Farmers' perceptions, drivers and impact of the adoption of Good Agricultural Practices on yield: Evidence from the cashew nut production in Côte d'Ivoire

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Abstract

Côte d'Ivoire, the world's leading cashew nut producer with 1,200,000 tons in 2022, faces low productivity of raw cashew nuts (350–500 kg/ha) due to the limited adoption of Good Agricultural Practices (GAP). This study explored the relationship between producers' perceptions and GAP adoption, identified factors influencing both the adoption and intensity of GAP use, and assessed the impact of GAP adoption on cashew nut yield. Using probit, Poisson regression, and marginal treatment effect models on data from 845 cashew producers, we found that plot preparation, direct seeding, shaping pruning, firebreak strips, thinning, and pruning were the most adopted GAP practices. The probit model results indicate that training, supervision by extension services, and producers' perceptions significantly determine GAP adoption. Additionally, gender, education level, social background, and access to extension services were key factors. Notably, the results from the marginal treatment effect models show that adopting thinning and pruning practices increased cashew nut yields by 194 kg/ha and 195 kg/ha, respectively. These findings emphasize the need for policies prioritizing training programs and strengthening extension services to boost GAP adoption and improve farmers' yield. Scaling up these initiatives can contribute to sustainable yield improvements in Côte d'Ivoire and the wider West African region

Keywords: Cashew nuts, good agricultural practices, adoption, impact, marginal treatment effect model

JEL code : Q16, Q18, D91

1. INTRODUCTION

Cashew cultivation in Côte d'Ivoire began in the late 1950s through environmental initiatives (Ducroquet et al., 2017), 1960 by the Société d'Assistance Technique pour la Modernisation de l'Agriculture en Côte d'Ivoire (SATMACI) and the Société de Développement des Forêts (SODEFOR) as part of programmes to protect the environment and combat erosion and deforestation (Ducroquet et al., 2017). A decade later, the rise in the price of raw cashew nuts led producers to focus on the production of raw cashew nuts to the detriment of forestry (Gouma, 2003), with the creation of the first plantations in 1972 (Conseil Coton Anacarde, 2017). The cashew nut production area gradually expanded from the savannah zone (Dugué, 2002; Kone et al., 2019) towards the south around 2000, in cocoa-growing areas at the forest-savannah contact, in the former cocoa loops (M'Bahiakro and Bouaflé), and around 2010 in certain cocoa-growing areas (Bayota, Gagnoa) (Ruf et al., 2019). However, this crop was adopted on a massive scale by producers without any substantial technical or financial support from the state (Ruf, 2016; Ruf et al. 2019).

The adoption of cashew production by producers has resulted in a remarkable increase in the number of plots over the years. The surface area of cashew orchards increased from 6,000 ha in the 1970s to 500,000 ha in 2006, 1,000,000 ha in 2011, and approximately 3,000,000 ha in 2018 (Mariam, 2018). These areas are developed by approximately 350,000 growers (FIRCA, 2018). The average areas varied according to the population density. They fluctuate between 1 ha in densely populated areas and 4 ha in less densely populated areas (Konan et al., 2010). However, these plots are planted with planting material that comes mainly from various origins (previous harvests, planting by other producers, etc.) and performs poorly (ICA-CCA, 2014).

Consequently, Ivorian raw cashew nut production has grown remarkably in recent decades. It rose from 8,500 tons in 1989 to 70,000 tons in 1999, then to 350,000 tons in 2010 (Kone, 2014; Banque Mondiale, 2015), reaching 500,000 tons in 2013 and 738,000 tons in 2018 (Conseil Coton Anacarde, 2018). This level of production makes Côte d'Ivoire the world's leading producer, ahead of India (650,000 tonnes) and Vietnam (325,000 tonnes), out of an estimated global production of 2.9 million tonnes.

However, the increase in production is due more to an increase in surface area than to an increase in yields. Indeed, yields in Côte d'Ivoire have remained well below world yields, which fluctuate between one (01) and two (02) tons/ha (Cashew Hanbook, 2014). Crude nut yields from Ivorian orchards remain low, fluctuating between 350 and 500 kg/ha (Djaha et al., 2012). Several factors seem to be behind this low productivity, including i) the aging of the orchard,

ii) the decline in soil fertility, iii) the delay in production due to climatic phenomena, and iv) the low adoption of good agricultural practices (GAP) in cashew nut plantation management (ICA-CCA, 2014).

To address this situation and ensure the sustainability of cashew cultivation, the Côte d'Ivoire government reformed the cashew industry in 2013 with the creation of the Conseil de Régulation, de Suivi et de Développement des filières Coton et Anacarde (Cotton and Cashew Council) to replace the Autorité de Régulation du Coton et de l'Anacarde (ARECA). This reform will be operationalized through six (06) strategic axes, including the one relating to the training and coaching of cashew nut producers. The implementation of this axis will be concretised by the signature of a tripartite agreement for a period of four (04) years between the Conseil du Coton et de l'anacarde, the Fonds Interprofessionnel pour la Recherche et le Conseil Agricole (FIRCA) and the Agence Nationale d'Appui au Développement Rural (ANADER). The latter is responsible for disseminating agricultural innovations and monitoring the application of good agricultural practices (GAP) by producers, and was able to train and mentor 102,282 producers in 2014 and 149,600 in 2015 (Ouattara, 2017). The government's objective is to increase cashew nut farm productivity by changing the production technology.

Despite these efforts, the application of good agricultural practices (GAP) remains low (Chiapo, 2018). Indeed, the cashew orchard does not follow the recommended technical itinerary. The ICA-CCA (2014) report noted an average density of 500 cashew plants per hectare over the period 2010–2012, which is well above the standard of 100 trees/ha (Chiapo, 2018). However, the implementation of these GAPs has a positive impact on cashew nut yields, as producers who apply GAPs strongly have higher yields of around 716 kg/ha (Coulibaly et al., 2019). These authors note that the implementation of GAP has a positive impact on gross revenues, as producers who strongly implement GAP have the highest gross revenues of around 157,529 F CFA /ha; however, they are the least profitable compared to those who weakly implement GAP, due to higher costs.

In terms of tools for analyzing the adoption of good agricultural practices, Ouattara (2017) identified the determinants of GAP adoption using a multinomial logit model. However, in her analysis, she did not consider post-harvest operations that influence cashew nut quality. Other authors, such as Coulibaly et al. (2019), used the score method to analyze GAP adoption and the budgeting method to assess the financial profitability of cashew production.

Moreover, these methods, although relevant, are not robust enough to measure the intrinsic impact of the application of GAP on cashew productivity. Furthermore, the issue of producers' perception of the adoption of good practices has been the subject of few studies in the cashew nut sector. This study investigates the role of producers' perceptions in GAP adoption and assesses its impact on yield to provide actionable insights for the agricultural sector.

The remainder of this paper is structured as follows. The next section presents the literature review related to the key concepts of the study in relation to good agricultural practices, followed by the methodology used to analyze the data. Section 4 presents and discusses the empirical results of this study. The final section presents the conclusions and policy implications.

2. LITERATURE REVIEW

2.1. Concept of good agricultural practice

(Coulibaly et al., 2019) state that good agricultural practice is an expression used by various organizations linked to agriculture and that this term refers to a set of rules to be followed (good practices) in establishing and developing crops to optimize agricultural production while reducing as far as possible the risks associated with such practices, both for humans and the environment. Indeed, in the run-up to the World Summit on Sustainable Development, the UN (2002) stressed the importance of sustainable agriculture for food security and resource management, stating that FAO (2002) specified that good agricultural practice is a set of sustainable agricultural production systems that are socially viable, economically profitable, and productive, while protecting human and animal health and welfare and the environment. In this context, Good agricultural Practices can be considered as practices that contribute to sustainable agriculture.

According to the FAO, good agricultural practices are based on 11 guiding principles. These principles apply to the entire production and value chain of a plant or animal product on a given farm, as well as to various subcomponents of agriculture.

In Côte d'Ivoire, several agricultural innovations, including good agricultural practices for various crops (cocoa, cashew nuts, etc.), are being disseminated to farmers by several extension agencies. As far as cashew nuts are concerned, twelve (12) themes (Table 1) that bring together all the agricultural practices that respect the environment and ethical values in cashew nut production areas have been retained as part of the framework agreement (2014-2017) between the Conseil du Coton et de l'anacarde and ANADER. These practices concern both good production and post-harvest practices. The adoption and application of these good practices aim to improve the productivity and quality of cashew nuts in the country.

Table 1: Themes of good production practices in cashew nut cultivation

N°	Themes
1	Plot preparation
2	Plant material acquisition when creating a new orchard
3	Staking when creating a new orchard
4	Digging and filling in when creating a new orchard
5	Direct seeding when creating a new orchard
6	Planting when creating a new orchard
7	Fertilization during the planting stage
8	Creation of firebreaks around your orchard
9	Replanting when creating a new orchard
10	Shaping pruning
11	Thinning
12	Pruning

Source: ANADER

These themes were disseminated by ANADER through an agricultural advisory service dedicated to cashew nut growers, which provided information and training in villages, school fields, demonstration units, and plot visits to the farmers. The dissemination of these themes involves an "agricultural advisor’s extension agent as a channel of dissemination, and a producer as the "advised agent" advised agent. Local radio stations are also used to broadcast information in local languages.

2.2. Determinants of the adoption of agricultural innovations

Among the definitions proposed by several authors who have worked on the adoption of innovations, Rogers (1963, 2003) definition appears most often. He defines innovation as an idea, practice, or object perceived as new by a person or unit of adoption’. For him, one of the characteristics of technological innovations is that they are not automatically adopted once they appear, even if they have superior qualities compared to older technologies. Rogers (2003) considers that the degree of adoption is linked to the level of diffusion, which is the process by which an innovation is communicated through certain channels over time to the members of a social system. Thus, adopting agricultural innovation means that it offers something more than the current practice.

Citing (Baumgart-Getz et al., 2012; Knowler & Bradshaw, 2007; Prokopy et al., 2008), Roussy et al. (2015) revealed that many studies on innovation adoption behavior are based on the hypothesis that the overall perceived utility of an innovation corresponds to the sum of the utilities of the characteristics that make up that innovation, referring in this respect to the work of Lancaster (1966).

In addition, several theoretical models have been developed on the adoption and choice of technologies since Rogers (1983) to explain the behavior of players. These include i) the diffusion of innovations model (Rogers (1983, 1995)), ii) the technology acceptance model (Davis, 1989), iii) the theory of interpersonal behavior (Triandis, 1980), and iv) the neoclassical theory of rational expectations (Muth, 1961). Work based on these theories indicates that the determinants of technology and innovation adoption are of various kinds: social, technical, economic, and environmental.

At the empirical level, recent studies have been conducted on the adoption of good agricultural practices for cashew cultivation in Côte d'Ivoire. Ouattara (2017) identified the determinants of the adoption of good pre-harvest cultivation practices for cashew. Using an unordered multinomial logit model, she showed that social variables, such as location and level of education, favor the adoption of good pre-harvest cashew production practices. Conversely, certain variables, such as the age of the farm manager and household size, negatively impacted the adoption of certain good cashew-growing practices.

The financial profitability of adopting good production practices was the subject of a study by Coulibaly et al. (2019). They used a scoring method and budgeting. The analyses show that 54.7% of producers apply good production practices, which have a positive impact on yield and income. However, their application is less profitable, as it generates higher costs.

2.3. Perceptions and adoption of agricultural innovations

Since the seminal work of Kivlin and Fliegel (1966; 1967), several studies in agricultural economics have been conducted on the factors influencing producers' perceptions and adoption of new agricultural technologies. Perceptions are psychological factors that can influence an individual's behavior. Sheth and Mittal (2004) state that it is a process by which an individual selects, organizes, and interprets information. Perception is subjective. Economists (Jones, 1989; Lin & Milon, 1993) who have studied consumer demand have corroborated that consumers have subjective preferences for product characteristics and that their demand for products is significantly affected by their perceptions of product attributes. In the context of agriculture, key attributes described in the literature include (i) compatibility, (ii) complexity, (iii) observability and transferability, (iv) cost and profitability, (v) risk and uncertainty, (vi) trialability, and (vii) relative advantage (Barroga, 2019).

Empirically, according to Rogers' (2003) model, the particular characteristics of the technology and how potential users perceive its value can explain between 50% and 90% of variations in adoption rates. Similarly, Adesina and Zinnah (1993) and Adesina and Baidu-Forson (1995) show that the adoption of technologies by farmers reflects rational decision-making based on farmers' perception of the relevance of the characteristics of the technologies studied through their work on the adoption decisions of improved rice varieties by Sierra Leonean farmers. They showed that farmers' adoption decisions depend mainly on their perceptions of these new varieties. More specifically, factors such as cooking, yield, and ease of mashing and milling play a decisive role in the decision to adopt these rice varieties (Adesina and Baidu-Forson, 1995).

2.4. Impact of good agricultural practices

The impact of programs and policy interventions is increasingly assessed using the potential results approach. There is an abundance of economic literature on assessing the causal effect of programmes (Ashenfelter, 1978, Heckman & Robb, 1985, Manski, 1990). Two main methods are used to evaluate the impact of programmes: experimental and quasi-experimental (matching, discontinuity regression, double difference, and instrumental variable methods) (Heckman et al., 1999; Cavaco et al., 2013; Fougère et al., 2007).

Nacro et al. (2010) showed that good agricultural practices have a positive influence on soil organic matter, nitrogen, and assimilable phosphorus content compared with agricultural practices. The results of work by Belém (2017) show that the application of good agricultural production practices improves yields. Indeed, the adoption of good cultivation practices shows that adopters obtain approximately twice the yield of non-adopters. 383.78 kg/ha and 176.37 kg/ha, respectively. Singh et al. (2011) showed the important role of soil preparation in rice cultivation through its quality and timely execution in rice growth.

Several authors have used the Instrumental Variable method to estimate the impact of the adoption of good agricultural practices on producer households in terms of improved productivity, food security, and poverty reduction. Ndiaye (2019) used the Local Average Response Function (LARF) method to estimate the impact of the adoption of Good Agricultural Practices on the yield of rice farmers in the Senegal River Valley. The results show that Good Agricultural Practices increased rice yields by 3.7 tonnes/ha. In cashew nut cultivation, Basse et al. (2022) used the local average treatment effect (LATE) to estimate the impact of adopting good agricultural practices for cashew nuts on farmers' yields. The results show that the adoption of good cashew nut agricultural practices have a positive and significant impact on the yields of adopting farmers of 528.84 kg/ha in the model without interaction and 609.87 kg/ha in the model with interaction.

3. METHODOLOGY

3.1. Study area and sampling

The present study was conducted from October to November 2017 in the cashew nut production basin in Côte d'Ivoire, which covers 19 regions in the northern half of the country, These regions are: Béré, Gontougo, Hambol, Poro, Worodougou, Gbèkè, Kabadougou, Bagoué, Marahoué, Bounkani, Haut-Sassandra, Tchologo, Iffou, Folon, Indenié-Djuablin, Bafing, Bélier, N'zi and the Moronou region (Figure 1).

The methodological approach was based on a survey of raw cashew nut producers in the various production and intervention zones of the agricultural advisory agency (ANADER). A number of beneficiary and non-beneficiary localities were identified to make up the sample of producers. A two-stage stratified survey was used to select the sample of producers for the survey. The first level of stratification concerned fifty-four (54) localities producing raw cashew nuts in which the Conseil du Coton et de l'Anacarde is represented. The second level of stratification involved the selection of producers who had or had not participated in the training on good agricultural practices, and who were chosen at the level of each locality. The choice of each producer surveyed was random. Thus, the sample targeted 1020 raw cashew nut producers in the cashew production zone, i.e. a sampling rate of 15% compared with a parent population of 149,600 producers. The final database covers 845 cashew nut growers throughout the production zone, whether or not they were included in the GAP training and monitoring project.

Data were collected using a questionnaire intended for cashew nut producers. It covers the socio-demographic information of the producers (age, gender, level of education, social status, household size), the characteristics of the plots (surface area, age of plantation, production, good production practices, etc.), the producers' perception of good agricultural practices, and economic data (selling price, etc.).

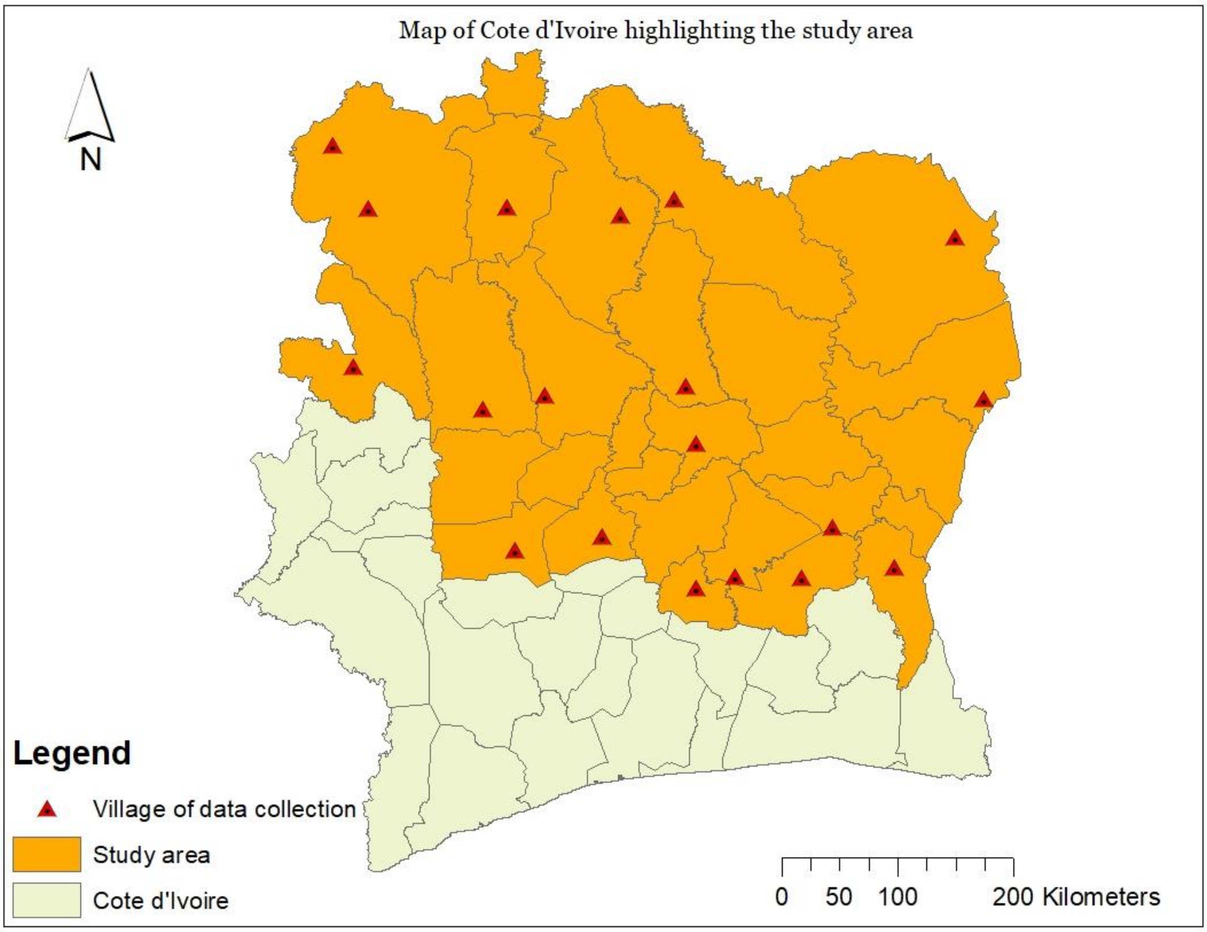

Figure 1: Study survey areas
Source: Author based on survey data

3.2. Data analysis

The data were processed using STATA software and focused mainly on the socioeconomic and demographic characteristics of producers, technical characteristics of cashew nut plots, producers' perceptions, and institutional factors. The data were analyzed using descriptive statistics (mean, standard deviation, percentile, etc.), correlation coefficients, the scoring method, probit regression models, and the marginal treatment effect (MTE) approach.

3.2.1. The score method

A scoring method was used to assess the attitude toward adopting good agricultural practices. This method was implemented as follows. For each good practice, the farmer was asked to choose the level of appreciation or application. Four modalities (not at all, little, moderately, and strongly) were submitted to the producer's judgement. The ratings were as follows: Not at all = 1; Somewhat = 2, Moderately = 3, and Strongly = 4.

The average score for each good practice is obtained by averaging the scores that each producer i assigns to the theme. The average score was obtained as follows:

$$average\ score = \frac{\sum score_i}{N} \quad (1)$$

where i is the responding producer and N is the total number of responding producers.

The average score per practice was between 1 and 3. The more a theme is adopted, the more its adoption score tends to approach 4. A theme with a score tending towards 1 implies that it has not been adopted at all.

3.2.2. Probit model

Let Uij be the utility that producer i hopes to obtain from using technique j, where i = {1, 2,..., n}. The producer's decision is a process of two mutually exclusive alternatives. The ith producer will use technique j if Ui1 >Ui0 (1 for the good agricultural practice technique and 0 for the peasant practice). The expected profit (U*i) is an unobserved latent variable that depends on alternative choices and the socio-economic, demographic, and institutional characteristics of the farmer (Xij). According to the probit model, if the farmer considers good agricultural practice to be more profitable, Ui*>0; otherwise, he continues with the technique he was using, and Ui*≤ 0. With Ui* the unobservable latent variable associated with the adoption decision; where Xij is a vector of explanatory variables, βi the parameter vector and Ɛi the error term.

$$U_i = \sum_{j=1}^{n} \beta_i X_{ij} + \varepsilon_i; i = 1, \dots, n; j = 1, \dots, n \quad (2)$$

$$\begin{cases} U_i = 1 & \text{adoption of good agricultural practice} \\ U_i = 0 & \text{non} - \text{adoption of good agricultural practice} \end{cases}$$

The probability of adopting a good practice is then equal to

$$P_i = \text{prob}\ (a_i = 1) = \sum_{j=1}^{n} \beta_i X_{ij} + \varepsilon_i > 0 \quad (3)$$

$$P_i = F(\sum_{j=1}^{n} \beta_i X_{ij});\ i = 1, \dots, n; j = 1, \dots, n \quad (4)$$

Where F is the normal distribution function.

$$F(x) = \int_{-\infty}^{x} \frac{1}{\sqrt{2\pi}} e^{-t^2/2} dt \quad (5)$$

The distribution function F follows a normal distribution. The Z statistic was used to estimate the various coefficients and parameters of the equation (Hurlin, 2003; Fougère & Kramaz, 2008).

3.2.3. Poisson model

Poisson regression is estimated by considering the total number of Good Agricultural Practices that can be adopted by a producer. Poisson regression is usually employed when the dependent variable is a count variable, which in this case is the sum of the good agricultural practices adopted. The Poisson probability distribution is more appropriate than the normal distribution used in the probit model, or the logistic distribution used in the logit model. The probability density function is expressed as follows:

$$F\left(\frac{y_i}{x_i}\right) = P\left(\frac{Y_i}{y_i}\right) = \frac{e^{-\lambda}\lambda^y}{y!}, \quad y = 0,1,2,3,4,5, \qquad (6)$$

Where y_i is the total number of good agricultural practices adopted by the farmer and x_i is the variables influencing the adoption process. The expected mean parameter (λ) of the probability function is defined as

$$E(y_i/x_i) = \lambda_i = exp(x_i'\beta) = exp(\beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots\ldots + \beta_k x_{ki}) + \varepsilon_i \quad (7)$$

3.2.4. Impact estimation model

The counterfactual approach of modern impact evaluation theories (Wooldridge, 2002; Heckman, 1997; Imbens & Angrist, 1994; Rubin, 1974) based on the potential outcomes developed by Rubin (1974), is used to determine the impact of the adoption of good agricultural practices on cashew farm productivity.

In addition, the marginal treatment effect (MTE) framework accounts for treatment effect heterogeneity in observed and unobserved characteristics (Cornelissen et al., 2018). The MTE approach estimates a continuum of treatment effects along the entire distribution of farmers' unobserved resistance to adoption (Frölich & Sperlich, 2019). In addition, it allows the estimation of several economically useful treatment effect parameters, including the average treatment effect (ATE), average treatment effect on treated (ATET), average treatment effect on untreated (ATUT), and average local treatment effect (LATE).

The Generalized Roy Model is based on the potential outcomes model and a latent variable discrete choice model for selection into treatment.

$$\mathrm{Y} = Y_1 D + (1 - D) Y_0 \qquad (8)$$

Y_1 is the individual's return if he adopts a good agricultural production practice

Y_0 is the yield of an individual who does not adopt good agricultural production practices.

$$Y_j = X b_j + U_j \text{ for j = 0,1} \qquad (9)$$

where j =1 designates producers who adopt good agricultural practices and 0 designates non-adopters.

The MTE parameter can be defined as follows (Heckman, 2010).

$$\text{MTE (x, u)} = E(Y_1 - Y_0 | X = x, U_D = \mu_D) = X(b_1 - b_0) + k(u) \quad (10)$$

4. RESULTS AND DISCUSSION

4.1. Socio-demographic characteristics of cashew nut producers

The descriptive statistics for the continuous and discrete categorical variables used in this study are shown in Table 2. The results showed that cashew-nut growers were mainly men (95%) with a marginal proportion of women (5%). The average age of the producers was 47 years, with a standard deviation of 11 years. The predominance of men over women in cashew nut cultivation can be explained by the difficult access of women to land, as noted by Koné (2011), who affirmed that, traditionally, women rarely receive or inherit valuable land definitively with exclusivity and are excluded from the management rights of lineage land heritage. Indeed, given its occupation of space over several years and its economic interest, the cultivation of cashew trees constitutes a cash crop owned mainly by men in the region.

The average size of the cashew-growing households was 10 members who could participate in the fieldwork. With regard to the education level of cashew nut growers, the results showed that a majority of the growers (63%) were illiterate. In terms of social status, the results showed that the majority of cashew nut growers were natives (82%), with a small proportion being non-natives (8%) and allochthonous (10%). The most likely explanation is that non-native and non-native faces, in the same way as women, have difficulty accessing land capital. Indeed, the majority of non-natives and non-natives had access to land for establishing cashew plots through purchase or rental. In terms of marital status, most of the cashew growers lived as couples (64%), either cohabiting or married. The results of the study showed that the majority of cashew growers acquired their plots by inheritance (54%), compared with 21% of growers who created their own farms and owned their plots. On average, producers own approximately 1.5 plots per farming household. The average size of the cashew plots was 4.2 ha. These plots were, on average, 17 years old; therefore, the cashew orchards tended to age. These plots were located approximately 4 km from the producers' homes. Within the framework of the training program dedicated to producers, the study revealed that 79% of producers had been trained, sensitized, or informed about good cashew-growing practices, compared to 56% who had received advisory support from supervisory services.

Table 2: Producer socio-economic characteristics and cashew nut farm techniques

Variables	N	Mean	Std. Dev.
Socio-demographics			
Sex (Female=0; Male=1)	845	0.948	0.222
Producer age (year)	845	46.807	11.182
Household size	845	10.372	5.499
Literate (0= illeterate; 1= literate)	845	0.370	0.483

Social status (0=non-native; 1=native)	845	0.820	0.384
Marital status (1=in couple; 0=not in couple)	845	0.645	0.479
Cashew nut plot			
Inheritance mode (1=inheritance; 0=other)	845	0.544	0.498
Ownership mode (1=owner; 0=other)	845	0.214	0.411
Purchase mode (1= Purchase; 0=other)	845	0.044	0.205
Rental of plot (1= Rental of plot; 0=other)	845	0.031	0.173
Number of plots	845	1.498	0.667
Plot age (year)	845	16.843	6.805
Production area (ha)	845	4.172	3.205
Plot distance (km)	845	3.507	2.597
Institutional			
GAP training (1= GAP training; 0=other)	845	0.796	0.403
Contact with extension agent (1= Contact with extension agent; 0=other)	845	0.563	0.496

Source: Author based on survey data

4.2. Perception and frequency of adoption of good agricultural practices by cashew producers

The cashew producers' perceptions of the effect of applying good practices on improving cashew yield and quality are presented in Table 3. The mean rank of producers' perception of each good agricultural practice was calculated, and the rank was determined using Kendall's concordance coefficient. Among the various good agricultural practices, Kendall's test revealed that the application of pruning was the first and most important in terms of perception by growers. This is followed by thinning and the creation of fire strips around the orchards. Practices such as fertilization, hole filling, and replanting were the least preferred.

Table 3: Kendal's w test on farmers' perception of good agricultural practices

Good agricultural practices	Mean rank	Rank
Pruning	5.40	1
Thinning	5.57	2
Making firebreaks around your orchard	5.89	3
Plot preparation	6.15	4
Acquiring plant material when creating a new orchard	6.58	5
Training pruning	6.59	6
Direct seeding when creating a new orchard	6.81	7
Staking when creating a new orchard	6.81	8
Planting when creating a new orchard	6.93	9
Fertilization during the planting stage	6.95	10
Digging and filling when creating a new orchard	7.03	11
Regarnishing when creating a new orchard	7.29	12
W de Kendalla	0.076 ***	

Khi-deux	705.706
ddl	11

Source: Author based on survey data

Table 4 presents the level of adoption of various good agricultural practices (GAPs) by producers. It highlights the practices that are the most and least commonly adopted by cashew nut farmers. Notably, plot preparation, direct seeding, laying firebreaks, shaping pruning, thinning, and pruning showed a high level of adoption, with mean scores consistently above 2,000, indicating that these practices are widely implemented and considered essential for successful orchard management. These practices are fundamental for improving productivity and ensuring the sustainability of orchards.

Table 4: Level of adoption of good agricultural practices by producers

Good agricultural practices	Not at all	Little	Moderately	Very much	Mean score	Adoption level
Plot preparation	411	78	114	242	2.221	High
Acquiring plant material when creating a new orchard	517	102	122	104	1.779	Low
Staking when creating a new orchard	559	48	100	138	1.783	Low
Digging and filling in when creating a new orchard	578	59	90	118	1.702	Low
Direct seeding when creating a new orchard	473	57	127	188	2.036	High
Planting when creating a new orchard	567	62	103	113	1.718	Low
Fertilization during the planting stage	621	55	64	105	1.589	Low
Laying firebreaks around your orchard	398	42	79	326	2.394	High
Replanting when creating a new orchard	532	91	94	128	1.785	Low
Shaping pruning	422	104	129	190	2.103	High
Thinning	326	99	135	285	2.449	High
Pruning	325	81	130	309	2.501	High

4.3. Factors determining the intensity of adoption of Good Agricultural Practices

4.3.1 Frequency of intensity of adoption of Good Agricultural Practices

Among the 12 GAP, cashew nut growers can adopt different sums of good agricultural practices, referred to here as adoption intensity, ranging from 0 to 12 (Figure 2). This study revealed that producers adopt an average of five GAP at a time. In terms of proportion, the study shows that 28% of cashew growers have not adopted any of the 12 Good Agricultural Practices, preferring traditional farming practices. On the other hand, approximately 19% of growers have adopted all twelve (12) recommended agricultural practices for the better management of cashew plots. Between these extremes, the proportion of growers with adoption intensities ranging from 1 to 11 fluctuated between 3.2% and 6.86%. The results also show that more than half of the growers (53%) did not adopt the entire technological package of good agricultural practices, but rather made partial or sequential choices of the package of good agricultural practices they applied to the plots. Similar results were reported by Roussy *et al.*, (2015). Indeed, several factors can explain producers' sequential adoption behavior of technological packages, including fixed costs, credit constraints, risk, and uncertainty (Aldana *et al.*, 2011).

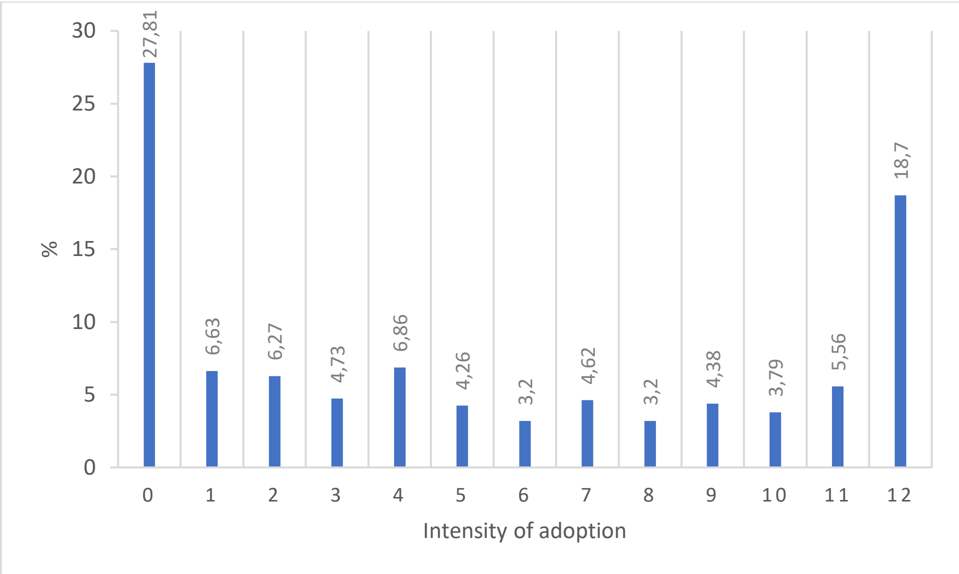

Figure 2: Intensity of adoption of good agricultural practices
Source: Author based on survey data

4.3.2 Test for normality of independent variable

The Skewness and kurtosis test shows that the "Intensity_Adopt" dependent variable does not follow a normal distribution. The Skewness p-value was less than 0.05; therefore, we rejected the H0 hypothesis, and the data did not have a normal distribution.

4.3.3 Multicollinearity test between variables

Before proceeding with multivariate analysis, it is essential to examine the correlations of the explanatory variables to detect any multicollinearity that may bias the conclusions of the analysis. Examination of the correlation matrix shows that there is no strongly elevated level of correlation that requires corrective actions. The correlation coefficients ranged from -0.571 to a maximum of 0.509. All these correlation coefficients are below the 0.8 threshold and therefore, do not reveal the presence of a serious multicollinearity problem.

4.3.4 Detecting over-dispersion

The Poisson model is the most widely used probabilistic framework for the analysis of count data; however, this model is only appropriate if the mean of the count variable is equal to its variance E(y) = Var (y). If this hypothesis is not verified, the parameters estimated using the maximum likelihood method will be biased. In this case, an alternative counting model that considers overdispersion (negative binomial model) is indispensable. The ratio of the variance to the mean of the dependent variable estimated for the 845 producers in the sample, with a value of 4.24, favoured an over-dispersion of observations in relation to the Poisson distribution hypothesis.

4.3.5 Model estimation using Poisson and Negative binomial regression

The over-dispersion test performed after estimating the regression of the Poisson model shows a highly significant over-dispersion (p-value < 0.05), allowing us to reject the null hypothesis of equality of the mean and variance of the "Intensity_Adop" variable. Therefore, it is necessary to use a negative binomial model.

The estimates of the Poisson and negative binomial models (Table 5) confirm the superiority of the negative binomial model. The likelihood ratio test (Prob ≥ chibar2 = 0.000) led to the choice of a negative binomial model.

The Poisson model is a nonlinear model, and Incidence Rate Ratios (IRR) were used to interpret the coefficients obtained after regression. An incidence rate ratio of less than 1 (IRR < 1) means that an adopter is less likely to adopt several good agricultural practices, while an incidence rate ratio of greater than or equal to 1 (IRR ≥ 1) means that an adopter is more likely to adopt several good agricultural practices.

The results of the Poisson regression model show that the gender of the producer, level of education, social status, marital status, and training and supervision of producers in good agricultural practices have positive effects on the intensity of adoption of good agricultural practices within the population studied. On the other hand, the mode of acquisition of cashew plots (inheritance, ownership, rental) and the number of cashew plots owned by the producer had a reducing effect on the intensity of adoption of good agricultural practices.

The marital status of couples positively influenced the intensity of the adoption of good agricultural practices. This result is similar to that of Sale et al. (2014), who noted that married farmers have children who serve as their labor force for various agricultural tasks. This marital status determines the farmer's needs and expenses, and conditions his decisions to improve agricultural productivity.

The incidence rate ratio associated with the sex variable was greater than 1 (1.439 > 1) and was statistically significant at the 1% threshold. This means that the intensity of the adoption of good agricultural practices among men was 1.439 times higher than that among women. The incidence rate ratio associated with the literacy variable was greater than 1 (1.206> 1) and was statistically significant at the 1% threshold. This means that the intensity of the adoption of good agricultural practices among literate farmers is 1.206 times higher than that among non-literate farmers. This result confirms the importance of producers' level of education in the adoption of good agricultural practices. Male producers, who comprise 95% of cashew nut growers, have a higher adoption intensity than female producers. This result is consistent with several studies that have shown a positive correlation between decisions to adopt innovation and education level in sub-Saharan Africa (Kebede *et al.*, 1990). Indeed, a high level of education influences the attitudes and thoughts of producers, making them more open, rational, and able to analyze the benefits of good production practices. Education facilitates critical thinking and the effective use of information received by producers (Dissanayake *et al*., 2022). Thus, literate producers understand their interest in adopting the entire technological package of good agricultural practices, which impacts the yield and quality of raw cashew nuts. This implies that actions to strengthen the capacities of current cashew producers in functional literacy will have to be carried out to improve their level of education and to make them aware of educating future generations of producers, with the aim of improving their decision to adopt good production practices.

The incidence rate ratio associated with the social status variable was greater than 1 (1.233> 1) and statistically significant at the 1% threshold. This means that the intensity of adoption of good agricultural practices among indigenous producers is 1.233 times higher than that of allogeneic or allochthonous producers. This result shows that origin has a positive influence on producers' adoption behavior. This result can be explained by the fact that indigenous producers are more likely to take part in training courses (75%) on good agricultural practices and receive coaching (80%) from extension agents, as well as by their access to land (Nkamleu & Coulibaly, 2000).

The incidence rate ratio associated with the training variable was greater than 1 (3.813> 1) and statistically significant at the 1% threshold. This means that the intensity of the adoption of good agricultural practices among producers who have been trained in good agricultural practices is 3.813 times higher than that among producers who have not been trained. The incidence rate ratio associated with access to advisory support from extension services is greater than 1 (3.813> 1) and is statistically significant at the 1% threshold. This means that the intensity of adoption of good agricultural practices among producers who receive support from extension services on good agricultural practices is 3.813 times higher than that of producers who receive no support.

Conversely, the incidence rate ratios associated with the plot acquisition mode variable are less than 1 and statistically significant at the 1% threshold for the owner and lease modes, and 10% for the inheritance mode. These results show that these modes of access to plots by producers have a reducing effect on the intensity of adoption of good agricultural practices.

Table 5: Parameter estimates for Poisson and negative binomial models of intensity of adoption of good agricultural practices

Variables	Poisson regression		Negative binomial regression	
	IRR	dydx	IRR	dydx
= 1 if male	1.586*** (0.150)	2.408*** (0.496)	1.439** (0.251)	1.923* (0.924)
Producer age	1.002 (0.001)	0.010 (0.008)	1.001 (0.003)	0.003 (0.017)
Household size	1.004 (0.003)	0.023 (0.016)	1.004 (0.007)	0.019 (0.036)
= 1 if Literate	1.136*** (0.036)	0.664*** (0.166)	1.206** (0.085)	0.991** (0.378)
= 1 if native	1.198*** (0.055)	0.942*** (0.241)	1.233** (0.118)	1.108* (0.511)
= 1 if married	1.062* (0.036)	0.316 (0.177)	1.143* (0.085)	0.707 (0.396)
= 1 if Inheritance mode	0.844*** (0.033)	-0.882*** (0.205)	0.854* (0.079)	-0.833 (0.494)
= 1 if Ownership mode	0.647*** (0.032)	-2.269*** (0.262)	0.697*** (0.078)	-1.904** (0.596)
= 1 if Purchase mode	0.935 (0.082)	-0.352 (0.459)	1.029 (0.199)	0.149 (1.019)
= 1 if Rental of plot	0.276*** (0.053)	-6.717*** (1.006)	0.232*** (0.067)	-7.716*** (1.579)
Number of plots	0.96* (0.023)	-0.210 (0.127)	0.904* (0.049)	-0.531 (0.291)
Plot age	0.991*** (0.002)	-0.048*** (0.013)	0.995 (0.005)	-0.026 (0.028)
Production area	1.001 (0.005)	0.006 (0.028)	0.996 (0.012)	-0.022 (0.061)
Plot distance	0.992 (0.006)	-0.043 (0.033)	0.998 (0.014)	-0.013 (0.073)
= 1 if GAP training	3.416*** (0.281)	6.412*** (0.440)	3.813*** (0.443)	7.069*** (0.695)
= 1 if Contact with extension agent	2.073*** (0.083)	3.805*** (0.217)	2.107*** (0.163)	3.935*** (0.462)
Constant	0.715** (0.107)		0.69 (0.195)	
Observations	845		845	
Prob > chi2 =	0.000		0.000	
Chi-square =	1593.600		355.338	
Pseudo R2 =	0.240		0.077	

Source: Author based on survey data

4.4. Impact of the adoption of good practices on farm yield

The naïve estimation of the impact of the adoption of each good practice on the yield of the plots in raw cashew nuts was done via a Student's t test, of the average yields between the producers who adopt and those who do not adopt shows significant differences at the level of two good agricultural practices out of twelve, that is, thinning and pruning. The results in Table 5 show that there is a significant difference in average raw cashew nut yields between adopters and non-adopters of the good agricultural practices of thinning at the 5% threshold, pruning at the 10% threshold, and the combination of thinning and pruning at the 5% threshold. These three good practices have a positive impact on farm yields and will be used in our study to analyze the determinants of adoption and their impact on farm yield.

Table 6: Average yields according to application of good agricultural practice

Good agricultural practices	Non adopters		Adopters		t-test Diff.
	Number	Mean yield (kg/ha)	Number	Mean yield (kg/ha)	Mean yield (kg/ha)
Plot preparation	411	443.098	434	447.322	-4.224
Acquiring plant material when creating a new orchard	517	436.962	328	458.360	-21.398
Staking when creating a new orchard	559	444.760	286	446.261	-1.502
Digging and filling in when creating a new orchard	578	441.450	267	453.533	-12.084
Direct seeding when creating a new orchard	473	433.636	372	460.058	-26.422
Planting when creating a new orchard	567	437.696	278	460.710	-23.014
Fertilization during the planting stage	621	437.680	224	466.305	-28.625
Laying firebreaks around your orchard	398	438.401	447	451.382	-12.981
Replanting when creating a new orchard	532	439.705	313	454.722	-15.017
Shaping pruning	422	441.432	423	449.095	-7.663
Thinning	326	422.358	519	459.658	-37.300**
Pruning	325	426.497	520	457.000	-30.503*
Thinning& Pruning	342	424.128	503	459.641	-35.513**
GAP (12)	235	441.063	158	473.209	-32.146

*** p<0.01 ; ** p<0.05 ; * p<0.1

4.5. Determinants of the adoption of good agricultural practices (GAPs)

The results of the maximum likelihood probit estimation and marginal effects for the adoption of good production practices (thinning, pruning, and a combination of both) are presented in Table 6. The critical probabilities associated with the different likelihood ratio statistics were significant at the 1% level (p=0.000), indicating that the models were highly significant overall. This confirms that there are meaningful relationships between the explanatory and dependent variables representing the adoption of each good agricultural practice. Given the nature of probit models, the coefficients should not be interpreted directly, but their signs indicate whether they increase or decrease the probability of adoption.

The level of literacy is a key determinant of adoption, showing positive and significant relationships at the 1% threshold for thinning, pruning, and their combination. The marginal effects analysis suggests that an additional year of education increases the probability of adopting thinning, pruning by 7.2 %, and the combined practice by 8.3 %, 7.2 %, and 6.8%, respectively. This finding aligns with Kpadenou et al. (2020), who demonstrated that education positively influences the adoption of agroecological practices among vegetable farmers in the Niger Valley of Benin. Education likely enhances farmers' ability to understand and implement improved agricultural techniques, thereby fostering higher adoption rates.

Access to coaching services also plays a crucial role in adopting good agricultural practices. The results indicate a significant positive relationship at the 1% level between extension services and the adoption of thinning, pruning, and their combination. The marginal effects suggest that an increase in the level of extension support by one unit raises the probability of adoption by 15.6% for thinning and pruning and by 16.1% for pruning alone. These findings support those of Olayemi, Oko, and Oduntan (2020), who found that training on Good Agricultural Practices (GAP) and advisory visits by extension agents significantly influenced the adoption of GAP technologies among smallholder farmers in Nigeria. The presence of extension services facilitates knowledge transfer and encourages farmers to implement the best practices in cashew nut production.

Similarly, training in GAP has a strong positive and significant effect on the adoption of all three good agricultural practices at the 1% significance level. The analysis of the marginal effects indicates that an increase in training by one unit enhances the probability of adoption by approximately 23% for each practice. This result further confirms the importance of capacity-building initiatives for agricultural development. As farmers gain practical skills and knowledge through training programs, they become more confident in implementing the recommended techniques, leading to higher adoption rates.

Farmers' perceptions of the benefits of good agricultural practices significantly influence their adoption decisions. The study found that perceptions were positively and significantly associated with the adoption of thinning, pruning, and their combination at the 1% level. The marginal effects analysis shows that an improved perception of the benefits of thinning increases the likelihood of adoption by 30.4%, while improved perceptions of the combination of thinning and pruning raise adoption probabilities by 33%. These findings suggest that the more farmers recognize the positive impact of these practices on tree yield and nut quality, the more likely they are to adopt these practices. This result is consistent with that of Djaha et al. (2012), who noted that high plantation densities contribute to low yields in cashew nut production areas. They emphasized that thinning helps optimize tree spacing (100 trees per hectare), whereas pruning eliminates diseased, dead, or excessive branches, thereby enhancing productivity.

Moreover, the study's findings align with those of Adesina and Zinnah (1993), who demonstrated that Sierra Leonean farmers' adoption of improved rice varieties was strongly influenced by their perceptions of these new technologies. This highlights the crucial role of awareness and information dissemination in the adoption of technology. To promote the widespread use of good production practices, emphasis should be placed on demonstrating their benefits to producers. Practical demonstration sessions in farmers' school fields, comparing demonstration plots with farmers' traditional plots, can serve as effective tools for illustrating yield improvements and the quality of raw cashew nuts. By strengthening perception-based interventions, policymakers and extension agents can enhance adoption rates among farmers.

Table 7: Estimation of the probit regression model of the factors determining the adoption of good agricultural practices

Variables	Thinning		Pruning		Thinning & Pruning	
	Coef.	dy/dx	Coef.	dy/dx	Coef.	dy/dx
= 1 if male	0.470* (0.257)	0.088 (0.048)	0.407 (0.254)	0.076 (0.047)	0.538** (0.258)	0.106* (0.051)
Producer age	-0.001 (0.006)	-0.000 (0.001)	-0.000 (0.006)	-0.000 (0.001)	-0.005 (0.005)	-0.001 (0.001)
= 1 if Literate	0.439*** (0.130)	0.083** (0.024)	0.385*** (0.130)	0.072** (0.024)	0.344*** (0.126)	0.068** (0.025)
= 1 if native	0.254 (0.171)	0.048 (0.032)	-0.021 (0.175)	-0.004 (0.033)	0.106 (0.170)	0.021 (0.033)
Household size	-0.005 (0.012)	-0.001 (0.002)	-0.010 (0.012)	-0.002 (0.002)	-0.007 (0.011)	-0.001 (0.002)
= 1 if contact with extension agent	0.845*** (0.129)	0.159*** (0.023)	0.866*** (0.129)	0.161*** (0.023)	0.789*** (0.127)	0.156*** (0.024)
= 1 if GAP training	1.258*** (0.187)	0.237*** (0.033)	1.235*** (0.186)	0.230*** (0.033)	1.184*** (0.187)	0.234*** (0.035)
Number of plots	-0.244** (0.100)	-0.046* (0.019)	-0.209** (0.100)	-0.039* (0.018)	-0.246** (0.097)	-0.049* (0.019)
Plot distance	-0.008 (0.024)	-0.002 (0.004)	-0.028 (0.024)	-0.005 (0.004)	-0.030 (0.023)	-0.006 (0.005)
Total area	-0.070 (0.078)	-0.013 (0.015)	-0.068 (0.080)	-0.013 (0.015)	-0.039 (0.076)	-0.008 (0.015)
Production area	0.021 (0.086)	0.004 (0.016)	0.041 (0.088)	0.008 (0.016)	-0.003 (0.084)	-0.001 (0.017)

Plot age	0.014 (0.010)	0.003 (0.002)	0.022** (0.010)	0.004* (0.002)	0.020** (0.009)	0.004* (0.002)
Production	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
= 1 if Ownership mode	0.258* (0.153)	0.049 (0.029)	0.170 (0.153)	0.032 (0.029)	0.272* (0.150)	0.054 (0.029)
= 1 if Rental of plot	-0.948* (0.509)	-0.178 (0.095)	-1.013** (0.511)	-0.189* (0.095)	-0.794 (0.506)	-0.157 (0.100)
= 1 if Purchase mode	0.308 (0.298)	0.058 (0.056)	0.060 (0.298)	0.011 (0.056)	0.051 (0.289)	0.010 (0.057)
Thinning_Perception	1.616*** (0.132)	0.304*** (0.019)	NA	NA	NA	NA
Pruning_Perception	NA	NA	1.663*** (0.133)	0.310*** (0.018)	1.664*** (0.132)	0.329*** (0.019)
Constant	-2.745*** (0.455)	NA	-2.581*** (0.449)	NA	-2.517*** (0.443)	NA
N	845	845	845	845	845	845

Standard errors in parentheses
*** p<0.01 ; ** p<0.05 ; * p<0.1

4.5. Impact of the adoption of good agricultural practices on cashew farm productivity

Table 7 presents the results of the Marginal Treatment Effect Regression Model, estimating the determinants of performance under three different adoption scenarios: thinning, pruning, and a combination of thinning and pruning. The results indicate that access to extension services significantly affects performance. The base effects are negative and statistically significant for thinning (-75.247), pruning (-89.649), and their combination (-76.613), indicating that performance is lower without extension services. However, the marginal effects are positive and significant at the 5% or 1% level for all three practices, with values of 137.727, 166.861, and 152.300, respectively. This suggests that access to extension services significantly improves performance, consistent with findings from Olayemi, Oko, and Oduntan (2020), who reported that advisory services enhance the adoption of Good Agricultural Practices (GAP) among farmers.

GAP training also had a strong positive influence on performance. The base effects are negative and significant at the 5% level, indicating that farmers without GAP training perform worse (-77.614 for thinning, -76.301 for pruning, and -74.704 for the combination). However, the marginal effects were significantly positive (215.215, 248.742, and 262.857, respectively), showing that farmers who received GAP training experienced substantial performance improvements. These findings align with those of Kpadenou et al. (2020), who found that education and training are critical for adopting sustainable agricultural practices.

The total area variable exhibits a negative and significant impact on performance across all three practices, with values of -65.517, -67.618, and -66.462. However, the marginal effects were smaller in magnitude, with thinning (-13.203, $p < 0.1$) and thinning & pruning (-12.307, p < 0.1) remaining statistically significant. This suggests that larger landholdings are associated with lower performance, potentially due to challenges in effectively managing extensive cashew plantations. Conversely, production levels had a strong positive effect, with values of 0.178, 0.182, and 0.181, respectively, significant at the 1% level. This confirms that higher production volumes contribute positively to the performance.

Household size shows a mixed effect: while the base effect is positive and significant (5.221 to 5.593, $p < 0.05$), the marginal effect is negative and significant (-5.747 to -6.608, $p < 0.05$). This suggests that although larger households initially improve performance, increasing household size beyond a certain threshold reduces efficiency, possibly because of resource constraints. Similarly, marital status follows a similar trend, with significant negative marginal effects (-63.689 to -64.941, $p < 0.05$), implying that being married negatively impacts performance improvement, potentially due to competing family responsibilities.

Social status and sex did not show significant effects in most cases. Although sex has positive marginal effects (ranging from 69.418 to 106.779), these are not statistically significant. This contrasts with previous findings on adoption (Table 6), where male farmers were more likely to adopt good agricultural practices. Social status had no significant impact, suggesting that hierarchical position in the community does not strongly influence performance.

The results highlight the importance of extension services, GAP training, and farm size in determining the performance outcomes. The strong positive effects of extension services and GAP training suggest that policymakers should emphasize agricultural training programmes and farmer support services. Additionally, land management strategies should be optimized to prevent the inefficiencies associated with large-scale cashew farming. These findings reinforce the need for targeted interventions to improve agricultural performance through education, training, and advisory support.

Table 8: Determinants of performance: Marginal Treatment Effect Regression Model

Variable	Thinning		Pruning		Thinning & Pruning	
	beta0	beta1-beta0	beta0	beta1-beta0	beta0	beta1-beta0
= 1 if male	-12.880 (39.401)	69.418 (75.968)	-14.924 (39.285)	76.855 (76.236)	-26.792 (37.663)	106.779 (79.751)
= 1 if Literate	12.949 (24.233)	28.963 (33.916)	18.261 (23.761)	21.357 (32.885)	22.586 (23.113)	16.553 (32.951)
=1 if contact with extension agent	-75.247* (39.351)	137.727** (60.696)	-89.649** (39.644)	166.861*** (61.866)	-76.613** (36.883)	152.300** (59.327)
=1 if GAP training	-77.614** (34.951)	215.215** (104.650)	-76.301** (34.342)	248.742** (102.844)	-74.704** (32.617)	262.857** (103.871)
Total area	1.268 (1.728)	0.013 (2.386)	0.932 (1.730)	0.930 (2.419)	1.207 (1.682)	0.488 (2.412)
Surface_total	-65.517*** (4.725)	-13.203* (6.905)	-67.618*** (4.732)	-9.163 (6.776)	-66.462*** (4.644)	-12.307* (6.931)
Production	0.178***	0.010	0.182***	0.003	0.181***	0.007

	(0.010)	(0.014)	(0.010)	(0.014)	(0.010)	(0.014)
Household size	5.221**	-5.747**	5.593***	-6.608**	5.357***	-6.513**
	(2.067)	(2.895)	(2.046)	(2.878)	(2.007)	(2.904)
= 1 if married	30.318	-63.689**	27.901	-58.853*	30.708	-64.941**
	(21.741)	(31.367)	(21.471)	(31.219)	(21.152)	(31.332)
= 1 if native	-28.958	30.783	-13.926	4.725	-20.887	19.416
	(24.451)	(38.075)	(23.960)	(36.466)	(23.638)	(37.602)
Constante	336.325***	-174.456	335.575***	-227.150	343.580***	-274.325*
	(50.391)	(150.707)	(50.264)	(149.518)	(48.690)	(157.638)
N	845	845	845	845	845	845

Standard errors in parentheses
*** p<0.01 ; ** p<0.05 ; * p<0.1

The MTE curves are shown in Figure 3a, 3b, and 3c illustrate the relationship between the treatment effect of adopting good agricultural practices (thinning, pruning and their combination) and the unobserved resistance to treatment among the cashew farmers in the sample. The black solid line represents the estimated marginal treatment effect. The shaded region indicates a 95% confidence interval. The red dashed line represents the Average Treatment Effect (ATE), providing a benchmark for comparison.

The MTE curve for thinning exhibited a downward trend. indicating that farmers with lower resistance to adopting thinning practices tended to experience higher treatment effects on farm productivity. As the unobserved resistance to treatment increases, the marginal treatment effect declines and becomes negative at higher levels. This suggests that farmers who are more inclined to adopt thinning practices will benefit the most. In contrast, those who are reluctant to adopt experience lower or even negative impacts on productivity.

The MTE curve for pruning followed a pattern similar to that of thinning. Farmers with low resistance to adoption achieved significant productivity gains. This is shown by the higher treatment effects at lower levels of resistance. However, as the resistance increased. the effect diminishes. Eventually became negative. This trend suggests that pruning is most beneficial for farmers who are open to adopting new agricultural techniques. However, those resistant to adoption may struggle to implement the practice effectively.

The combined adoption of thinning and pruning exhibited the most pronounced downward trend among the three graphs. The initial treatment effect was high for farmers with minimal resistance. However, as the resistance increased, the effect declined sharp and became negative. This suggests that the simultaneous adoption of both practices yields the highest productivity gains for proactive farmers but may present challenges for those less inclined to adopt them. The sharper decline compared to that in Figures 3a and 3b indicates that adopting both practices together may require greater technical knowledge and management skills.

The declining trend across all three graphs highlights that the impact of adopting good agricultural practices varies significantly among farmers based on their willingness or ability to adopt. This is because farmers with lower resistance achieve higher benefits. Extension services should focus on educating and assisting reluctant adopters to improve adoption effectiveness in the future. The negative treatment effects at high resistance levels suggest that blanket adoption policies may not be equally effective for all farmers. Policymakers should design targeted interventions that consider the varying levels of adoption resistance among farmers.

These findings reinforce the importance of tailored agricultural extension programs and training initiatives to maximize the benefits of good agricultural practices across different farmer profiles in the study area.

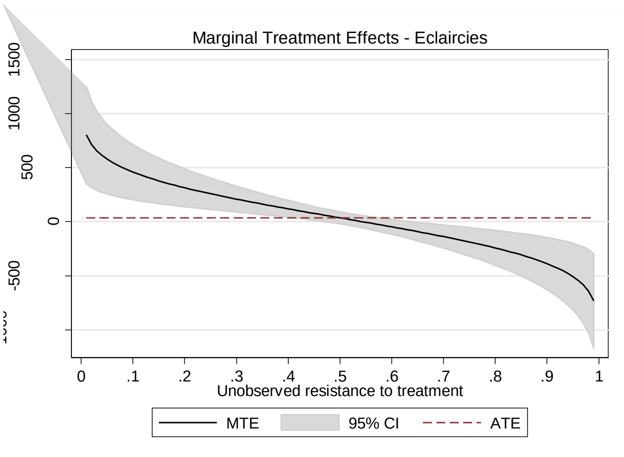

Fig 3 a : MTE curve for the adoption of thinning

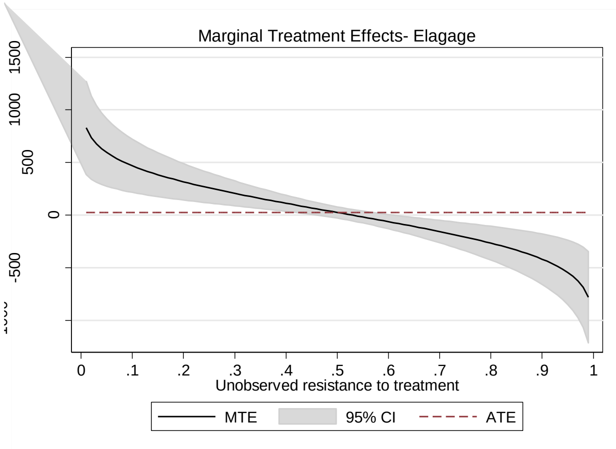

Fig 3 b : MTE curve for the adoption of pruning

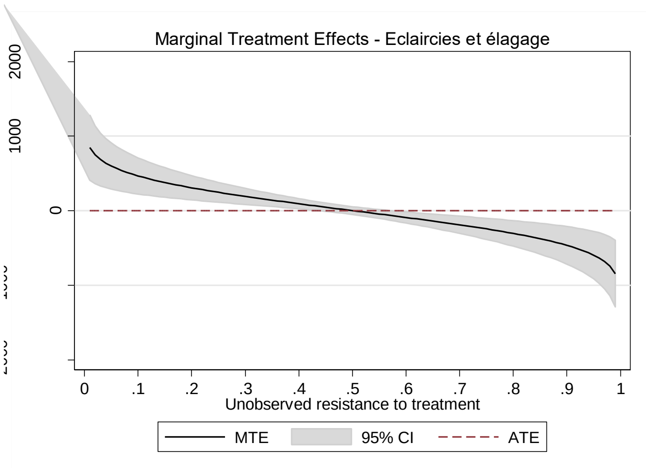

Fig3 c : MTE curve for the adoption of thinning and pruning

Figure 3: MTE curves for yield equations for adoption of different good agricultural practices

Table 9 presents the estimates of four key treatment effect parameters: the average treatment effect (ATE). the average treatment effect on the treated (ATET). the average treatment effect on the untreated (ATUT) and the local average treatment effect (LATE) for compliers. This study sheds light on the impact of adopting good agricultural practices on raw cashew nut yields. The results indicate that while the average treatment effect (ATE) of adopting thinning, pruning, or both practices is positive, none of these effects are statistically significant. This suggests that the entire sample was included. The adoption of good agricultural practices does not have a consistently measurable impact on yield when considering all farmers. regardless of whether they adopt these practices.

In contrast, the average treatment effect on the treated (ATET) is positive and highly significant at the 1% level for each of the three good agricultural practices. This finding is consistent with previous studies, such as the work by Alem. Eggert. and Ruhinduka (2015) in Tanzania, which showed similarly strong impacts for adopters of good agricultural practices. Specifically, the results show that, on average, a cashew farmer adopting thinning saw an increase of 194 kg/ha in raw cashew nut yield, while pruning led to a 195 kg/ha increase in the same. The combined adoption of both thinning and pruning resulted in a yield increase of 188 kg/ha. These significant positive effects for adopters underscore the effectiveness of these practices in improving productivity among those who choose to implement them in their operations.

Conversely, the average treatment effect on the untreated (ATUT) was negative and highly significant, with substantial yield reductions observed for non-adopters. Specifically, farmers who did not adopt thinning saw their yield decrease by 218 kg/ha, those who did not adopt pruning experienced a nearly 250 kg/ha reduction, and non-adopters of both thinning and pruning faced a yield drop of 275 kg/ha. This suggests that failing to adopt good agricultural practices result in substantial yield losses, emphasizing the importance of these practices in maintaining or improving productivity.

The local average treatment effect (LATE). which reflects the impact on compliers (those who would adopt a practice if encouraged), is positive for each of the three good agricultural practices but only statistically significant for thinning adoption. For this group. adopting thinning resulted in an average yield increase of nearly 47 kg/ha. This result aligns with the findings of Basse, Mbaye, and Diop (2022), who also observed positive impacts of good cashew nut agricultural practices on yield, with increases of 528.84 kg/ha in a model without interaction and 609.87 kg/ha in a model with interaction.

Taken together these results suggest that adopting good agricultural practices leads to higher yields for those who adopt them, whereas non-adopters experience significant yield losses. The ordering of the treatment effect parameters ATET > ATE > ATUT indicates positive selection of the gains from adopting good agricultural practices, implying that the impact of these practices is more pronounced among those who adopt them. This reinforces the idea that those who invest in adopting these practices experience significant benefits, while those who do not adopt these practices are left at a disadvantage.

Table 9: Estimation results for the model of the impact of adopting good agricultural practices on plot productivity (MTE)

Parameters	Thinning	Pruning	Thinning & Pruning
ATE	35.548 (28.335)	24.751 (27.503)	1.113 (26.808)
ATET	194.249*** (60.021)	195.499*** (58.877)	188.141*** (55.407)
ATUT	-218.117*** (82.661)	-249.649*** (82.125)	-274.833*** (84.634)
LATE	46.606* (26.686)	39.544 (26.019)	38.416 (25.274)
Test of observable heterogeneity. p-value	0.0090***	0.0031**	0.0020**
Test of essential heterogeneity. p-value	0.0006***	0.0003***	0.0002***
N	845	845	845

Standard errors in parentheses; *** p<0.01 ; ** p<0.05 ; * p<0.1

This study makes several significant contributions to the literature on agricultural productivity and the adoption of good agricultural practices (GAPs) in cashew nut farming. First, it highlights the critical role of producers' perceptions in the adoption of GAPs, specifically thinning, Pruning, and the combination of both, which are identified as the most important practices for improving the yield and quality. Second, it provides empirical evidence that the adoption of these practices has a significant and positive impact on productivity, with yield increases of 194 kg/ha for thinning, 195 kg/ha for pruning, and 188 kg/ha for the combination of both. This aligns with the growing body of literature emphasizing the importance of capacity building and training in enhancing agricultural productivity. Additionally, the study's use of the Marginal Treatment Effect (MTE) approach to assess the heterogeneous impacts of GAPs adoption offers valuable insights into the variation in treatment effects based on factors such as coaching and training, further enriching the understanding of how these practices impact productivity across different producer groups. Finally, the findings underscore the importance of fostering positive perceptions and providing incentives for the adoption of GAPs, contributing to the broader discourse on sustainable agricultural development.

Although this study offers valuable insights, it has some limitations that should be considered. First, the study focuses primarily on cashew nut farming; therefore, the findings may not be directly generalizable to other crops or agricultural sectors, limiting the broader applicability of the results. Second, the analysis is based on cross-sectional data, which limits the ability to draw causal inferences regarding the relationship between GAP adoption and productivity in the long run. Longitudinal studies would be useful for establishing the long-term effects of GAPs on farm productivity. Additionally, the study primarily examined the perceptions of producers and their adoption behaviors without delving into the specific mechanisms through which these practices impact productivity. Future research should explore the underlying processes contributing to the observed increase in yield. Finally, while this study highlights key determinants of GAPs adoption, such as education level and access to coaching, it does not account for other potential factors, such as farm size, access to markets, and climatic conditions, which could also influence adoption decisions and productivity outcomes.

5. CONCLUSION AND POLICY IMPLICATIONS

This study aimed to examine the relationship between producers' perceptions and the productivity of cashew nut farms and to assess the impact of adopting good agricultural practices (GAP) on productivity. The results indicate that among the various GAPs disseminated for cashew nut farm management, thinning, pruning, and a combination of both practices are perceived as the most important for improving cashew nut yield and quality. These practices were the most widely adopted by the producers. Furthermore, a comparison of the average yields between producers who adopted these practices and those who did not revealed a clear positive impact on farm productivity. Specifically, Thinning, Pruning, and their combination led to increased cashew nut yields. The probit model results identified several key factors influencing the adoption of GAPs. including producers' perceptions of relative advantage, education level. and access to coaching services and training in GAPs. These factors significantly drive the decision to adopt thinning, pruning, or their combination. highlighting the importance of providing producers with the knowledge and resources to implement these practices. The Marginal Treatment Effect (MTE) approach was employed to assess the heterogeneous impacts of adopting thinning, pruning, and both practices on cashew nut productivity. The results revealed that the treatment effect was positive and statistically significant for producers who received coaching and training in GAPs. Specifically, the average treatment effect on the treated (ATET) showed significant yield increases for adopters: 194

kg/ha for thinning, 195 kg/ha for pruning. and 188 kg/ha for the combination of both. These findings suggest that capacity-building programs and incentives for adopting thinning, pruning. and their combination are crucial for improving the productivity of cashew nut farms, especially in orchards at more advanced ages.

In addition to these practical measures; this study emphasizes the importance of fostering positive perceptions of GAPs among farmers. Awareness campaigns highlighting the economic and environmental benefits of these practices could further encourage their adoption. Moreover, the study's results highlight the need for policymakers to integrate GAPs into broader agricultural development strategies. This would ensure that the adoption of these practices aligns with regional and national objectives for sustainable farming, ultimately contributing to increased productivity and environmental sustainability in the cashew sector.

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