	1.40%	52.20%		
	Osun	36	0	0	0	36		
		100.00%	0.00%	0.00%	0.00%	100%		
	Total	127	5	4	2	138		
		92.00%	3.60%	2.90%	1.40%	100.00%		
Sex	Male	103	1	2	2	108	13.012	0.005
		74.60%	0.70%	1.40%	1.40%	78.30%		
	Female	24	4	2	0	30		
		17.40%	2.90%	1.40%	0.00%	21.70%		
Age	Less than 30	18	0	2	2	22	29.687	0.000
		13.00%	0.00%	1.40%	1.40%	15.90%		
	30 - 50	76	0	0	0	76		
		55.10%	0.00%	0.00%	0.00%	55.10%		
	51 & above	33	5	2	0	40		
		23.90%	3.60%	1.40%	0.00%	29.00%		
Educational background	No formal education	10	2	0	2	14	30.026	0.003
		7.20%	1.40%	0.00%	1.40%	10.10%		
	Adult education	2	0	0	0	2		
		(1.40%)	(0.00%)	(0.00%)	(0.00%)	(1.40%)		
	Primary education	21	2	2	0	25		
		15.20%	1.40%	1.40%	0.00%	18.10%		
	Secondary education	67	1	2	0	70		
		48.60%	0.70%	1.40%	0.00%	50.70%		
	Tertiary education	27	0	0	0	27		
		19.60%	0.00%	0.00%	0.00%	19.60%		

Source: Field Survey, 2024

Table 4: **Perception of Farmers about the Negative Effect of Forest Trees on Cocoa Plants**

		Do some of these forest trees in your farm affect cocoa trees negatively?				
		No	Yes	Total	Chi-square Value	P-value
State	Oyo	12 (25.5%)	18 (19.8%)	30 (21.7%)	4.643	0.098
	Ondo	28 (59.6%)	44 (48.4%)	72 (52.2%)		
	Osun	7 (14.9%)	29 (31.9%)	36 (26.1%)		
	Total	47 (100%)	91 (100%)	138 (100%)		
Sex	Male	35 (74.5%)	73 (80.2%)	108 (78.3%)	0.603	0.438
	Female	12 (25.5%)	18 (19.8%)	30 (21.7%)		
Age	Less than 30	3 (6.4%)	19 (20.9%)	22 (15.9%)	10.630	0.005
	30 - 50	23 (48.9%)	53 (58.2%)	76 (55.1%)		
	51 and above	21 (44.7%)	19 (20.9%)	40 (29.0%)		
Educational background	No formal education	3 (6.4%)	11 (12.1%)	14 (10.1%)	11.12	0.025
	Adult education	0 (0.0%)	2 (2.2%)	2 (1.4%)		
	Primary education	15 (31.9%)	10 (11.0%)	25 (18.1%)		
	Secondary education	19 (40.4%)	51 (56.0%)	70 (50.7%)		
	Tertiary education	10 (21.3%)	17 (18.7%)	27 (19.6%)		

Source: Field Survey, 2024

This indicates a statistically significant relationship between age groups, educational level and the response to whether forest trees negatively affect cocoa trees. There is no significant difference in the negative effect of forest trees on cocoa plants based on state and sex regarding their perception on the negative effects of forest trees since the p-values (0.098, 0.438) are much greater than 0.05. There is no statistically significant relationship between the state and whether forest trees affect cocoa trees. The lack of a statistically significant relationship suggests that farmers' perceptions of forest trees' impact on cocoa farming do not vary significantly across states. This implies that interventions or awareness programmes can be designed uniformly across all regions without state-specific adjustments.

Conclusion

While forest trees can offer ecological benefits such as providing necessary shade, regulating the microclimate and preventing soil erosion, they also pose challenges to cocoa plantations in Southern Nigeria. Their perceived negative effects on cocoa plantations such as low yield, competition for resources, increased pest and disease spread, excessive shading, and physical damage have made them a challenge for farmers in the study areas. However, with careful management, these challenges can be mitigated and the beneficial roles of forest trees can be harnessed. Striking a balance between forest conservation and cocoa production is crucial for sustainable agriculture ensuring the long-term productivity of cocoa plantations while preserving the ecological integrity of the region. Hence, to balance cocoa productivity and environmental sustainability, proper shade management, selective tree retention, selective pruning and agroforestry optimization may be necessary to optimize cocoa yields while maintaining ecosystem services.

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