Agroforest Syst
https://doi.org/10.1007/s10457-024-01062-y

Effect of shade management practice on cocoa seedling mortality: micro evidence from the Amansie-West district of Ghana

Amos Mensah · Faizal Adams · Bright Owusu Asante · Stephen Prah · Badu Yaw Tweneboa · Prince Asiedu

Received: 20 March 2024 / Accepted: 22 August 2024

Abstract The paper examines the effect of shade management practices on cocoa seedling mortality. It investigates farmer awareness and adoption of the recommended shade practices and its influence on reducing cocoa seedling mortality. The constraints facing cocoa farmers in adopting the recommended shade management practices were also examined. Using data collected from 180 smallholder cocoa farmers, the ordered logit and poisson regression models were employed. The results indicate that majority of the farmers were highly aware of the recommended shade management practices, however, relatively moderate number of the farmers have adopted the recommended shade management practices. Our results further revealed that educational level, extension service, source of a shade tree, the type of shade practice, spraying insecticide, and weeding had a significant effect on reducing seedling mortality. Furthermore, the prevalence of diseases and pest infestation was identified as the major constraint faced by farmers in shade management. We, therefore, recommend that Cocobod should intensify extension services to increase the adoption of shade management practices through trainings to offset the high mortality in unshaded cocoa farms and sustain the survival of the cocoa seedlings.

Keywords Shade management · Seedlings · Mortality · Cocoa · Recommended practices

Introduction

Cocoa remains one of the most important cash crops in Ghana. It is a major foreign exchange commodity contributing an average of 15% of Ghana's Gross Domestic Product (GDP) (https://www.undp.org/sites/g/files/zskgke326/files/migration/gcp/GHANA-COCOA.pdf). Recent publication by an international trade monitor (statistica.com) indicate that, from January to September 2021, the export value of cocoa beans and cocoa products from Ghana amounted to around 2.3 billion U.S. dollars. Europe, Asia and the USA are the main export destinations of Ghana's cocoa and related products. Ghana and Ivory Coast continue to dominate the world's cocoa production, supplying about 70% of the global demand, followed by Asia and Oceania represent 16%, and the Americas with 14% (World Cocoa Foundation, 2014; Shahbandeh 2019; Wessel

A. Mensah · F. Adams · B. O. Asante · B. Y. Tweneboa
Department of Agricultural Economics, Agribusiness and Extension, College of Agriculture and Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

S. Prah (✉)
Department of Agribusiness, Applied Economics and Agriscience Education, North Carolina A&T State University, Greensboro, USA
e-mail: stephenprah888@gmail.com

P. Asiedu
Department of Development Studies, University of Passau, Lower Bavaria, Germany

and Quist-Wessel 2015). Due to favourable weather and soil conditions, Ghana is ranked the second largest producer of cocoa after Côte D'Ivoire with a production of 800,000 tons in 2020 (Danso-Abbeam and Baiyegunhi 2020; Wongnaa et al. 2021; World Cocoa Foundation, 2014). Cocoa production serves as a dominant source of livelihood and poverty alleviation among rural dwellers in Ghana (Danso-Abbeam and Baiyegunhi 2020; Wongnaa et al. 2021).

In spite of the economic promise of the sector, several studies have examined cocoa yield gaps between actual and potential output (Asante et al. 2022; Wongnaa et al. 2021; Danso-Abbeam and Baiyegunhi 2020; Aneani and Ofori-Frimpong 2013; Bosompem, et al., 2011; World Cocoa Foundation, 2014; ISSER, 2012; Asante-Poku and Angelucci, 2013), however, empirical literature on shade management and its effect on cocoa output is limited. The national average production has been estimated at around 350 kg per hectare (kg/ha). This is lower than Ghana's main competitors Cote d'Ivoire and Indonesia which produces about 600 kg and 1000 kg per hectare, respectively (Wongnaa et al. 2021; Asante et al., 2022; Asante et al. 2023; Asare et al. 2016). In a recent study by Asante et al. (2022), it was observed that the national cocoa yield gap was around 1891.3 kg/ha. The main reasons for such a huge yield gap could be attributed to poor agronomic practices.[1] One such critical agronomic practice that contribute to the huge yield gap is farmers inability to keep to the recommended shade management practices leading to poor plant density per hectare. The Cocoa Research Institute of Ghana (CRIG) has established that, over exposure of cocoa seedling to excessive heat and sunshine during the cocoa plantation establishment phase usually leads to high seedling mortality (leading to poor plant density per hectare). However, inadequate finance prevents farmers from refilling the empty spaces after the establishment to help meet the recommended plant density per hectare. To bridge the yield gap, it is imperative that farmers adhere strictly to the recommended shade management practices to reduce seedling mortality. However, it has been observed that, cocoa farmers in Ghana generally, do not keep to the recommended shade management practices. Lack of awareness of the recommended shade management practices and its beneficial effect of reducing seedling mortality could influence farmers decision not to adopt or comply with the recommendation (Paschall and Seville, 2012; Hütz-Adams and Fountain, 2012).

To address this challenge, CRIG has established a list of recommended good agronomic practices including shade management practices for adoption during the seedling establishment phase. In addition, the Ghana Cocoa Board (Cocobod) has embarked on a series of cocoa productivity enhancement programs dubbed "The National Cocoa Rehabilitation Programme" (Cocobod 2020). According to Asare et al. (2010), shade management can help farmers to obtain the recommended 435 cocoa seedlings per acre. Recent study by Somarriba and Lopez-Sampson (2018) and Asubonteng et al. (2018) observed that a lot of cocoa farmers in Ghana are not keeping to the recommended shade management practices during seedling establishment phase as recommended by GRIG. This has led to low plant density per acre far below the recommended 435 trees per acre. It has been observed that, most farmers do not use any shade management technique at all or use the wrong shade trees on their farms (Obiri et al. 2007; UNDP, 2011). None adherence to the recommended shade management practices or usage of the wrong shade trees do affect seedling survival. Beside protecting the fragile seedling from the scorching sun, keeping to the recommended shade management trees has various advantages that enhances farm output. For instance, planting shades one year before planting the seedlings help conserve soil water as well as reducing disease and pest attack. To derive the full protection from shade trees, it is important that farmers select and plant certain desirable shade trees with the correct spacing and density per acre (Smith et al. 2013; Kaba et al. 2020). The spacing, density, shade cover, and shade tree species play a vital role in good shade management. Shade trees have been demonstrated to diminish windborne fungal disease transmission (Rice and Greenberg 2000). All of these shade elements have a direct impact on the yield per acre at the economic phase of the plantation (Schroth et al. 2000). According to Daghela et al. (2013), planting the recommended shade tree enhances the spread of natural enemies of cocoa pests. Schroth et al. (2000) emphasized the relevance of correct spacing and the

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[1] This was characterized by poor cocoa shade management, high seedling mortality, poor farming practices, lack of training, low adoption of modern technologies, disease and pest incidence, aged cocoa trees.

planting of desirable shade tree species to control disease and pests on the plantation.

Despite the critical role that shade management plays in the establishment of cocoa plantation, it has been observed that, majority of farmers do not keep to the recommendation. This may be due to lack of knowledge or poor access to obtaining the desirable shade trees during the plantation establishment phase (Somarriba and Lopez-Sampson 2018; Asare and David, 2010, Adjei-Frimpong 2016). As a result, farmers prefer to grow cocoa seedlings without the recommended shade trees, leading to a high seedling mortality over the period of plantation establishment. Dormon et al. (2004) and Somarriba and Lopez-Sampson (2018) opined that farmers knowledge and awareness of the benefits of shade trees may be low, hence the low adoption behaviour toward growing the recommended shade trees on their cocoa farms (Asare et al. 2016; Nederlof and Dangbegnon (2007), Mills et al. (2016), Wartenberg et al., 2018). Recent study by Asitoakor et al. (2022) and Akpalu et al., (2021) indicated that, the poor cocoa shade management practices used during production is one of the main elements affecting farm yield and income in the cocoa sector. Indeed, various studies have examined the net welfare benefit of proper agroforestry techniques on cocoa production (Clough et al., 2016; Somarriba and Lopez-Sampson 2018; Abdulai et al. 2018, Nederlof and Dangbégnon, 2007; Martini et al., 2017), however, none of these studies assessed the drivers of shade management practices and its effect on reducing seedling mortality in Ghana. The majority of cocoa farmers in Ghana continue to establish their cocoa plantation without. Furthermore, this paper contributes by investigating farmers knowledge, perception and awareness of the recommended shade management practices and its effect on reducing seedling mortality. The findings are relevant to policy makers and stakeholders in the cocoa sector as it provides empirical evidence and recommendation to support future policy programs to enhance the growth of the cocoa sector.

Materials and methods

Study area

The study was conducted in the Amansie Central District, Ashanti region of Ghana. The district is located between latitudes $6^{0}34'$N and $1^{0}57'$W, and shares boundaries with Obuasi and Bekwai, Amansie West, Adansi North, Adansi South, and Upper Denkyira. It has Jacobu as the district capital and covers a total area of 710 square kilometers with a 93,052 population (GSS, 2021). Most of the people engaged in agriculture because of the suitable climatic conditions. The climate in the district is semi-equatorial with a bimodal rainfall pattern. March to July is the main rainy season whereas September to November is the minor rainy season. The yearly rainfall ranges from 1600 to 1800 mm. The study area has a tropical climate with average mean annual temperature range between 28.2 and 27.3 °C. Relative humidity ranges between 70 and 80 percent throughout the year. Due to the high humidity and temperature regime in the study area, providing shade trees during plantation establishment is important to protect the cocoa seedlings from the scorching sun. The district has a generally flat topography with a few undulating uplands that rise between 240 and 300 m above sea level. Tree crops, food crops, and vegetables are all grown by farmers in the study area. The three dominant trees cultivated in the study are: crops are cocoa, citrus, and oil palm. Approximately 50–60% of the district's total arable land is devoted to cocoa production (MoFA, 2020). Figure 1 illustrated the distribution of the selected farmers across the five communities in the district; Amamomm (57), Anyankyerem (50), Adaase (32), Nankawura (23), and Bekwamene (18). These areas are well-known for large-scale cocoa seedling nurseries and high levels of cocoa bean production. In collaboration with experts working at the Ghana Cocoa Health and Extension Directorate Division database (Obuasi office), these communities were selected for the study since farmers received training and support services in cocoa seedling protection in the past production seasons.

Data

The study uses cross-sectional survey data collected from 180 smallholder cocoa farmers. The mixed research approach based on the use of a structured questionnaire, focus group discussion and key informant interviews was adopted in the collection of primary data. The structured questionnaire contained both closed and open-ended questions to captured both household and farm level information. The household level data captured detail socioeconomic and institutional factors while the farm level

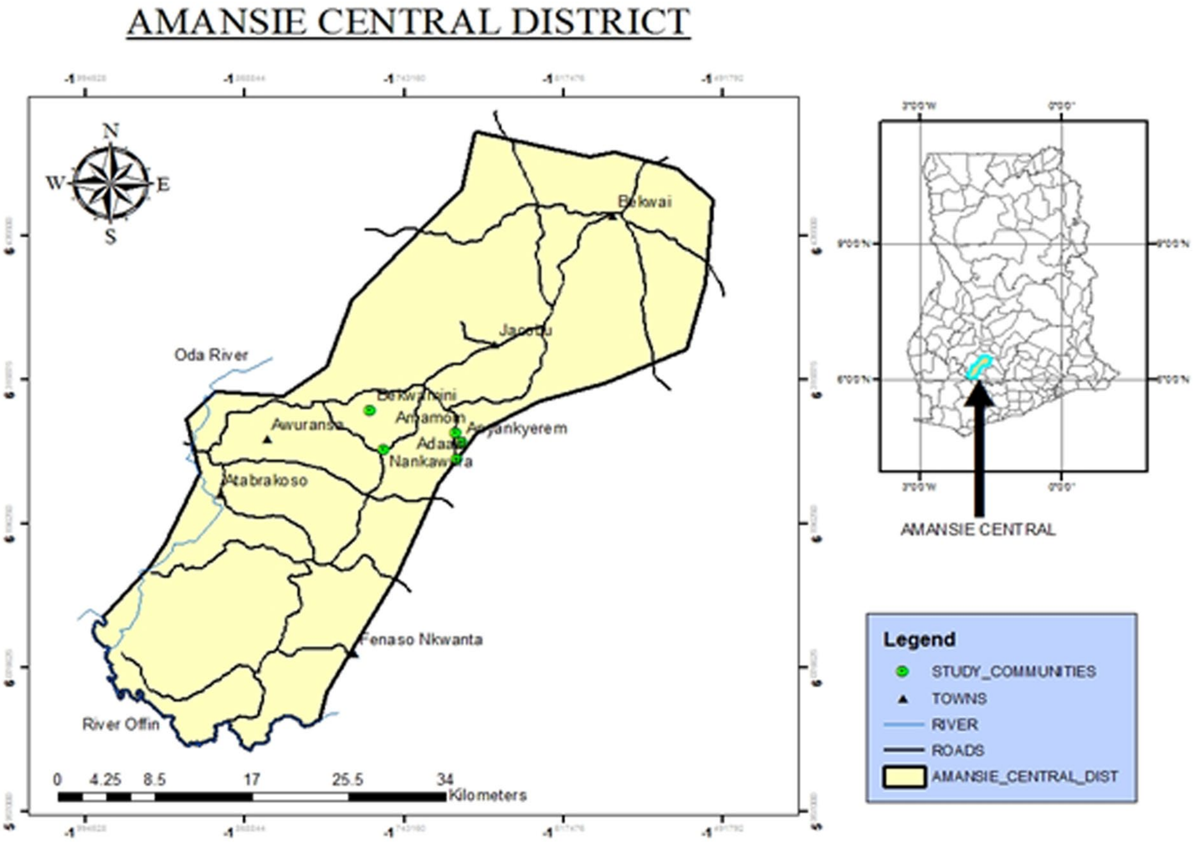

Fig. 1 . *Source*: Author's construct, 2021

data captured input usage, output and postharvest management, farmers awareness and adoption of recommended shade management and constraints to shade management. The study specifically targeted cocoa farmers who obtained cocoa seedlings and training from the Seed Production Unit of Cocobod over the past two years in the study area. A multi-stage sampling approach was utilized in this study. First stage, Amansie Central district was purposively selected, as it is one of the leading cocoa producing areas in Ghana and is recognized for its cocoa shade management practices. Second stage, five communities within the district (namely Amamom, Adaa, Nankawaa, Anyankyerem, and Kwahelem) were sampled due to their significant cocoa and shade management production. According to the Cocobod Seed Production Unit database, a total of 180 cocoa farmers in the district had received seedlings. Finally, a census sampling technique was employed to interview all the 180 cocoa farmers.

Theoretical framework

The theoretical framework for examining farmers' perception, awareness, and adoption of the recommended shade management practices is drawn from the decomposed theory of planned behaviour of decision unit introduced by Taylor and Todd (1995). Taylor and Todd (1995) postulated that the theory combines the influence of three key factors such as attitude, subjective norm, and perceived behavioral control to determine an individual's intention to perform a behavior. These factors are influenced by the person's beliefs about the outcomes of the behavior, the expectations of important referents, and the presence of facilitating or impeding factors, respectively. The theory also suggests that perceived behavioral control can directly influence behavior and its indirect effect through intention, as it can reflect actual control over the behavior. The TPB has been widely used in various fields, including psychology, marketing, and

Table 1 Recommended shade management practices

Recommended practices	
1	6 to 8 shade trees to be planted per acre
2	One year plantation of temporal shade trees before cocoa seedlings are planted
3	Removal of temporary shade during the first year to allow 50% of the total light to pass through the cocoa farm
4	Progressive removal of temporal shade to allow up to about 25% shade as the cocoa trees develop
5	Removal of all temporal shade by fifth year

management, to understand and predict individual or group decision-making and behavior.

In our study, farmers' perception and awareness of the expected benefits of shade management practices do influence their decision to adopt (or not adopt) the practice. The decomposed theory of planned behaviour describes the three main factors which influences an individual to move from an intention (awareness and perception) to actual behaviour change (adoption or not). We assume that farmers' attitude towards adopting a particular farming practice is deeply rooted in their perception of the expected benefit, the available resources at their disposal, and the sociocultural environment pressures. The theory refers to three specific attributes of a decision unit that influences actual behavioral change. These are innate attitudes (i.e., whether the farmer is risk averse, risk neutral or risk taker), subjective norms (i.e., social environmental pressures) and perceived behaviour control (i.e., perception of the benefit of the technology). Therefore, perception and awareness of benefits play an important role in the adoption decision process of farmers. The perception of farmers on the recommended shade management practices, the reasons for the non-adoption of such practices and their impact on seedling mortality is however not thoroughly documented. This study therefore aims to make a contribution in filling this gap.

Empirical specification

To obtain empirical estimates, various analytical approaches were employed. In a typical cocoa producing community, lack of awareness may lead to non-compliance to the recommendation or the application of the wrong shade management techniques which eventually affect seedling mortality or plant density per acre, hence, this paper applies an awareness index analytical approach to assess farmer's awareness and hence, categorizing farmers into three awareness groups as follows:

1. High awareness group (i.e., farmers that are aware of all the recommended shade management practices—awareness of 4 to 5 practices)
2. Medium awareness group (i.e., farmers partially aware of some of the recommended shade management practices—awareness of 2 to 3 practices)
3. Low awareness group (i.e., farmers that are not aware of the recommended shade management practices—awareness of 0 to1 practice).

To compute the awareness index, a set of recommended shade management practices were presented to farmers to indicate the ones they are aware of (i.e., either 1 = Yes or 0 = No). Table 1 provide an overview of the recommended shade management practices.

Based on the responses provided, a farmer's awareness score[2] is computed based on the number of practices they are aware of as follows:

Farmers awareness score = sum of awareness statement farmer indicated "Yes"

$$\text{Mean awareness index } = \frac{\text{Number of Yes responses}}{\textit{Total number of awareness statements}}$$

In our case, where there are 5 awareness statements, the formula simplifies to:

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[2] Positive awareness refers to a "Yes" response on our awareness index. This indicates that the respondent is aware of the awareness statement. The mean awareness index measures the proportion of "Yes" responses relative to the total number of awareness statements, providing clear indication of the level of positive awareness among the respondents.

$$\text{Mean awareness index} = \frac{\text{Number of Yes awareness responses}}{5}$$

Since "No" responses are coded as 0 and do not affect the numerator, including them in the calculation is not necessary. This formula effectively captures the proportion of positive awareness among the total number of statements.

Based on farmers' awareness, it is expected that a certain number of farmers will adopt and implement all the five recommended shade management practices. Out of the 180 farmers interviewed, the adoption distribution ranges between 1 to all the five. The proportion of farmers that have adopted and implemented the various shade management practices were therefore grouped into the following adoption categories:

1. High-level adopters (i.e., farmers that have adopted and implemented almost all the five recommended shade management practices—adoption of 4 to 5 practices)
2. Medium level adopters (i.e., farmers that have adopted some part of the shade management practices—adoption of 2 to 3 practices)
3. Low-level adopters (i.e., farmers that have adopted just one or none of the shade management practices—adoption of 0 to1 practice).

To calculate the adoption index to enable the categorization of the farmer into the groups as listed above, a set of recommended shade management practices were presented to farmers to indicate the ones they have adopted. A farmers adoption score is calculated based on the number of practices they have adopted as follows:

Farmers adoption score = sum of adoption statement farmer indicated "Yes"

$$\text{Mean adoption index} = \frac{\textit{Number Yes adoption statement}}{\textit{Total number of Adoption statements}}$$

$$\text{Mean adoption index} = \frac{\text{Number of Yes adoption statements}}{5}$$

We examined the factors influencing the adoption of shade management practices. The ordered probit or logit models are most appropriate for such analysis given that we measure the level of adoption of shade management practice using categorical and ordinal data (Anderson 1984; Brant 1990; Wooldridge 2010; Teshome et al. 2016; Shee et al. 2019). The error term is assumed to be distributed logistically by the logit model or normally distributed when the ordered probit model is used. In real-world situations, the logistic and normal distributions typically produce analogous estimates. We provide a brief description of the ordered logit model because it is frequently used in empirical econometric applications (Anderson 1984; Brant 1990; Liu 2016). Consider the ordinal dependent variable z takes the values 0, 1, 2, …, J for some known integer J. The variable z conditioned on a set of independent variables derived from a latent continuous variable z* thus, unobservable is specified as:

$$z_i^* = \beta x_i\prime + \varepsilon_i \tag{1}$$

where β denote the unknown coefficients to be estimated, ε_i denote the disturbance term[3] and $x_i\prime$ denote set of independent variables (i.e., socioeconomic, farm level and institutional factors). Recent studies used explanatory variables including gender, age, experience, farm size, education, extension access and credit access (Teshome et al. 2016; Shee et al. 2019). Following Long and Freese (2014, chap. 7), the category $i = 1$ is the minimum value, i = 2 as the next ordered value and so on for determined k categories. Based on our data, z is three values where 1 if a farmer falls in low level, 2 if a farmer in medium level and 3 if fall in high level. Since the error term is standard logistically distributed, each response probability can be specified as:

$$P_{ij} = \Pr\left(z_j = i\right) = \Pr(K_{i-1} < X_j\beta + \varepsilon \leq K_i) = \frac{1}{1 + \exp\left(-K_i + X_j\beta\right)} - \frac{1}{1 + \exp\left(-K_{i-1} + X_j\beta\right)} \tag{2}$$

where K_0 and K_k denote $-\infty$ and $+\infty$, respectively.

The log likelihood is specified as:

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[3] In our ordered logit model, the error term is assumed to follow a logistic distribution and is considered random, meaning it is independently distributed and not systematically related to the explanatory variables. This assumption helps mitigate concerns about selection bias, as it ensures that any unexplained variation in the dependent variable is due to random factors rather than systematic errors. This approach supports the robustness and validity of our results by ensuring that the estimates are not driven by selection bias.

$$lnL = \sum_{j=1}^{N} W_j \sum_{i=1}^{K} I_i(Y_j) lnP_{ij} \tag{3}$$

where W_j denote an optional weight and

$$I_i(Y_j) = \begin{cases} 1, if\ Y_j = i \\ 0, otherwise \end{cases} \tag{4}$$

The empirical ordered logit model is specified as:

$$\begin{aligned} Adoplvl = \beta_0 + \beta_1 Edu + \beta_2 HHz + \beta_3 Marit + \beta_4 FarmExp \\ + \beta_5 FBO + \beta_6 Ext + \beta_7 Sourtree + \beta_8 Shadlev \\ + \beta_9 Sprainsec + \beta_{10} Fertapp + \beta_{11} Weedin + \varepsilon_i \end{aligned}$$

The number of seeding that died (mortality rate) one year after establishment of the plantation is a nonnegative count variable, hence we used poisson regression[4] to estimate the effect of shade management on seedling mortality. Poisson regression[5] is a generalized linear model form of regression analysis used to fits models of the number of occurrences (counts) of an event. In this case, we define mortality as the number of seedlings that died in a given period of time (i.e., one year after planting). In Poisson regression, we attempt to model a response variable that is a count (rate) based on some predictor variables. So, poisson model is a special case of the standard linear regression (SLR). When we model data with SLR, we make certain assumptions. Those assumptions allow us to make statistical statements about our model and predictions. For standard linear regression (SLR), we make the following assumptions:

$$Y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \beta_k x_{ik} + \varepsilon_{i,} \quad i = 1, \ldots, n \tag{5}$$

Based on the relevant assumptions underlying the two models, to find the probability of k events in an exposure of size E, you divide E into n subintervals E_1, E_2,..., E_n, and approximate the answer as the binomial probability of observing k successes in n trials. If you let $n \to \infty$, you obtain the Poisson distribution. In the Poisson regression model, the incidence rate for the *jth* observation is assumed to be given by:

$$r_j = e^{\beta_0 + \beta_1 x_{1,j} + \ldots + \beta_k x_{k,j}} \tag{6}$$

If E_j is the exposure, the expected number of events, Cj, will be

$$c_j = E_j e^{\beta_0 + \beta_1 x_{1,j} + \ldots + \beta_k x_{k,j}}$$

$$= e^{In(E_j) + \beta_0 + \beta_1 x_1 + \ldots + \beta_k x_{k,j}} \tag{7}$$

This model is then fit with the STATA command poisson. Without the exposure () or offset () option, E_j is assumed to be 1 (equivalent to assuming that the exposure duration is unknown), and controlling for exposure, if necessary is the responsibility of the researcher. Comparing rates is most easily done by calculating incidence-rate ratios (IRRs). For instance, what is the seedling mortality rate of farmers as they adopt the recommended shade practices? That is, you want to hold all the independent variables in the model constant except one, say, the *ith variable*. The IRR for a one-unit change in x_i is expressed as:

$$\frac{e^{In(E) + \beta_1 x_1 + \ldots + \beta_i (x_i + 1) + \ldots + \beta_k x_k}}{e^{In(E) + \beta_1 x_1 + \ldots + \beta_i x_i + \ldots + \beta_k \beta_k}} = e^{\beta_i} \tag{8}$$

More generally, the IRR for a Δx_i change in x_i is $e^{\beta_i \Delta x_i}$. The lincom command in STATA can be used after poisson to display incidence-rate ratios for any group relative to another.

Furthermore, we identify the challenges that farmers face in shade management. Farmers were asked to rank a series of constraints where 1 = most pressing, 2 = more pressing, 3 = least pressing and so on. Kendall's coefficient of concordance was used to analyze various constraints farmers face in shade management. The Kendall's W was expressed as:

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[4] The basic idea of Poisson regression was outlined by Coleman (1964, 378–379). See Cameron and Trivedi (2013; 2010, chap. 17) and Johnson, Kemp, and Kotz (2005, chap. 4) for information about the Poisson distribution. See Cameron and Trivedi (2013), Long (1997, chap. 8), Long and Freese (2014, chap. 9), McNeil (1996, chap. 6), and Selvin (2011, chap. 6) for an introduction to Poisson regression. Also see Selvin (2004, chap. 5) for a discussion of the analysis of spatial distributions, which includes a discussion of the Poisson distribution. An early example of Poisson regression was Cochran (1940).

[5] Poisson regression has been extensively used in death/mortality rate studies, such as the number of soldiers kicked to death by horses in the Prussian army (von Bortkiewicz 1898); the pattern of hits by buzz bombs launched against London during World War II (Clarke 1946), and disease incidence, typically with respect to time, but occasionally with respect to space.

Table 2 Independent variables in the model. *Source*: Field survey, 2021

Variable	Description	Measurement	Expected sign
Seedlin_mort	Seedling mortality	Number	
Edu	Education	1 = formal and 0 = informal	±
Farm size	Farm Size	hectare	+
FarmExp	Farming experience	Years	+
HHZ	Household size	Number	±
ShadLevl	Shade level	1 = Shade monoculture (10–20%), 2 = Commercial polyculture (20–30%), 3 = Traditional polyculture (30–50%) and 4 = Rustic (> 50% shade)	±
Age_{Shad}	Age of shade	Years	
$Fert_{app}$	Fertilizer application	Number (bags/acre)	+
Ext	Extension contacts	1 if a farmer has extension contact and 0 = otherwise	±
FBO	Member of farmer group	1 member and 0 = not member	±
credt	Credit access	1 = yes and 0 = no	±
$\beta_{10}STP_{intro}$	Permanent shade trees	1 = none, 2 = Right from planting, 3 = 3yrs after planting, 4 = 4yrs after planting, and 5 = 5yrs after planting	±
$Spra_{insec}$	Spraying insecticides	Number (litres/acre)	±
$\beta_9 Weedin$	Weeding	Number (litres/acre)	±

$$W = \frac{12 \sum \overline{R}_i^2 - 3n(n-1)^2}{n(n-1)} \tag{9}$$

where: W = Kendall's value; n = total sample size; R = mean of the rank.

Results and discussion

Table 2 present the description of the variables and the unit of measurement. The potential directions (expected signs) of the independent variables have also been stated. Table 3 presents a summary of the socioeconomic characteristics of farmers. On average, farmers are in their productive age (48 years), more than a decade experienced in cocoa production (14 years), operates on a relatively small farm size (8 ha) and have an average of 4 persons as family size. Also, the mean age of the cocoa farm was 14.6 years. Our findings are consistent with other findings indicating that the household size of cocoa farm families is moderately high (Bandanaa et al. 2016) and farmers are quite old (CRIG, 2017). The data also reveal that, the majority of the farmers are males, completed Junior High School and are married. More than half of the farmers owned the land and had irregular extension services. Even though the socioeconomic characteristics in Table 3 shows that, the data is dominated by men with a relatively small farm size with irregular extension contacts, it does not give us any causal insight of the propensity of the household to adopt the recommended shade management practices. Table 4 gives an overview of the level of shade trees adopted by farmers. The results indicate that most farmers shade their cocoa trees till they are 6–10 years, used commercial polyculture shade techniques[6] while others introduced permanent shade trees 3 years after planting. Among these farmers, a notable proportion utilize commercial polyculture shade techniques, which involve planting a diverse mix of tree species to provide shade. Additionally, there are farmers who opt to introduce permanent shade trees to their cocoa plantations approximately 3 years after the initial planting. This approach reflects a strategic decision

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[6] Commercial Polyculture, as used in agricultural production, describes the practice of simultaneously cultivating multiple crop species in one area. In polyculture, the variety of natural ecosystems is imitated. Using fewer pesticides, commercial polyculture can help control some pests, weeds, and diseases. On low-nitrogen soils, intercropping legumes and non-legumes can increase yields because biological nitrogen fixation takes place. The numerous control issues one faces with the crops is polyculture's main disadvantage.

Table 3 Socioeconomic characteristics of farmers. *Source*: Field survey, 2021

Quantitative variables	Mean	Std. Dev	Min	Max
Age of farmer	48.2	8.61	29	68
Household size	4.08	1.50	1	8
Farm size	8.08	3.48	4	22
Cocoa Farm age	14.58	4.83	5	38
Farming experience	14.35	8.07	4	38

Categorical variables	Frequency	Percentage
Marital status		
Single	15	8.33
Married	140	77.78
Divorced	25	13.89
Sex of respondent		
Male	111	61.67
Female	69	38.33
Educational Level		
No formal education	3	1.67
Primary	46	25.56
JHS	113	62.78
SHS	18	10.00
Tertiary	0	0
Farmer Status		
Farm owner	131	72.78
Caretaker	34	18.89
Lease/Rent	9	5.00
Abunu (division into two shares where the farmer receives 1/2)	6	3.33
Extension Service		
Sometimes (once in every 6 month)	108	60.00
Often (4–5 visits every 6 month)	72	40.00
Never	0	0

to ensure long-term shading and potentially enhance the health and productivity of the cocoa trees.

Young cocoa plants are shaded by temporary shade trees before permanent shade trees are formed. Aside, most farmers obtained shade trees from Cocobod and other sources. This observation resonates with Asare et al. (2016) who observed that planting cocoa seedlings with permanent shade trees after 3 years is deemed to be the best good agricultural practice in Amansie West, Atwima Nwabiagya, Sefwi Wiawso and Wassa Amenfi West of Ghana. These findings are also consistent with recent report by CRIG (2017) indicating that most farmers obtain shade trees from Ghana Cocobod through farmer based organizations.

Figures 2 and 3 illustrates the reasons for adopting the specific shade trees and the major cultural benefits derived from adopting these shade trees by smallholder cocoa farmers, respectively. Less competition with cocoa seedlings (30.7%) was the major reason behind farmers' selection, followed by adoption of shade trees that allows good light penetration (21.3%), fast growth rate (16.5%), and the less water management requirement (11.2%). More than 95% of respondents mentioned additional cultural and economic benefits for adopting these specific shade trees besides the direct protection they provide to the seedlings. The major economic benefits include harvesting of fruit (26.11%), and organic fertilizer (23.22%). Harvested fruits are sold to supplement farm income.

Table 4 Shade trees among farmers. *Source*: Field survey, 2021

Variables	Frequency	Percentage
Age of Shade trees on the farm		
Less than 5 years	33	18.33
6–10 years	67	37.22
11–15 years	33	18.33
16–20 years	29	16.11
Greater than 20 years	18	10.00
Shade cover on the farm during plantation establishment		
No Shade at all (0–9% Full exposure to the sun)	0	0
Shade monoculture (10–20% exposure to the sun)	23	12.78
Commercial polyculture (21–30% exposure to the sun)	89	49.44
Traditional polyculture (31–50% exposure to the sun)	52	28.89
Rustic, > 50%	16	8.89
Permanent Shade tree species		
Terminalia superba (Ofram)	13	7.22
Terminalia ivorensis (Emire)	11	6.11
Alstonia boonei (Nyamedua)	10	5.56
Spathodea campanulata (Kukuoninsuo)	21	11.67
Terminalia superba (Ofram) and Terminalia, ivorensis (Emire)	51	28.33
Ceiba pentandra (Onyina), Terminalia superba (Ofram), and Terminalia ivorensis (Emire)	27	15.00
Spathodea campanulata (Kukuoninsuo), Terminalia superba (Ofram)	10	5.56
Khaya senegalensis (Mahogany), and Triplochitin scleroxylon (Wawa)	18	10.00
Albizia zygia (Okuro), Pycnanthus angolensis (Otie), and Funtuma elastica (Funtum)	17	9.44
Albiza coriaria (Awiemfo samina), Ficus exaperata (Nyankyeren), Funtumia africana (Sesedua)	2	1.11
Temporal Shade tree species		
Banana and plantain	70	38.89
Cocoyam	40	22.22
Cassava	15	8.33
Coconut and pear	20	11.11
Others	35	19.44
Source of shade tree		
Cocobod	67	37.22
Neighboring farmer	24	13.33
Market	7	3.89
Own sources	82	45.56
Time of introduction of shade trees		
3 years after planting	61	33.89
4 years after planting	19	10.56
5 years after planting	34	18.89
Trees already existed on farmland	30	16.67
Right from planting	36	20.00

The foliage and other organic debris of nitrogen fixing shade trees directly improve the soil organic matter content which enhances soil moisture retention and nutrient absorption. Shade trees also serve

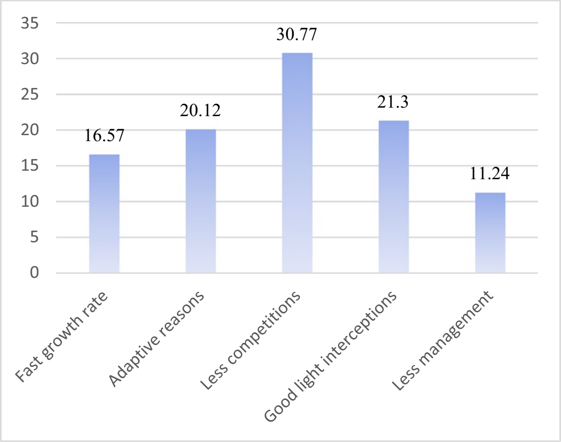

Fig. 2 Specific reason behind shade tree species selection. *Source*: Field survey, 2021

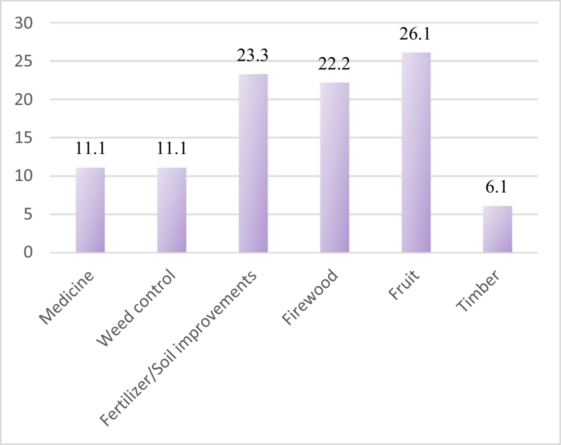

Fig. 3 Other major benefits of shade trees

as energy sources for household (firewood and charcoal). In addition, the adopted shade trees also serve as traditional herbal & medicinal plants essential for the treatment of diseases. The shade trees also serve as erosion and weed control during the early seedling establishment stage, which contributes to enhancing the survivability of the seedlings (FAO, 2014; Asare et al. 2016). Some of the economic shade trees (i.e., cocoyam, plantain and banana) provide food, fodder and extra income for the farmer during the seedling establishment phase. Though these household and farm level information are insightful, it however does not give us any indication of farmers' awareness and adoption level of the recommended shade management practices. We therefore examine the awareness and adoption level of farmers on the recommended shade management practices. Also, we examine the effect of shade management practices on seedling mortality and further, investigate the challenges faced by farmers.

The result of the awareness of farmers to the recommended shade management practices is presented in Table 5. Except those who are aware of 6 to 8 shade trees to be planted per acre, the majority of the farmers (over 50%) generally have a positive awareness of the recommended practices. Most farmers responded agreed with the awareness statement that the progressive removal of temporal shade allows up to about 25% shade as the cocoa trees develop. The awareness of these recommended practices may be enforced by farmers' experience in cocoa production. Consistent with the findings of Adjei-Frimpong (2016) found that cocoa farmers in Ghana had a positive awareness of good agricultural practices. Furthermore, it was evident that most of the farmers (71.51%) were highly aware of the recommended shade management practices. This implies that with high awareness, farmers are expected to reduce the high mortality in their cocoa farms. CRIG (2017) found that cocoa farmers were aware of good sustainable practices with no exception to shade management in cocoa production.

According to Table 6, the majority of farmers (64%) who adopted the recommended shade management practices are in the medium adoption category (2–3 practices), while 18% were in the high adoption category (4–5 practices) and 17% were in the low adoption category (0–1 practice). These findings are similar to those of previous studies (Nunoo et al. 2014; Obuobisa-Darko 2015; Matata et al. 2010). Danso-Abbeam and Baiyegunhi (2017) and Mmbando and Baiyegunhi (2016) also found that most cocoa farmers are aware of the benefits of shade trees and therefore tend to practice some form of shade management during the early stages of establishment.

Table 7 presents the results of an ordered logit model used to examine the factors that influence the level of adoption of shade management practices. The result shows that, the adoption level of shade management practices by farmers is influenced by various factors, including education level, farming experience, frequency of contact with extension services, informal sources of shade trees (such as

Table 5 Awareness of some recommended shade management practices. *Source*: Field survey, 2021

Recommended practices	Yes Frequency (Percentage)	No Frequency (Percentage)	Mean
6 to 8 shade trees to be planted per acre	106 (58.89%)	74 (41.11%)	0.59
One year plantation of temporal shade trees before cocoa seedlings are planted	150 (83.3%)	30 (16.67%)	0.83
Removal of temporary shade during the first year to allow 50% of the total light to pass through the cocoa farm	146 (81.11%)	34 (18.89%)	0.81
Progressive removal of temporal shade to allow up to about 25% shade as the cocoa trees develop	157 (87.22%)	23 (12.78%)	0.87
Removal of all temporal shade by fifth year	158 (87.77%)	22 (12.22%)	0.88
Mean Index			0.80
Awareness level	Category	Frequency	Percentage
High	4–5	128	71.51
Medium	2–3	46	25.69
Low	0–1	5	2.79

Table 6 Adoption of some recommended shade management practices. *Source*: Field survey, 2021

Recommended practices	Yes Frequency (Percentage)	No Frequency (Percentage)	Mean
6 to 8 shade trees to be planted per acre	70 (38.89%)	110 (61.11%)	0.39
One year plantation of temporal shade trees before cocoa seedlings are planted	123 (68.33%)	57 (31.67%)	0.68
Removal of temporary shade during the first year to allow 50% of the total light to pass through the cocoa farm	134 (74.44%)	46 (25.56%)	0.74
Progressive removal of temporal shade to allow up to about 25% shade as the cocoa trees develop	156 (86.67)	24 (13.33%)	0.87
Removal of all temporal shade by the fifth year	151 (84.36%)	28 (15.64%)	0.84
Mean Index			0.70
Adoption Category (levels)	Number of practices adopted	Frequency	Percentage
High	4–5	33	18.33
Medium	2–3	115	63.89
Low	0–1	32	17.78

those from neighboring farmers), age of shade trees at the time of distribution, and cost of weed control. Having a senior high school education is associated with a higher level of adoption of shade management practices. This is likely because educated farmers are highly aware of the importance of these practices in cocoa production compared to uneducated farmers. These findings are consistent with those of previous studies that have found a positive relationship between education and the adoption of sustainable cocoa practices (Asfaw et al. 2012; Mariano et al. 2012; Wongnaa et al. 2021; Kumar et al. 2016). Also, the adoption of shade management practices is positively and significantly correlated with a farmer's experience in cocoa production. As a farmer's years of experience in cocoa production increases, their likelihood of adopting these practices also increases. This suggests that farmers who have been in the cocoa industry for a longer period of time may have witnessed the benefits of such good agricultural practices and are therefore more likely to adopt shade management techniques. These findings are consistent with those of Avane et al. (2021), who found that a farmer's experience is positively related to the adoption of organic fertilizers.

Table 7 Factors influencing the level of adoption of shade management practices. *Source*: Field survey, 2021

Variables	Ordered logit		Low		Medium		High	
	Coef	Robust Std. err	Marginal effects	Standard error	Marginal effects	Standard error	Marginal effects	Standard error
Educational level								
Primary	0.064	0.908	− 0.070***	0.024	0.030	0.037	0.010	0.141
JHS	0.361	0.904	0.047	0.104	0.040	0.036	0.050	0.139
SHS	0.851***	0.097	0.010	0.110	− 0.043	0.041	0.042***	0.015
Household size	0.003	0.076	0.021	0.016	0.020	0.013	0.022**	0.011
Marital status (married)	− 0.476	0.402	0.062	0.053	0.045	0.090	− 0.066	0.056
Experience in farming	0.041***	0.014	0.067	0.052	0.056***	0.022	0.074***	0.029
FBO membership	− 0.022	0.443	0.030	0.058	0.034**	0.014	0.059***	0.021
Extension service	0.118***	0.022	-0.065**	0.029	0.041	0.035	0.068**	0.031
Source of shade tree								
Neighboring Farmer	0.579*	0.351	0.075	0.050	0.061**	0.025	0.080*	0.044
Market	− 0.101	0.617	0.149	0.114	− 0.066***	0.024	− 0.123	0.056
Cocobod	− 0.526**	0.251	0.067**	0.033	0.008	0.011	0.074***	0.035
Shade level								
Commercial polyculture (20–30%)	− 0.531	0.328	0.066*	0.037	0.012	0.019	− 0.077	0.052
Traditional polyculture (30–50%)	− 0.123	0.349	0.013	0.037	0.007	0.021	− 0.020	0.058
Rustic (> 50% shade)	− 0.530	0.464	0.066	0.060	0.012	0.020	− 0.077	0.066
Age of shade tree (years)	− 0.181**	0.091	− 0.021	0.012	− 0.023	0.014	0.026**	0.013
Spraying insecticide								
Once a year	0.728	0.463	− 0.101	0.067	0.005	0.016	0.096	0.060
Twice a year	0.487	0.622	− 0.072	0.083	0.053**	0.023	0.059	0.086
Fertilizer application								
Once a year	0.113	0.648	− 0.012	0.067	-0.007	0.043	0.019	0.110
Twice a year	− 0.637	0.427	0.085	0.058	0.020	0.014	− 0.088**	0.040
Weeding								
Once a year	− 0.128*	0.076	0.226	0.158	− 0.103	0.106)	− 0.123	0.058
Twice a year	0.221	0.316	− 0.026	0.037	− 0.080*	0.043	0.034	0.049
/cut1	− 2.866***	1.100						
/cut2	1.513***	0.587						
Observations	180							
Pseudo R^2	0.353							
Wald chi^2	223.62							

Table 7 (continued)

Variables	Ordered logit		Low		Medium		High	
	Coef	Robust Std. err	Marginal effects	Standard error	Marginal effects	Standard error	Marginal effects	Standard error
Prob > chi^2	0.000							
Log likelihood	− 335.218							

***, ** and * denotes 1%, 5%, and 10%, respectively

The results also demonstrate that extension service has a positive and significant effect on the adoption of shade management practices. Specifically, receiving one additional service from an extension agent increases the likelihood of adopting these practices. This indicates that extension service is a strong influence on the adoption of shade management practices. Extension services play a crucial role in communicating information about technologies that can improve agricultural productivity to farmers. According to Kassie et al. (2013), extension agents can set up demonstration plots where farmers can learn about and try out new technologies, which can encourage adoption. In addition, an increase in the frequency of extension services provided by extension agents is associated with a higher likelihood of adopting new agricultural technologies (Ilesanmi and Afolabi, 2020; Kuboja et al. 2020). Obtaining shade trees from nearby farmers was found to increase the likelihood of implementing shade management practices, but obtaining them from cocobod had a negative effect on adoption. This finding is unexpected and contradicts our expectations. Results from focus group discussions indicated that sourcing shade trees from cocobod is more time-consuming and bureaucratic than sourcing them from other farmers. This observation aligns with the findings of CRIG (2017), which showed that farmers prefer to source shade trees from other farmers rather than from governmental organizations. The marginal effect of years of adoption indicates that as the age of shade trees increases, the likelihood of adopting shade management practices decreases. This may be because older shade trees are more likely to have been removed to allow for light penetration.

Table 8 presents the results of the analysis on the impact of shade management practices and other agronomic practices on cocoa seedling mortality. The result shows that different shade management practices, including agronomic techniques, impacted cocoa seedling mortality. The marginal effects of the explanatory variables (such as educational level, use of extension services, shade tree source, shade level, insecticide spraying, and weeding) on the dependent variable (seedling mortality) indicate the true effect of the explanatory variable since the estimated coefficients do not necessarily reflect the true magnitude of these effects (as described by Cameron and Trivedi in 2011 and Drukker in 2016). Our results suggest that these variables have a statistically significant effect on reducing seedling mortality.

In addition to shade management practices, educational level was found to have a negative and significant effect on seedling mortality at a 5% level. This means that each additional level of formal education allows the farmer to reduce seedling mortality by 2.5%. This result is not surprising, as farmers who have completed at least Junior High School (JHS) level are able to read and write and thus are more likely to adopt appropriate shade management measures to reduce cocoa seedling mortality compared to farmers with no formal education. This is consistent with the findings of Danso-Abbeam et al. (2014), who found that educated farmers are more likely to adopt good agricultural practices such as pruning, shade management, and fertilizer application to improve cocoa production. Extension service was also found to have a negative and significant effect on seedling mortality. This suggests that the more a farmer has contact with extension services, the more likely they are to adopt recommended shade management practices, leading to fewer seedling mortalities during the early establishment phase. Overall, extension services aim to help farmers adopt good agronomic practices that enhance cocoa production. Therefore, frequent contact with extension officers increases farmers'

Table 8 Effects of shade management practices on seedling mortality. *Source*: Field survey, 2021

Variables	Coefficients	Standard error	Marginal effects	Standard error	IRR	Standard error
Educational level						
Primary	− 5.271**	1.883	− 0.025**	0.010	1.28**	0.126
JHS	− 9.522***	1.872	− 0.041***	0.009	1.505***	0.148
SHS	1.575	1.986	0.080	0.104	1.084	0.113
Household size	0.095	0.188	0.004	0.007	1.004	0.007
Marital status (married)	− 0.526	0.960	− 0.020	0.037	0.98***	0.036
Experience in farming	0.091***	0.035	0.003***	0.001	1.003***	0.001
FBO membership	− 4.455***	1.157	− 0.170***	0.044	0.844***	0.037
Extension service	− 2.698***	0.549	− 0.103***	0.021	0.902***	0.019
Source of shade tree						
Neighboring Farmer	10.570	0.981	0.036***	0.003	1.431***	0.043
Market	3.920	1.616	0.148***	0.057	1.16***	0.067
Cocobod	0.709	0.596	0.028	0.024	1.029	0.025
Shade level						
Commercial polyculture (20–30%)	7.009***	0.768	0.288***	0.034	1.333***	0.046
Traditional polyculture (30–50%)	3.208***	0.810	0.142***	0.037	1.153***	0.042
Rustic (> 50% shade)	8.842***	1.148	0.035***	0.004	1.421***	0.063
Age of shade tree (years)	− 0.650***	0.224	− 0.025***	0.009	0.976***	0.008
Spraying insecticide						
Once a year	− 7.122***	1.298	− 0.259***	0.046	0.772	0.350
Twice a year	− 7.608***	1.430	− 0.279***	0.058	0.756***	0.044
Fertilizer application						
Once a year	1.527	1.402	0.062	0.056	1.064	0.06
Twice a year	4.607***	1.115	0.177***	0.042	1.193***	0.05
Weeding						
Once a year	3.367**	1.760	0.132**	0.066	1.141	0.750
Twice a year	4.230***	0.791	0.163***	0.031	1.177***	0.036
Adoption level						
Medium	− 1.024	0.725	− 0.039	0.027	0.962	0.026
Low	− 0.850	0.904	− 0.032	0.034	0.969	0.033
Constant	2.742***	0.117			15.515***	1.821
Observations	180				180	
Pseudo R^2	0.3026				0.580	
Wald chi^2	536.32				536.324	
Prob > chi^2	0.000				0.000	
Log-likelihood	− 234.476				− 1557.33	

IRR is the Incidence Rate Ratio. ***, ** and * denotes 1%, 5%, and 10%, significance respectively.

awareness and knowledge of shade management, resulting in reduced seedling mortality.

There was a positive relationship between the source of a shade tree and seedling mortality, specifically sourcing from neighboring farmers increases seedling mortality. When farmers sourced shade trees from other farmers, seedling mortality increased by 3.6% at a 1% significance level. This suggests that farmers could reduce seedling mortality by sourcing shade trees from the proper channel, such as Cocobod. On the other hand, the marginal effect of weeding and weed management was negative, indicating that adhering to the recommended regime of weeding can help reduce seedling mortality. This means that as farmers control weeds

Table 9 Constraints faced by farmers in shade management. *Source*: Field survey, 2021

Constraints	Mean score	Rank
Diseases and pest infestation	2.34	1st
Lack of access to important information on cocoa seedlings and shade management	3.27	2nd
Time-consuming	3.50	3rd
Lack of training on shade management	3.73	4th
Competition with seedlings	3.76	5th
Increased labour input	5.12	6th
High cost of shade trees	6.85	7th
Lack of access to desirable shade trees	7.43	8th

Test statistics	Value
Kendall's W[a]	0.680
Chi-square	684.886
df	7
Asymptotic significance	0.000

during cocoa production, seedling mortality decreased by 13.2%. This is likely because longer intervals between weeding can lead to the overgrowth of weeds, causing etiolation and death of seedlings. Weeds can compete with seedlings for nutrients and sunlight, leading to reduced survival rates. Similar results were observed by Asare et al. (2016), who found that farmers who allowed their cocoa farms to become weedy had higher seedling mortality rates compared to those who adhered to the recommended weeding schedule of 2–3 times every six months. Fertilizer application was found to have a significant impact on reducing mortality, specifically when applied twice per year. Providing regular nutrients to plants through fertilization can help fragile seedlings survive better and reduce mortality. As a result, farmers are encouraged to follow the recommended fertilizer application regimen to help seedlings survive and grow more quickly. These findings align with the research of Ali et al. (2018) and Kassie et al. (2013).

Controlling insects through the use of insecticides was found to significantly reduce seedling mortality. For example, as farmers increased insecticide application by 1%, seedling mortality declined by 27.9%. However, pest and disease attacks on seedlings due to the growth of undesirable shade trees can lead to increased seedling mortality. To reduce mortality, farmers are encouraged to use the recommended insecticides to combat insect and pest infestations during the establishment phase. Furthermore, it was found that farmers who practiced commercial polyculture and rustic techniques had increased seedling mortality by 28.8% and 35%, respectively. This is because these practices do not follow the recommended shade management practice of planting 6–8 shade trees per acre, resulting in either too few or too many shade trees per acre, which can negatively impact mortality.

Table 9 shows that cocoa farmers in the study faced a number of challenges in their shade management practices. These challenges included diseases and pest infestations, lack of access to useful agronomic information, and time-consuming processes in obtaining shade trees from cocobod. The Kendall's W indicates that there is a high level of agreement among the farmers on the ranking of these challenges. Previous research has also identified these challenges (Adjei-Frimpong 2016; Drechsel and Keraita 2014; Babalola et al. 2016; Kuwornu et al. 2018). One key way to address these challenges is to improve extension education programs focused on pest and disease control, and to provide more regular contact with extension agents who can provide useful information on cocoa seedling protection through shade management. Additionally, increasing stakeholder support for extension services in the study area could help improve cocoa production and output.

Conclusion and recommendations

This paper investigated the impact of shade management on cocoa seedling mortality in Ghana. The majority of the farmers surveyed were aware of the recommended shade management practices, and a significant proportion of them actually implemented these practices. The main reasons for adopting the recommended shade management practices were to reduce competition between the seeding and weeds while improve light penetration and soil quality on the farms. Most of the farmers believed that, adopting the recommended shade trees had a positive effect on reducing seedling mortality. The motivation for the adoption also included the expectation of meeting the recommended seedling density per acre to achieve higher cocoa pod yields.

The results further show that having completed senior high school, farming experience, extension service, sourcing shade trees from neighboring farmers or the Cocobod agency, the age of the shade tree, and weed control had a significant influence on the adoption of shade management practices. Furthermore, seedling mortality is influenced by educational level, extension service, source of shade trees, shade level, spraying insecticides, and regular weeding. Addressing these factors is essential for reducing seedling mortality in cocoa production in the study area. The study also identified several constraints faced by farmers, including time-consuming processes of obtaining shade trees from cocobod offices, lack of continuous training in shade management, high costs of shade trees, increased labor requirements, diseases and pest infestations caused by undesirable trees, and lack of access to useful information on cocoa seedling and shade management. The transition to less shaded cocoa systems was partly driven by a lack of farmer education on the benefits of incorporating shade trees. In focus group discussions, some farmers proposed non-monetary incentives, such as free transportation of shade trees to cocoa-growing communities, to encourage adoption. These farmers pointed out that the high cost of transportation can deter farmers from obtaining shade trees from reliable sources.

The government's efforts to increase cocoa production and foreign exchange revenue are admirable, but it is important to address the issue of low per-acre productivity due to high seedling mortality. The policy implication of this empirical observation is that the role of farmers' awareness of these recommended practices is crucial to farmers and cannot be ignored during adoption education outreach programs. The results of this study have identified the factors contributing to seedling mortality, which should be taken into account when addressing cocoa productivity in Ghana. This should be done in conjunction with improving the supply of quality seedlings to farmers when needed. It is also necessary to prioritize a broad policy framework that addresses the specific needs and constraints preventing the adoption of recommended shade management practices. Support mechanisms that target the specific challenges faced by remote farmers in accessing recommended shade trees should also be considered. To reduce the high seedling mortality rate, it is recommended that the Cocobod agency increase its extension services by regularly educating and training farmers on the importance of adopting recommended shade management practices. Both Cocobod and relevant stakeholders should prioritize educating farmers on the benefits of shade trees for cocoa, as well as their long-term advantages for soil health.

Author contribution A.M: Conceptualization, methodology, data curation, reviewing and editing. F.A: Conceptualization, reviewing and editing. B.O.A: Methodology, reviewing, and editing. S.P: Data curation, writing original draft and editing. B.Y.T: Conceptualization, data collection, data curation, writing original draft. P.A: Data curation, writing original draft and reviewing. All authors read and reviewed the final manucsript.

Funding The study did not receive any funding.

Data availability The data of study is available upon request from the corresponding author.

Declarations

Conflict of interest The authors declare no competing interests.

References

Abdulai I, Vaast P, Hoffmann MP, Asare R, Jassogne L, Van Asten P, Graefe S (2018) Cocoa agroforestry is less resilient to sub-optimal and extreme climate than cocoa in full sun. Glob Change Biol 24(1):273–286. https://doi.org/10.1111/gcb.13885

Adesina AA, Zinnah M (1993) Technology characteristics, farmers' perceptions and adoption decisions: a tobit model application in Sierra Leone. Agric Econ 9:297–311. https://doi.org/10.1111/j.1574-0862.1993.tb00276.x

Adjei-Frimpong E (2016) The challenges of the cocoa industry: A myth or reality? AGRIFIN. Retrieved from http://www.bftonline.com on 18th November, 2016

Akpalu MM, Ofosu-Budu GK, Kumaga FK, Ofori K, Mintah L (2021) Field performance and survival of cocoa seedlings raised in different growing media. Acta Univ

Sapientiae Agric Environ 13:100–112. https://doi.org/10.2478/ausae-2021-0009

Ali EB, Awuni JA, Danso-Abbeam G (2018) Determinants of fertilizer adoption among smallholder cocoa farmers in the western region of Ghana. Cogent Food Agric 4:1538589. https://doi.org/10.1080/23311932.2018.1538589

Anderson JA (1984) Regression and ordered categorical variables (with discussion). J Roy Stat Soc B 46:1–30

Aneani F, Ofori-Frimpong K (2013) An analysis of yield gap and some factors of cocoa (*Theobroma cacao*) yields in Ghana. Sustain Agric Res 2:526–2016

Asante BO, Etuah S, Adams F, Mensah A, Prah S, Mensah JO, Aidoo R (2023) Does adoption of cocoa hand pollination (CHP) improve welfare of farmers? Evidence from smallholder cocoa farmers in Ghana. Int J Agric Sustain 21(1):2253659. https://doi.org/10.1080/14735903.2023.2253659

Asare R, Afari-Sefa V, Muilerman S (2016) Access to improved hybrid seeds in Ghana: implication for establishment and rehabilitation of cocoa farms. Expl Agric. https://doi.org/10.1017/S0014479716000247

Asare, R., & David, S. (2010). Cocoa tree planting, replanting, and tree diversity. Learning about sustainable cocoa production: a guide for participatory farmer training. Manual No. 2. Forest & Landscape Denmark University of Copenhagen Hørsholm Kongevej 11 DK-2970 Hørsholm. Asante, P.A., Rahn, E., Zuidema, P.A., Rozendaa, D.M.A., van der Baan, M.E.G., L¨aderach, P., Asare, R., Cryer, N.C., & Anten, N.P.R (2022) The cocoa yield gap in Ghana: a quantification and an analysis of factors that could narrow the gap. Agric Syst 201:103473. https://doi.org/10.1016/j.agsy.2022.103473

Asfaw S, Shiferaw B, Simtowe F, Lipper L (2012) Impact of modern agricultural technologies on smallholder welfare: evidence from Tanzania and Ethiopia. Food Policy 37(3):283–295. https://doi.org/10.1016/j.foodpol.2012.02.013

Asitoakor BK, Vaast P, Ræbild A, Ravn HP, Eziah VY, Owusu K, Mensah EO, Asare R (2022) Selected shade tree species improved cocoa yields in low-input agroforestry systems in Ghana. Agric Syst 202:103476. https://doi.org/10.1016/j.agsy.2022.103476

Asubonteng KO, Pfeffer K, Ros-Tonen M, Verbesselt J, Baud I (2018) Effects of tree-crop farming on land-cover transitions in a mosaic landscape in the eastern region of Ghana. Environ Manag 62:529–547

Avane A, Amfo B, Aidoo R, Mensah JO (2021) Adoption of organic fertilizer for cocoa production in Ghana: perceptions and determinants. Afr J Sci Technol Innov Dev. https://doi.org/10.1080/20421338.2021.1892254

Babalola SO, Adeoye IB, Adegbite OO (2016) Patterns and challenges in exotic vegetables marketing. Internat J Veg Sci 22(4):376–438

Bandanaa J, Egyir IS, Asante I (2016) Cocoa farming households in Ghana consider organic practices as climate smart and livelihoods enhancer. J Agric Food Sec. https://doi.org/10.1186/s40066-016-0077-1

Bisseleua HBD, Fotio D, Missoup Y, Vidal AD (2013) Shade tree diversity, cocoa pestdamage, yield compensating inputs and farmers' net returns in West Africa. PLoS ONE. https://doi.org/10.1371/journal.pone.0056115

Bosompem MA, Kwarteng JA, Ntifo-siaw ED (2011) Towards the implementation of precision agriculture in cocoa production in Ghana: evidence from the cocoa high technology programme in the Eastern region of Ghana. J Agric Res Dev 10(1):11–17

Brant R (1990) Assessing proportionality in the proportional odds model for ordinal logistic regression. Biometrics 46:1171–1178

Cameron AC, Trivedi PK (2010) Microeconometrics Using Stata, Rev. Stata Press, College Station

Cameron AC, Trivedi PK (2013) Regression analysis of count data, 2nd edn. Cambridge University Press, New York

Clarke RD (1946) An application of the poisson distribution. J Inst Actuaries 72:481

Cochran WG (1940) The analysis of variance when experimental errors follow the poisson or binomial laws. Ann Math Stat 11:335–347

Cocoa Research Institute of Ghana (CRIG) (2017) Report on land tenure and cocoa production in Ghana: a CRIG/WCF collaborative survey. Available online at: https://www.worldcocoafoundation.org/wp-content/uploads/files_mf/1492612620CRIGLandTenureSurveyFinal41217.pdf. (Last accessed on Nov 2022).

Cocobod (2020) Cocoa hand pollination: impact, challenges & prospects. Retrieved from: https://thebftonline.com/2020/12/21/cocoa-hand-pollination-impact-challenges-prospects/. Accessed on Nov 2022.

Coleman JS (1964) Introduction to mathematical sociology. Free Press, New York

Danso-Abbeam G, Baiyegunhi LJS (2017) Adoption of agrochemical management practices among smallholder cocoa farmers in Ghana. Afr J Sci Technol Innov Dev 9(6):717–728. https://doi.org/10.1080/20421338.2017.1380358

Danso-Abbeam G, Baiyegunhi LJS (2020) Technical efficiency and technology gap in Ghana's cocoa industry: accounting for farm heterogeneity. Appl Econ 52(1):100–112. https://doi.org/10.1080/00036846.2019.1644439

Danso-Abbeam G, Edinam DS, Ansah IGK (2014) Modelling farmers investment in agrochemicals: the experience of smallholder cocoa farmers in Ghana. Res Appl Econ 6(4):12–27. https://doi.org/10.5296/rae.v6i4.5977

Dormon ENA, Huis AV, Leeuwis C, Obeng-Ofori D, Dawson OS (2004) Causes of low productivity of cocoa in Ghana: farmers' perspectives and insights from research and the socio-political establishment. NJAS 52:237–259

Drechsel P, Keraita B (2014) Irrigated urban vegetable production in Ghana: characteristics, benefits and risk mitigation. Int Water Manag Inst (IWMI), 247p. https://doi.org/10.5337/2014.219

Greene WH, Henscher DA (2010) Modeling ordered choices. A Primer Cambridge University Press, Cambridge

Ilesanmi JO, Afolabi JA (2020) Determinants of adoption of improved cocoa technologies in Ekiti state. Nigeria Int J Agric Econ 5(2):36

Johnson NL, Kemp AW, Kotz S (2005) Univariate discrete distributions, 3rd edn. Wiley, New York

Kaba JS, Otu-Nyanteh A, Abunyewa AA (2020) The role of shade trees in influencing farmers' adoption of cocoa agroforestry systems: insight from semi-deciduous rain forest agroecological zone of Ghana. NJAS Wageningen J Life Sci 92(1):1–7. https://doi.org/10.1016/j.njas.2020.100332

Kassie M, Jaleta M, Shiferaw B, Mmbando F, Mekuria M (2013) Adoption of interrelated sustainable agricultural practices in smallholder systems: evidence from rural Tanzania. Technol Forecast Soc Chang 80(3):525–540. https://doi.org/10.1016/j.techfore.2012.08.007

Kuboja NM, Isinika AC, Kilima FTM (2020) Adoption and impacts of improved beehive technologies in the miombo woodland of Tanzania. Afr J Sci Technol Innov Dev 13(2):157–166

Kumar A, Singh RKP, Kumar A, Betne R, Singh KM (2016) Adoption of modern rice cultivation practices in Bihar, India: micro-level evidences from village-level studies. Agric Res 5(4):433–439

Kuwornu JK, Oduro E, Amegashie DP, Fening KO, Yangyouru M, MacCarthy DS, Datta A (2018) Cost-benefit analysis of conventional and integrated crop management for vegetable production. Int J Veg Sci 24(6):597–611

Liu X (2016) Applied ordinal logistic regression using stata. SAGE, Thousand Oaks

Long JS (1997) Regression models for categorical and limited dependent variables. SAGE, Thousand Oaks

Long JS, Freese J (2001) Predicted probabilities for count models. Stata J 1:51–57

Long JS, Freese J (2014) Regression models for categorical dependent variables using stata, 3rd edn. Stata Press, College Station

Mariano MJ, Villano R, Fleming E (2012) Factors influencing farmers' adoption of modern rice technologies and good management practices in the Philippines. Agric Syst 110:41–53

Matata PZ, Ajay OC, Oduol PA, Agumya A (2010) Socio-economic factors influencing adoption of improved fallow practices among smallholder farmers in western Tanzania. Afr J Agric Res 5(9):818–823

McNeil D (1996) Epidemiological research methods. Wiley, Chichester

Mmbando FE, Baiyegunhi LJS (2016) Socio-economic and institutional factors influencing adoption of improved maize varieties in Hai District. Tanzania J Hum Ecol 53(1):49–56. https://doi.org/10.1080/09709274.2016.11906955

Nederlof S, Dangbêgnon C (2007) Lessons for farmer-oriented research: experiences from a West African soil fertility Management project. Agric Hum Values 24:369–387

Nunoo I, Frimpong BN, Frimpong FK (2014) Fertilizer use among cocoa farmers in Ghana: the case of Sefwi Wiawso District. Int J Environ 1(3):22–31

Obiri BD, Bright GA, McDonald MA, Anglaaere LCN, Cobbina J (2007) Financial analysis of shaded cocoa in Ghana. Agrofor Syst 71:139–149

Obuobisa-Darko E (2015) Socio-economic determinants of intensity of adoption of cocoa research innovations in Ghana. Int J Afr Asian Stud 12:29–40

UNDP Report (2011) Environmental baseline report on cocoa in Ghana; UNDP: Accra, Ghana, p. 144

Rice RA, Greenberg R (2000) Cacao cultivation and biological diversity conservation. Ambio 29(3):167–173. https://doi.org/10.1579/0044-7447-29.3.167

Rogers EM (2003) Diffusion of innovations, 5th edn. The Free Press, New York

Schroth G, Krauss U, Gasparotto L, Duarte Aguilar JA, Vohland K (2000) Pests and diseases in agroforestry systems of the humid tropics. Agrofor Syst 50(3):199–241. https://doi.org/10.1023/A:1006468103914

Selvin S (2004) Statistical analysis of epidemiologic data, 3rd edn. Oxford University Press, New York

Selvin S (2011) Statistical tools for epidemiologic research. Oxford University Press, New York

Shahbandeh M (2019) Cocoa production worldwide from 1980/81 to 2018/19 (in 1000 tons). Retrieved from: www.statista.com/statistics/262620/global-cocoa-production/. Accessed on Nov 2022

Shee A, Mayanja S, Simba E, Stathers T, Bechoff A, Bennett B (2019) Determinants of postharvest losses along smallholder producers maize and Sweetpotato value chains: an ordered Probit analysis. Food Sec 11:1101–1120. https://doi.org/10.1007/s12571-019-00949-4

Smith J, Pearce BD, Wolfe MS (2013) Bringing environmental protection and productivity together: Is temperate agroforestry the answer? Renewable Agric Food Syst 28(1):80–92. https://doi.org/10.1017/S1742170511000585

Somarriba E, Beer J (2011) Agroforestry systems with shade trees that offer timber or legumes increase the productivity of Theobroma cacao. (http://cadenacacaoca.info/CDOC-Deployment/documentos/Productivity_of_Theobroma_cacao_agroforestry_systems_with_timber_or_legume_service_shade_trees.pdf). Accessed on Nov, 2022

Somarriba E, Lopez-Sampson A (2018) Coffee and cocoa agroforestry systems: pathways to deforestation, reforestation, and tree cover change. Tech Rep 52:1–52

Taylor S, Todd P (1995) Decomposition and crossover effects in the theory of planned behavior: a study of consumer adoption intentions. Int J Res Mark 12:137–155. https://doi.org/10.1016/0167-8116(94)00019-K

Teshome A, de Graaff J, Kassie M (2016) Household-level determinants of soil and water conservation adoption phases: evidence from north-western Ethiopian highlands. Environ Manag 57:620–636. https://doi.org/10.1007/s00267-015-0635-5

von Bortkiewicz L (1898) Das Gesetz der Kleinen Zahlen. Teubner, Leipzig

Wessel M, Quist-Wessel PF (2015) Cocoa production in West Africa, a review and analysisof recent developments. NJAS Wageningen J Life Sci 74:1–7

Wongnaa CA, Apike IA, Babu S, Awunyo-Vitor D, Kyei AB (2021) The impact of adoption of artificial pollination technology in cocoa production: evidence from Ghana. J Agric Food Res 6:100208. https://doi.org/10.1016/j.jafr.2021.100208

Wooldridge JM (2010) Econometric analysis of cross section and panel data. MIT Press, Cambridge

World Cocoa Foundation (WCF) (2014) Cocoa Market Update. Uploads. http://worldcocoafoundation.org/wp-content/uploads/Cocoa-Market-Update-as-of-4-1-2014.pdf