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FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

Towards environmental sustainability: The role of certification in the adoption of climate-smart agricultural practices among Ghanaian mango farmers

Rexford Akrong[1]*, Angela Dziedzom Akorsu[1], Praveen Jha[2] and Joseph Boateng Agyenim[1]

Abstract: The role of market interventions like certification in promoting climate action has received little attention in policy and academic circles. This study used a multivariate probit model (MVP) to analyze the factors that influence farmers' adoption of multiple climate-smart agriculture (CSA) practices. An endogenous treatment effects (eteffects) regression was used to estimate the impact of certification on the adoption of different CSA practices. The study found that age, education, farm size, access to extension services and storage facilities influenced the adoption of different CSA practices. After accounting for endogeneity, we found that the adoption of certification reduces the likelihood that farmers will use inorganic fertilizers, herbicides and pesticides by about 50, 38 and 23 percentage points, respectively. We conclude that certification has the potential to reduce the adoption of agronomic practices that contribute to climate change. Our findings suggest that government, policymakers, the private sector and development partners should make efforts to enhance the adoption of certification. This can be done by enhancing access to credit facilities, extension services and high-value markets.

Subjects: Development Studies; Sustainable Development; Development Policy; Rural Development; Economics and Development; Environmental Economics

Keywords: Climate-smart agriculture; Ghana; mango farmers; policy; sustainability

1. Introduction

The agricultural sector is critical to economic growth and development. In developing countries, this sector contributes significantly to the achievement of desirable sustainable development goals (SDGs) including 1 (no poverty), 2 (zero hunger), and 8 (decent work and economic growth; Acheampong et al., 2022; Fahad et al., 2022; Pawlak and Kolodziejczak, 2020). The importance of agriculture as an engine of economic growth may be rivaled only by its importance to contribute to climate change and climate change mitigation. Agriculture contributes about 30% to total greenhouse gas (GHG) emissions. The total mitigation potential from this sector is estimated at 12 gigatonnes, with 75% of this potential located in the developing world (Potts, 2012). Attempts to feed the exponentially growing population of Africa, which is currently estimated at 1.17 billion (World Bank, 2022) have intensified agricultural transformation. This transformation has led to unsustainable agricultural expansion through rapid desertification and the use of agrochemicals (Asiedu-Ayeh et al., 2022; Musafiri et al., 2022). These practices increase anthropogenic greenhouse gas emissions and consequently aggravate climate change. Given that agriculture is the mainstay of SSA countries, the persistence of climate change threatens the livelihoods of tens of millions of people and leaves about 220 million people undernourished (African Development Bank (AfDB), 2022; Fahad et al., 2022).

In recent years, governments and development partners have made considerable efforts to promote the adoption of adaptation and mitigation measures that can improve food security and incomes among agricultural households in SSA (Kimaru-Muchai et al., 2020; Musafiri et al., 2022). These measures include soil and water conservation strategies (Martey & Kuwornu, 2021), a move from conventional to organic agricultural production (Kleemann et al., 2014), agricultural diversification relative to environmental and economic risks, and agroforestry (Yufang et al., 2019). Although these measures enhance farmers' adaptive capacities under climate change (Smit & Skinner, 2002), and promote agrobiodiversity and the sustenance of vital functions, structures, and processes in agro-ecosystems (Mijatović et al., 2013), the role of market innovations and interventions such as voluntary sustainability standards (VSS) or certification in advancing positive environmental outcomes has received little attention around policy and academic circles.

The ascendency of the neoliberal theory has given rise to production and trade standards such as the VSS which claim to certify the social and environmental sustainability of production conditions to verify compliance in global value chains (Jha & Yeros, 2019). Despite this claim, the rise of these standards is driven by economic gains. Meanwhile, following the theory of strong sustainability, sustainability is weak if it does not account for the environment (De Oliveira Neto et al., 2018). Several studies have attempted to measure the economic viability of these standards (Annor, 2018; Kleemann et al., 2014; Oya et al., 2017). However, the environmental aspect of VSS represents a relatively minor and unmeasured component of these standards. The underlying argument is that large scale compliance with VSS by farmers can contribute to the reduction of undesirable environmental outcomes. According to Smith et al. (2019), VSS can reduce GHG emissions from cultivation by 51% when farmers in developing countries comply with these standards. According to the theory of change of certification schemes, adopting certification or complying with VSS can hasten farmers' access to profitable markets (Ngenoh et al., 2019) as well as lead to positive environmental outcomes. Accordingly, certification can significantly increase farmers' income and promote environmental sustainability.

In SSA countries such as Ghana, sustainability standards have targeted non-food commercial crops like mango, pineapple, sugarcane, cocoa, coffee, and oil palm (Brako et al., 2021). Whereas most of these crops under various certification programmes have been in the cash crop industry of Ghana for several decades, mango is an emerging crop that has the potential of becoming the country's key export crop considering its growing local and global demand which is estimated to be US$20 billion in the year 2029 (Torgbor et al., 2021). Conventionally, the production of mango, a tree crop, presents an opportunity for farmers in Ghana to contribute to the mitigation of climate change, whiles maximizing gains from mango marketing. This is because whiles farmers could generate income from mango sales, mango trees absorb and sink the carbon that would otherwise contribute to climate change.

Development programs aimed at increasing mango farmers' productivity and income have focused on capacity development and the frequent provision of extension services in mango-producing areas including Yilo Krobo, Manya Krobo, and Shai Osudoku districts. These districts account for about 50% of the total mangoes exported, and host strong mango producers' associations and key mango processors (West Africa Competitiveness Programme (WACOMP), 2020). The interventions have contributed to improved farm productivity, mango quality, and certification among mango producers in the region. Yet, the adoption of certification by Ghanaian mango farmers remains low (50%; West Africa Competitiveness Programme (WACOMP), 2020) whereas the role of these interventions in climate change adaptation behavior of mango farmers in Ghana remain undocumented. Prior research has concentrated on how certification affects socioeconomic outcomes like return on investments (Kleemann et al., 2014); wage employment (Colen et al., 2012; Cramer et al., 2017); and food security and living standards

(Brako et al., 2021; Knößlsdorfer et al., 2021). Yet compliance with VSS can stimulate farmers to adopt sustainable agronomic practices which encompass the use of environmentally-friendly farming practices that can mitigate climate change (Makita, 2016; Smith et al., 2019), which needs to be accounted for in impact studies. Moreover, the landscape of sustainability certification throws up significant heterogeneity. Against this backdrop, the paper aims to: (a) assess the determinants of adoption of CSA practices by mango farmers in Ghana and (b) analyze the impact of certification on the adoption of adaptation and mitigation measures against climate change with a focus on Ghana and particularly on mango farmers.

The contribution of this paper to empirical literature and policy is two folds. First, we analyze the effects of certification on mango farmers' adoption of multiple climate change adaptation strategies. To the best of our knowledge, this has not been done in Ghana or elsewhere. Secondly, examining the effects of certification on farmers' adoption of adaptation measures is of great significance to policymakers in West Africa and SSA where climate change continues to threaten agricultural productivity which consequently decreases the ability of smallholder farmers to compete in remunerative markets including export markets.

The rest of the paper is organized as follows. Section 2 presents a review of literature on adoption of CSA practices by farmers. Section 3 presents the study area and the theoretical and empirical strategies employed in the study. Section 4 presents the results. Section 5 presents the discussion and Section 6 concludes the paper.

2. Literature review

Theoretically, interventions that seek to ensure the adoption of practices that promote environmental health are in line with the theory of strong sustainability (Muraca & Döring, 2017). In agriculture, sustainability has been the bedrock of the climate change discourse. Thus, to measure farmers' attitudes towards sustainable agriculture, researchers have mainly focused on farmers' willingness to adopt practices that constitute mitigation of and adaptation to climate change (Fahad et al., 2023; Hossain et al., 2022; Martey et al., 2022; Martey & Kuwornu, 2021). Overall, the literature show that CSA practices adopted by farmers include integrated soil fertility management practices, the use of pesticides, growing of cover crops, crop diversification, integrated agriculture, use of organic fertilizer and the adoption of crop insurance (Fahad et al., 2023; Kassa & Abdi, 2022; Kifle et al., 2022; Martey et al., 2022; Martey & Kuwornu, 2021; Thompson et al., 2022). Martey and Kuwornu (2021) assessed farmers' perceptions of climate variability and soil fertility management choices among farmers in Northern Ghana. The authors found that previous experience of climate variability and shocks as well as factors including demographic, farm-related variables, land quality and institutional factors influence farmers' adoption of CSA practices. In a similar study, Kifle et al. (2022) used the binary logit model to estimate factors influencing farmers adoption of CSA to respond to climate variability. The study found that factors including farming system, farm size, access to irrigated farm, access to extension service, distance to market and access to weather information influenced farmers adoption of CSA practices. A study by Kassa and Abdi (2022), found that the adoption of CSA practices by Ethiopian farmers is influenced by similar factors. Categorically, the authors reveal that education, household size, income, farm size, and climate change perception influenced the adoption of CSA practices.

As an attempt to analyze farmers' climate change adaption behavior, Hossain et al. (2022) used a binary probit model to estimate farmers' willingness to pay for flood insurance in Bangladesh. The authors highlight that farmers' willingness to pay for flood insurance is influenced by land ownership status, off-farm income, existing experience with flood, group membership, access to information, access to extension services and the subjective risk perceptions of farmers. On the impact of perceptions of risks and shocks, Martey et al. (2022) used a multivariate probit model to analyze perception of COVID-19 shocks and adoption of sustainable agricultural practices in Ghana. According to the study, farmers who perceived price hikes as a result of COVID-19 were more likely to adopt both pesticides and zero-tillage as CSA practices. On the other hand, farmers who perceived limited access to output markets practiced crop diversification (mixed-cropping) and mulching. Those who perceived a fall in output prices complemented pesticides with mixed cropping.

On the effect of certification of climate change adaption decisions of farmers, Thompson et al. (2022) used Coarsened Exact Matching to estimate the role of sustainability certification in the climate resilience of smallholder cocoa farmers in Ghana. The study found that certification influenced farmers use of inorganic fertilizer and participation in groups. The authors found that certification has no impact on crop diversification and yield. However, certification has a role in farmers' decision to diversify their income as regards sale of livestock as a resilience strategy.

The literature review reveals that climate risk perceptions, shocks, demographic, farm, and institutional factors influence farmers adoption of CSA practices. However, evidence of the impact of certification on the adoption of CSA practices remain scanty. The review also shows that the models used by previous studies to estimate factors that influence adoption of CSA practices include binary probit/logit models and the multivariate probit models. Also, although Thompson et al. (2022) attempted to use a more rigorous and robust model to analyse the impacts of certification, their model does not account for endogeneity. Meanwhile, certification is an endogenous variable that is influenced by several factors. To that end, their findings have some limitations. Our study extends the literature by using an endogenous treatment effects model to estimate the effects of certification on the adoption of CSA practices by mango farmers. Our econometric model differs from the ones used in the certification and climate change literature since our model corrects endogeneity and presents more robust results.

3. Methods

3.1. Study area

The study was carried out in Ghana's Southern Belt of mango production. This region covers the Greater Accra and Eastern Regions. The primary mango-producing districts in the Eastern Region are Yilo Krobo and Manya Krobo, whereas the Greater Accra Region's main mango-producing district is Shai-Osudoku. Of note is that although these districts are in different regions, they all lie along the foothills of the Akuapem-Togo Range. The research area's temperature is between 24.9°C, which is the lowest, and 30°C, which is the highest. The area experiences between 750 mm and 1600 mm of yearly rainfall because it is situated in the arid equatorial climate zone. The relatively warm temperature makes the area tropical and conducive for mango production. The region experiences a bi-modal rainfall season, with the heaviest rainfall occurring in May/June and the heaviest precipitation occurring in September/October. This rainfall pattern puts the region on a competitive edge over neighboring countries and regions. Mango farming is the main economic activity in the study area and remains gendered. The area hosts three strong mango producer associations and government agricultural offices, an indication of access to institutional support services such as capacity development and extension services. This area was chosen because of its high contribution to mango production in Ghana and its climatic conditions which make farmers susceptible to the impacts of climate change. Figure 1 presents a map of the study area.

3.2. Data collection

The study relied on primary data to analyze the impact of certification on the choice of CSA practices by mango farmers in Ghana. The study used a three-stage sampling procedure to select mango-producing households in three districts in the Southern Belt of mango production. The first stage involved the purposive selection of the Shai-Osudoku, Yilo Krobo, and Lower Manya Krobo districts considering the intensity of mango production in these districts. In the second stage, agriculture extension officers who were employed as field officers assisted with the identification of communities where mango production is the major economic activity. From these communities, mango-producing households were identified and the farm owners were randomly selected. This stage constitutes the final stage of the sampling procedure. The exercise resulted in 224 mango farmers who were willing to participate in the survey.

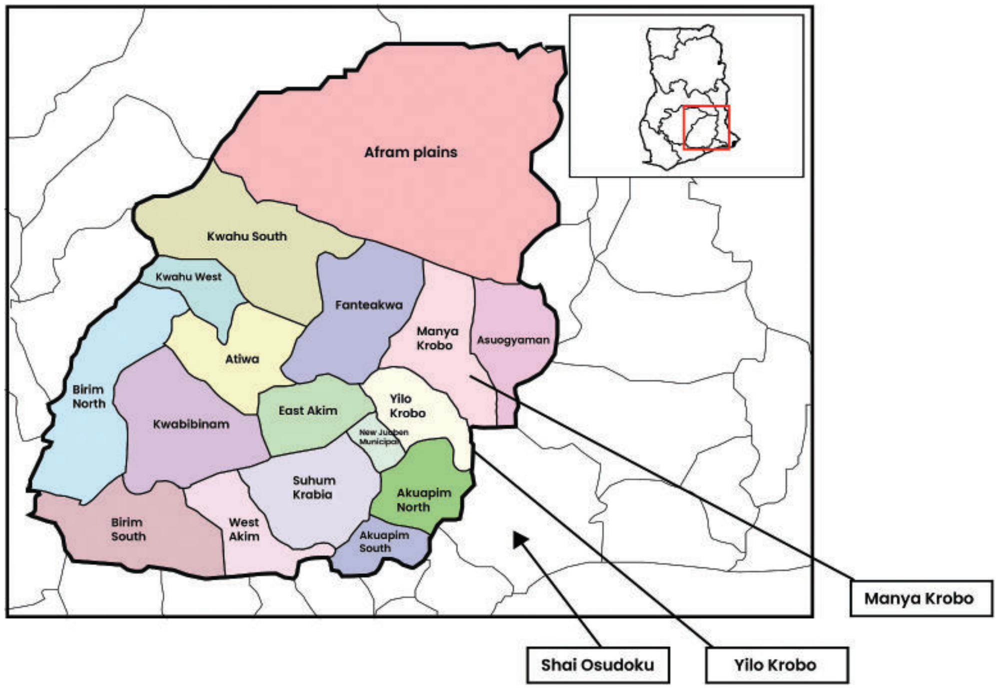

Figure 1. Map of study area.

Source: Anderson (2015)

A quantitative interview schedule served as the survey's data collection tool. It included modules on the demographics of the household, the methods used for mango production and marketing, certification, social capital, extension, credit, assets, access to institutional services, and the application of climate change adaptation measures. Three survey teams, each led by a district extension officer, each with four enumerators and one supervisor, were used to carry out the survey.

To improve the quality of data collection, the farmers were given the interview schedule utilizing a computer-assisted personal interview (CAPI) using Open Data Kit (ODK) software.

3.3. Theoretical framework

We analyze farmers' adoption of environmentally-friendly agronomic practices including weeding and slashing as opposed to the use of herbicides and the use of organic fertilizer such as manure as opposed to the use of inorganic or mineral fertilizer, and the use of indigenous technology such as ash to control pest rather than pesticides. According to Niggli et al. (2008), these practices remain important ways of adapting to climate change. Following Kitamura et al. (2021), we argue that the adoption of practices that are alternatives to the use of inorganic fertilizers, pesticides, and herbicides constitutes the adoption of CSA practices which consequently contribute significantly to the mitigation of climate change. We further argue that certification can contribute to a sustainable environment. Accordingly, farmers who adopt certification collectively contribute to the mitigation of climate change through the adoption of practices that do not harm the environment (Smith et al., 2019). Thus, following the random utility theory, a rational mango farmer *i* would adopt certification in order to maximize his/her utility. This utility can derive from the ability to adopt a CSA practice. The utility U that the *ith* mango farmer can derive from adopting certification can be expressed as a linear sum of a deterministic component Vi which represents the observable components of the utility and a random error term ε_i which represents the unobservable components of the utility. The utility is given by equation (1):

$$U_i = V_i + \varepsilon_i \tag{1}$$

3.4. Analytical framework

3.4.1. The multivariate probit model: Determinants of adoption of climate-smart agricultural practices

The choice of different CSA practices is not mutually exclusive. Thus, we used the multivariate probit (MVP) model to estimate the factors that influence the choice of different CSA practices by farmers in Ghana with special emphasis on certification. The model allows for the potential correlations between the error terms and the relationship between the adoption of different CSA practices. Complementarity and substitute associations between CSA practices are one of the main sources of correlations (Belderbos et al., 2004).

Let CSA practices be defined as *(j = F, P, H, C, W)* where *F* is inorganic fertilizer use, *P* is pesticide use, *H* is herbicide use, *C* is crop diversification and *W* is the decision to use indigenous tools for weeding. A mango-producing household *i* is faced with the decision to adopt from the set (*j*). Following the utility theory, adoption is realized when the net benefit is greater than zero, $T_{ij}* = E[U(\pi_A)] > E[U(\pi_N)]$. The net benefit T_{ij}* which a farmer derives from the adoption of *jth* CSA practice is a latent variable that is determined by certification, household and farm characteristics, and institutional characteristics (X_i), and the error term (μ_i). This is given by:

$$T^*_{ij} = X^{\prime}_i\delta_j + \mu_i(j = F, P, H, C, W) \quad (2)$$

The unobserved preferences in Equation (2) translate into the observed binary outcome equation for each choice based on the indicator function as follows:

$$T_{ij} = \begin{cases} 1 \ if \ T^*_j > 0 \\ 0 \ otherwise \end{cases} \quad (3)$$

In the MVP model where farmers can adopt several CSA practices, the error terms follow a multivariate normal distribution (MVN) with zero conditional mean, and variance normalized to unity (for identification of the parameters), where (μ_F, μ_P, μ_H, μ_C, μ_W) → $MVN(0, \Omega)$ and the symmetric covariance matrix Ω (nxn correlation matrix). The unobserved correlation between the stochastic components of the various SAPs is represented by the non-zero off-diagonal elements in the covariance matrix. This correlation coefficient defines the links between CSA practices that are complementary (positive correlation) and substituting (negative correlation).

2.4.2 The endogenous treatment effects model: Impact of certification on the choice of different CSA practices

Although we used the MVP model to estimate the effect of certification on the choice of different CSA practices, we suspect a possible endogeneity in the relationship between certification and the adoption of CSA practices. To address this issue, we use the endogenous treatment effects (eteffects) model to estimate the link between certification and adoption of CSA practices by mango farmers in Ghana. Our choice of this model is because of its ability to address the potential endogeneity that exists in the relationship between certification and adoption of climate change mitigation strategies. Endogeneity can result from bi-causality or the removal of some elements of transaction costs on certification, according to Awaworyi Churchill et al. (2020). We believe that endogeneity in this study is primarily the result of bi-causality, notwithstanding the possibility that the omitted variable problem exists in our situation. On one arm, people certify because they meet all requirements including the adoption of environmentally-friendly practices. On the other hand, people adopt environmentally-friendly practices because of their desire to certify. Several sanitary and phytosanitary measures have been stipulated in certification schemes to smoothen the adoption of environmentally-friendly practices by farmers. We resolve the endogeneity problem using membership in farmer groups as an instrument. To account for endogeneity, we have to account for factors that affect certification but do not affect a farmer's decision to adopt environmentally-friendly practices. In Ghana and other SSA countries, smallholder farmers certify through farmer groups- what is popularly known as group certification (West Africa Competitiveness Programme (WACOMP), 2020). Accordingly, being a member of a farmer group increases a farmer's propensity of being certified. On the other hand, membership in farmer groups does not have a direct influence on the adoption of environmentally-friendly practices, but only through certification.

Therefore, we specify the endogenous treatment-effects model as:

$$y_{i0} = E(y_{i0}|X_i) + e_{i0} \tag{4}$$

$$y_{i1} = E(y_{i1}|X_i) + e_{i1} \tag{5}$$

$$t_i = E(t_i|X_i) + v_i \tag{6}$$

$$y_i = t_i y_{i1} + (1 - t_i) y_{i0} \tag{7}$$

$$E(e_{ij}|X_i, Z_i) = E(e_{ij}|Z_i) = E(e_{ij}|X_i) = 0\, for\, j \in \{0, 1\} \tag{8}$$

$$E(e_{ij}|t) \neq 0\, for\, j \in \{0, 1\} \tag{9}$$

Where i represents individual-level characteristics, y_{i1} represents the potential outcome of being certified, y_{i0} is the potential outcome of not being certified, t_i is the observed binary treatment (certification), and y_i is the observed outcome (i.e., decision to adopt a climate-smart practice). X_i is a set of regressors from the potential outcome and e_i represents the random error term. Similarly, the treatment is given by its expectation, conditional on a set of regressors Z_i, which do not have to differ from X_i, and an unobserved component V_i.

Equations (4)—(8) represent the parametric treatment-effects models and equation (9) adds endogeneity to the framework. Equation (9) shows that unobservable in the potential outcome equations are correlated to the treatment status. This would happen if uncertified farmers are more conscious about the environment than certified farmers and if this consciousness or awareness is not observed in the data. If this awareness is not observed, the decision to certify or not to certify is not independent of the decision to adopt strategies that promote environmental awareness. The results of the test of endogeneity are presented in Appendix A.

From equation (8), the unobserved components in the potential outcome are independent of Z. Thus, the correlation between t_i and the unobserved components must be equivalent to the correlation between e_{ij} and v_i. From equations (6) and (8), this condition becomes:

From (6) $E(e_{ij}|t_i) = E(e_{ij}|E(t|Z_i)) + v_i$

From (8) = $E(e_{ij}|v_i)$

$$= v_i \beta_{2j} \tag{10}$$

The treatment equation is fitted using a probit model. For a binary outcome, we have

$$E(y_{ij}|x_i, v_i, t_i = j) = \phi\left(x_i' \beta_{ij} + v_i \beta_{2j}\right) \tag{11}$$

Where ϕ represents the cumulative density function.

The parameters of (6) and (10) and the average treatment on the treated (ATET) and the potential mean outcomes (POMs) are estimated using the generalized methods of moments (GMM). The moment equations used in the GMM are the sample analogs of $E\{w_i' e_i(\theta)\} = 0$, where

w_i represents the instrument (group membership in this case), $e_i(\theta)$ are residuals and θ are parameters of the model. The moment conditions in the GMM estimation for the probit model are given by:

$$\frac{1}{n}\sum_{i=1}^{n}\left\{\phi\left(x_i'\widehat{\beta_{ij}}+\widehat{v_i}\widehat{\beta_{2j}}\right)\frac{n}{n_t}-POM_0\widehat{\frac{n}{n_t}}-\widehat{ATET}\right\}=0 \tag{12}$$

$$\frac{1}{n}\sum_{i=1}^{n}\left\{\phi\left(x_i'\widehat{\beta_{ij}}+\widehat{v_i}\widehat{\beta_{2j}}\right)-\widehat{POM_1}\right\}=0 \tag{13}$$

Where $\widehat{ATET}$ and $\widehat{POM_1}$ are the parameters of the model, and n_t represents the number of treated units.

4. Results

4.1. Descriptive statistics

Table 1 presents the adoption rates of different CSA practices by mango farmers in Ghana. The results show that only 12% of certified mango farmers used inorganic fertilizer whereas 64% of the uncertified farmers used inorganic fertilizer. This difference is statistically significant at 1%. The results also show that 32% of the certified farmers used herbicides whereas 53% of the uncertified farmers used herbicides. Compared with certified farmers (31%), more of the uncertified farmers (43%) practiced crop diversification.

Table 2 presents the household, farm, and institutional characteristics of mango-producing households by the adoption of certification. The choice of the explanatory variables was motivated by studies on the determinants of certification (Annor, 2018; Kleemann et al., 2014; Quartey et al., 2021) and studies on determinants of farmers' choice of different CSA practices and sustainable agricultural practices (Daadi & Latacz-Lohmann, 2021; Martey et al., 2022; Martey & Kuwornu, 2021; Mkonda, 2022; Setsoafia et al., 2022). In terms of statistical significance, certified mango farmers had a higher farm income than uncertified mango farmers. More of the certified farmers kept records of farm activities, participated in high-value markets such as the export markets and industrial processors that offer relatively higher prices, and had access to storage facilities. More of the certified farmers accessed credit, used their mobile phones to access mango production and marketing information and were members of farmer-based organizations. Regarding infrastructural development, more of the uncertified farmers were farther from tarmacked roads but from their perceptions, the nearest roads to their farms were in good condition.

4.2. Determinants of adoption of climate-smart agricultural practices

The study considered five agricultural practices in the mango sector which can contribute to climate change. Mango farmers rely on inorganic fertilizer to improve farm productivity, yet this input can be detrimental to the environment. Also, farmers can choose to use indigenous methods

Table 1. Adoption rates of CSA practices by certification

CSA Practice	Certified (%) n = 111	Uncertified (%) n = 113	Chi-value
Inorganic Fertilizer (1 = yes)	12%	64%	64.3***
Herbicide (1 = yes)	32%	53%	9.76***
Weeding (1 = yes)	54%	44%	2.15
Pesticides (1 = yes)	72%	80%	1.76
Crop diversification (1 = yes)	31%	43%	3.89**

Notes: ** and *** represent statistical significance at 5% and 1% respectively.

Table 2. Description and measurement of variables used in the econometric models

Variable	Certified	Uncertified	
Continuous Variables	**(Mean)**	**(Mean)**	**Mean Difference**
Age (years)	48.43 (1.13)	46.79(1.23)	−1.64(1.68)
Years of schooling (years)	9.31(0.44)	8.36(0.47)	−0.94(0.65)
Household Size (individuals)	4.82(0.19)	5.57(0.22)	−0.75 (0.29)***
Farming experience (years)	9.32(0.44)	9.12(0.46)	0.20(0.64)
Farm income (Ghanaian Cedis)	11,672.97(834.11)	6040.09(671.51)	5632.88(1068.86)***
Mango land size (acres)	5.30(0.43)	4.71(0.50)	−0.59(0.66)
Distance to a tarmacked road (kilometers)	7.79(0.79)	11.73(1.20)	−3.93 (1.44)***
Categorical Variables	**Percentages (%)**	**Percentages (%)**	**Chi-value**
Record keeping (1 = yes)	90%	70%)	14.20***
High-value markets (1 = yes)	86%	24%	85.92***
Access to storage (1 = yes)	45%	9%	37.41***
Access to extension (1 = yes)	27%	25%	0.15
Access to production and marketing information (1 = yes)	38%	44%	0.95
Cellphone usage (1 = yes)	80%	50%	23.0***
Ownership of radio (1 = yes)	84%	88%	1.04
Access to credit (1 = yes)	60%	12%	58.21***
Perceived road condition (1 = good)	30%	57%	16.51***
Group membership (1 = yes)	83%	9%	123.74***

Note: *** represents statistical significance at 1% level. USD 1 = 8 Ghanaian Cedis at the time of the study. Mean difference was tested using t-test. Chi-square test was used to test for significant differences for categorical variables.

or chemicalized herbicides to control weeds. During outbreaks of pests, mango farmers can choose to use pesticides such as composite insecticides to control pests. Whiles weeding promotes environmental quality, the use of herbicides and pesticides threatens environmental quality. In some cases, although many mango farmers engage in monocropping, they can choose to practice crop diversification as a CSA practice. Table 3 presents the results of farmers' decision to choose a combination of the different CSA practices. The use of inorganic fertilizer was positively correlated with the use of pesticides. This implies that farmers who use pesticides are more likely to use inorganic fertilizers. A positive correlation was realized between the use of herbicides and pesticides. This indicates that farmers who use pesticides are more likely to use herbicides. The results show that farmers who use of indigenous methods to control weeds are less likely to use inorganic fertilizer. As expected, the use of indigenous methods to control weeds and the use of pesticides are substitutes. This shows that farmers who use pesticides are less likely to use indigenous methods to weed their farms. These correlations generally imply that farmers who adopt CSA practices do not adopt practices that threaten environmental sustainability.

Table 3. Correlation matrix derived from MVP

CSA practices	Pesticide use	Herbicide use	Crop diversification	Weeding
Fertilizer use	0.650(0.119)***	0.089(0.138)	0.079 (0.141)	−0.327(0.125)***
Pesticide use		0.261(0.131)**	−0.140(0.155)	0.062(0.133)
Herbicide use			−0.232(0.155)	−0.441(0.110)***
Crop diversification				−.027(0.142)

Notes: Positive correlations represent complementary associations whiles negative correlations represent substitutes. ** and *** represent statistical significance at 5% and 1% respectively.

Table 4 presents the results of the multivariate probit model estimates of the determinants of adoption of CSA practices among mango farmers in Ghana, with an emphasis on certification. The Likelihood Ratio test based on the Wald Chi-square value of 182 ($p < 0.01$), Akaike information criterion, and the Bayesian information criterion of 978.4367 and 1250.777, respectively measure the goodness of fit of the model. Indeed, the multivariate probit model fits the dataset. The results show that certified farmers were less likely to use inorganic fertilizers, pesticides, and herbicides. On the other hand, certified farmers were more likely to use indigenous technology for controlling weeds. This implies that certification reduces mango farmers' propensity of adopting practices that threaten the environment. Voluntary sustainability standards stipulate the practices that can ensure environmental sustainability. Accordingly, adopters of certification are more likely to adopt environmentally friendly practices. It is noteworthy that these results must be interpreted cautiously since we do not account for potential endogeneity at this stage.

Other factors that determine farmers' adoption of CSA practices include age, education, farm size, farming experience, access to storage facilities, record keeping, access to extension services, access to production information, ownership of working radio, and perceived working conditions. The study revealed that older farmers were more likely to produce multiple crops rather than practicing monocropping. Older farmers are more experienced and in the capacity to practice intercropping. More experienced farmers were more likely to adopt inorganic fertilizers and more likely to adopt indigenous forms of controlling weeds. The log of mango land size was positively related to the use of inorganic fertilizers and pesticides and negatively correlated with crop diversification. Education was positively related to the use of inorganic fertilizers. This implies that farmers with more years of formal education are more likely to use inorganic fertilizer.

Access to storage facilities reduced the likelihood of the adoption of inorganic fertilizers, pesticides, and crop diversification. On the other hand, farmers who had extension contacts were more likely to engage in crop diversification. Farmers who had access to information were more likely to adopt inorganic fertilizers and less likely to use pesticides. Farmers who owned a working radio were more likely to adopt herbicides and less likely to adopt intercropping. Radio stations in the study area host programmes that educate the farmers on opportunities in mango farming and ways to enhance productivity. This could account for the quest to intensify mango production through increased use of inorganic fertilizer and reduced crop diversification. Farmers in areas where roads were good were less likely to use herbicides and more likely to adopt crop diversification.

4.3. Endogenous treatment effects regression

The study estimated the effects of certification on the adoption of different CSA practices whiles accounting for endogeneity. Table 5 present results on the determinants of certification (treatment equation) and determinants of adoption of inorganic fertilizer, pesticides, herbicides, and crop diversification among certified and uncertified farmers, respectively.

Table 4. Coefficient estimates of multivariate probit model: determinants of CSA practices

Variable	Inorganic Fertilizer	Pesticide	Herbicide	Weeding	Crop diversification
Age	−0.801	0.799	−0.729	0.390	1.268*
	(0.728)	(0.694)	(0.569)	(0.556)	(0.667)
Schooling years	1.212**	0.131	−0.228	0.080	−0.372
	(0.562)	(0.532)	(0.422)	(0.404)	(0.478)
Household size	0.007	−0.175	0.040	0.261	−0.115
	(0.303)	(0.282)	(0.244)	(0.246)	(0.302)
Farm income	−0.029	0.243	0.030	0.249	−0.018
	(0.208)	(0.181)	(0.155)	(0.163)	(0.178)
Mango land size	0.508**	0.605***	−0.144	0.089	−0.396**
	(0.222)	(0.230)	(0.174)	(0.167)	(0.206)
Farming experience	0.072**	0.040	0.041	−0.048*	−0.044
	(0.035)	(0.032)	(0.025)	(0.024)	(0.030)
Record keeping	−0.239	0.655**	0.323	−0.081	−0.217
	(0.336)	(0.325)	(0.285)	(0.272)	(0.302)
Storage access	−1.433***	−0.452	−0.640**	−0.375	−0.657*
	(0.462)	(0.297)	(0.266)	(0.281)	(0.353)
Extension access	−0.698	0.479	0.218	0.271	1.116***
	(0.430)	(0.408)	(0.306)	(0.300)	(0.327)
Production information access	0.721**	−0.646**	−0.093	−0.244	0.444
	(0.371)	(0.284)	(0.250)	(0.246)	(0.301)
Radio	0.535	0.044	0.608**	−0.038	−1.404***
	(0.485)	(0.356)	(0.315)	(0.302)	(0.388)
Road condition	−0.079	0.389	−0.638**	0.321	0.598**
	(0.333)	(0.315)	(0.271)	(0.267)	(0.292)

(Continued)

Table 4. (*Continued*)

Variable	Inorganic Fertilizer	Pesticide	Herbicide	Weeding	Crop diversification
Distance to a tarmacked road	0.024	0.004	−0.005	−0.004	−0.001
	(0.016)	(0.015)	(0.011)	(0.012)	(0.012)
Certification	−1.925***	−0.830**	−0.693***	0.465*	0.065
	(0.364)	(0.341)	(0.270)	(0.267)	(0.311)
Constant	−0.640	−5.485**	2.731	−4.209*	−2.515
	(3.043)	(2.843)	(2.418)	(2.360)	(2.719)
Likelihood ratio test: Wald Chi2 (70) = 182.21		Log-likelihood = −404.22		AIC = 978.43	BIC = 1250.77

Notes: numbers in parentheses represent standard errors. *, ** and *** represent statistical significance at 10%, 5% and 1% levels respectively. USD 1 = 8 Ghanaian Cedis at the time of the study.

4.3.1. Determinants of adoption of certification

A larger farm size, access to production information, and distance to tarmacked roads were negatively correlated with certification. Farmers with large farm sizes are usually older farmers who are risk-averse and less likely to transition to the adoption of new farm practices and technology. The study found that farmers who were farther away from tarmacked roads were less likely to certify. This could be attributed to their reduced likelihood of receiving on-farm extension visits which could contribute to the adoption of practices that could enhance their compliance with voluntary sustainability standards.

Access to high-value markets, access to extension services, access to credit, usage of cell phones to access information, and group membership were positively correlated with the adoption of certification. Farmers who had access to extension services were more likely to adopt certification since they receive training on appropriate agronomic practices that are consistent with sustainability standards. Access to credit increases the resource endowment of households which in turn enables farmers to cover the costs of approved inputs and other costs associated with certification. Thus, access to credit increases farmers' propensity to adopt certification. The cell phone reduces transaction costs associated with information search. Thus, farmers who use cell phones to access mango production and marketing information are more likely to adopt certification.

4.3.2. Determinants of adoption of CSA practices among certified and uncertified farmers

The study used the eteffects model to analyze the factors that influence the adoption of different CSA practices among certified and uncertified. The results are presented in Table 5. The results show that older farmers who are uncertified have a higher propensity of using pesticides. This is intuitive because older farmers are risk averse and are less likely to change their production practices. Among uncertified farmers, education was positively related to the adoption of inorganic fertilizer and pesticides. This implies that education increases the uptake of modern production agricultural technologies. Accordingly, more educated mango farmers who are not certified are free to adopt agricultural technologies that enhance productivity, regardless of their environmental impacts.

Household size is a proxy for the availability of free labor. The results show that a relationship between household size and the adoption of inorganic fertilizers was positive for certified farmers and negative for uncertified farmers. This means that owing to availability of labor, certified farmers with a larger household size are more likely to adopt inorganic fertilizer in a bid to increase productivity. Uncertified farmers on the other hand could leverage the availability of labor to produce organic fertilizer, thereby reducing the use of inorganic fertilizer among this group. Also, household size a negatively related to the adoption of crop diversification as a CSA practice among uncertified farmers. This could be because could be attributed to the ability to intensify mango production.

Farming experience was positively related to the adoption of inorganic fertilizer and pesticides among uncertified and certified farmers, respectively. With experience, farmers are more likely to understand improved agricultural inputs that can reduce pest whiles increasing yield. Without certification, the use of these inputs would be intensified since farmers are not conscious of the effects of these practices on the environment.

The results show a positive relationship between farm income and the adoption of CSA practices including the use of inorganic fertilizer and herbicides. A higher farm income increased the propensity of adopting inorganic fertilizer and herbicides for both certified and uncertified farmers. A high farm income enables farmers to afford inputs that can accelerate farm productivity. It is expected that wealthier certified farmers would increasingly adopt approved inorganic fertilizers and herbicides and apply them in approved quantities. Uncertified farmers on the other hand would procure both approved and unapproved chemicals with no regard for environmental health.

Table 5. Estimation results of endogenous treatment effects

		Inorganic fertilizer		Herbicide Use		Pesticide use		Crop diversification	
Variables	**Treatment**	**Certified**	**Uncertified**	**Certified**	**Uncertified**	**Certified**	**Uncertified**	**Certified**	**Uncertified**
Age	0.015(0.016)	0.032(0.036)	−0.023(0.021)	−0.013(0.017)	0.004(0.016)	−0.027(0.023)	0.045(0.024)*	0.006(0.020)	0.008(0.014)
Years of schooling	−0.040(0.036)	−0.100(0.067)	0.176(0.048)***	−0.037(0.037)	0.034(0.033)	−0.010(0.048)	0.104(0.044)**	−0.008(0.044)	−0.038(0.035)
Household Size	−0.072(0.074)	0.461(0.199)**	−0.170(0.102)*	0.115(0.080)	−0.105(0.072)	0.108(0.090)	−0.035(0.079)	0.020(0.085)	−0.157(0.072)**
Farming experience	0.048(0.055)	0.145(0.116)	0.148(0.060)**	0.040(0.041)	−0.003(0.039)	0.082(0.048)*	0.041(0.056)	0.057(0.052)	0.050(0.037)
Farm income	0.000(0.000)	0.000(0.000)**	0.000(0.000)**	0.000(0.000)*	0.000(0.000)**	0.000(0.000)	0.000(0.000)	−2.1E-05(2.17E-05)	0.000(0.000)
Mango land size	−0.170(0.071)**	0.089(0.117)	0.220(0.100)**	0.110(0.039)***	−0.078(0.037)**	0.067(0.084)	0.227(0.102)**	0.002(0.038)	−0.006(0.034)
Record keeping	−0.068(0.468)	−1.619(0.697)**	0.390(0.452)	0.460(0.461)	0.092(0.317)	0.809(0.538)	1.172(0.506)**	−0.414(0.613)	0.155(0.368)
High-value markets	1.168(0.391)***	−0.131(0.868)	1.003(0.608)*	0.163(0.535)	0.005(0.435)	0.141(0.587)	0.519(0.708)	0.431(0.573)	0.206(0.403)
Access to storage	0.060(0.598)	−4.965(1.146)***	−0.617(1.061)	−0.821(0.383)**	−0.177(0.593)	−0.348(0.450)	−1.147(0.643)*	−1.146(0.417)***	0.363(0.708)
Access to extension	0.616(0.393)	1.960(1.330)	−1.937(0.638)***	0.243(0.535)	−0.038(0.377)	1.373(0.631)**	−0.500(0.422)	0.001(0.532)	0.419(0.429)
Access to production information	−0.944(0.387)**	−1.680(1.000)*	0.867(0.510)*	−0.596(0.450)	−0.230(0.340)	−1.598(0.442)***	0.107(0.489)	0.409(0.421)	0.002(0.412)
Cellphone usage	0.582(0.425)	−0.428(0.545)	0.187(0.395)	−0.214(0.409)	−0.780(0.324)**	−0.288(0.473)	−0.195(0.421)	−0.612(0.422)	1.121(0.346)***
Ownership of radio	−0.131(0.586)	3.609(1.062)***	0.606(0.802)	0.331(0.433)	1.700(0.510)***	0.595(0.410)	−1.035(0.793)	−0.999(0.465)**	−0.957(0.546)*
Access to credit	2.067(0.617)***	0.349(0.827)	−3.065(0.974)***	−0.230(0.577)	0.114(0.612)	0.174(0.745)	−0.729(0.719)	−0.245(0.621)	−0.299(0.703)
Perceived road condition	0.521(0.503)	−1.129(0.817)	−0.251(0.475)	−0.509(0.461)	−0.728(0.330)**	0.863(0.473)*	0.250(0.551)	0.354(0.457)	0.977(0.352)***

(*Continued*)

Table 5. (*Continued*)

		Inorganic fertilizer		Herbicide Use		Pesticide use		Crop diversification	
Variables	**Treatment**	**Certified**	**Uncertified**	**Certified**	**Uncertified**	**Certified**	**Uncertified**	**Certified**	**Uncertified**
Distance to a tarmacked road	−0.028(0.012)**	0.006(0.020)	0.052(0.017)***	−0.018(0.018)	−0.006(0.013)	−0.002(0.023)	−0.003(0.019)	0.009(0.017)	−0.002(0.016)
Group membership	2.731(0.369)***								
Constant	−2.740(1.051)***	−9.171(2.285)	−2.334(1.143)**	−0.194(1.394)	−0.110(0.819)	−0.329(1.801)	−2.371(1.301)*	0.460(1.725)	−0.074(0.884)
Observations	224								

Notes: *,** and *** represent statistical significance at 10%, 5% and 1% levels respectively. Numbers in parenthesis represent standard errors. USD 1 = 8 Ghanaian Cedis at the time of the study.

Farm size was positively related to the adoption of inorganic fertilizer and pesticides by uncertified farmers. Uncertified farmers who have large farm sizes are more likely to adopt inorganic fertilizer to induce productivity and pesticides to rapidly control pests. On the other hand, there was a positive relationship between farm size and the use of herbicides among both certified and uncertified farmers. This is intuitive since a larger farm size would require the use of improved technology to clear weeds, regardless of the certification status of the plot manager.

Among certified farmers, the results reveal a negative relationship between recording keeping and the use of inorganic fertilizers. This indicates that farmers who kept records were less likely to use inorganic fertilizer. Farmers who keep records are more likely to adhere to and comply with the stringent requirements of the certification schemes. This includes less use of inputs that threatens environmental sustainability. There exists a positive relationship between record keeping and the use of pesticides among uncertified farmers.

Access to high-value markets did not matter for the adoption of other CSA practices except the use of inorganic fertilizers. The results show that there was a positive relationship between access to high-value markets and the use of inorganic fertilizer among uncertified farmers. Uncertified farmers who have access to remunerative markets such as the processors and export markets are more likely to use inorganic fertilizer to meet quantity requirements.

The results show that access to institutional support services and production and marketing information influenced farmers' adoption of different CSA practices. Certified farmers who had access to storage facilities were less likely to use inorganic fertilizers. Access to storage facilities reduced the likelihood that a certified farmer would adopt herbicides. Among uncertified farmers, usage of cell phones to access production information and proximity to good roads reduced their likelihood of adopting inorganic fertilizers and pesticides. However, uncertified farmers who owned a working radio were more likely to adopt inorganic fertilizers and herbicides. Access to extension services, on the other hand, increased the likelihood that a certified farmer would adopt pesticides. Farmers who receive extension services are more likely to know the right proportions of pesticides to use in order not to violate sustainability standards. On the other hand, uncertified farmers who had access to storage facilities were less likely to adopt pesticides. In most cases, farmers who have access to storage facilities are more likely to access markets that are characterized by stringent entry requirements. Accordingly, these farmers are more likely to adopt practices including less use of pesticides to access these markets.

The results show that access to storage facilities and ownership of a working radio reduced the probability that certified farmers would practice crop diversification. Farmers who have access to storage facilities can intensify mango production and reduce the production of other crops. The ownership of a working radio increases the probability that a farmer would receive accurate mango marketing information which can induce the intensification of mango production and reduce their propensity of cultivating other crops. The use of a cell phone to access production and marketing information as well as proximity to good roads increased the propensity that mango farmers would engage in crop diversification. Cell phones can be used to facilitate trade. Thus, farmers who own cell phones can get information about where they could sell different farm produce. This can increase their probability of engaging in crop diversification. In rural Ghana, many small-scale farmers sell by the roadside. Roads in good condition attract more people to pay them. Accordingly, farmers who are close to good roads are more likely to diversify and sell other farm products beside these roads.

4.3.3. Impact of certification on the adoption of CSA practices

The study used the endogenous treatment effects model to analyze the impact of certification on the adoption of CSA practices. The results are presented in Table 6. Accounting for endogeneity, the study found that the adoption of certification reduced the use of inorganic fertilizer in mango production by 50 percentage points. The study revealed that the adoption of certification reduced the use of herbicides to control weeds by about 38 percentage points. The study also shows that certification has the potential to reduce the use of pesticides by about 23 percentage points.

Regarding the potential mean outcome, the results show that the use of inorganic fertilizer would increase by 69 percentage points if farmers do not adopt certification. Without certification, the use of herbicides and pesticides to control weeds and pests would increase by 70 percentage points and about 94 percentage points, respectively. The results show that the adoption of crop diversification would increase by about 60 percentage points if farmers do not certify.

5. Discussion

Our study shows differences across certified and uncertified farmers regarding the use of inorganic fertilizers, herbicides and crop diversification as coping strategies in response to climate change. Consistent with the findings Thompson et al. (2022), certification schemes, especially organic certification emphasizes on limited use of inorganic fertilizers that threaten environmental health. Thus, it is expected that the use of inorganic fertilizer was less among certified farmers. Although not mandatory, sustainability certification schemes recommend crop diversification. Studies including Martey et al. (2022) and Ngetich et al. (2022) highlight that farmers diversify their crops as a coping strategy in response to climate variability. Whereas Thompson et al. (2022) found that crop diversification was common among Ghanaian cocoa farmers under organic certification, our study shows that GlobalGAP certified mango farmers who intercropped were less than uncertified farmers who diversified their crops. First, this finding reveals that the effects of certification are heterogenous as they differ across crops and certification schemes. Next, the finding shows that certified farmers are vulnerable to climate change. This implies that certified farmers are prone to food insecurity and poverty, especially in periods where climate change affects mango output and quality. Regarding plot management practices such as weeding or the use of herbicides, farmers under GlobalGAP certification.

The findings of this study indicate that different CSA practices can either be complements or substitutes. According to Martey et al. (2022) highlight that exposure to shocks and perceived climate risks can influence farmers to either complement or substitute different CSA practices. For instance, the authors found that farmers exposed to precipitation shocks complement mulch with residue and substitute mulch with mineral fertilizer. Our study shows complementary relationships between the use of pesticides and inorganic fertilizer, and the use of pesticides and herbicides as plot management practices. On the other hand, mango farmers substitute weeding with herbicides. This is intuitive and can be tied with certification. Indeed, our study reveal that certified farmers are more likely to use indigenous methods to clear weeds on mango farms. According to Thompson et al. (2022), cocoa farmers practice weeding to respond to climate variability. However, the authors found no link between certification and weeding.

Farmers' decisions to adopt the different CSA practices which were considered in this study were influenced by age, education, farm size, experience, access to storage facility, record keeping, access to extension services, access to information, road condition and certification. Musafiri et al., 2022) highlights that older farmers are risk averse. Thus, they are more likely to adopt climate-resilient practices. In line with the theory of strong sustainability, farm size is a proxy of availability of natural capital and defines the defines the availability of land for experimenting with new technologies and practices (Ngetich et al., 2022). Smallholder farmers who are educated can easily comprehend agricultural technologies which can accelerate their adoption of technologies. This finding corroborates with findings of Martey and Kuwornu (2021), Hossain et al. (2022), Ngetich et al. (2022), and Kassa and Abdi (2022). Despite the fact that the adoption behavior of farmers as regards CSA practices is heterogenous across different contexts, this study confirms that socio-economic, plot level, institutional, and technological factors influence farmers' adoption of CSA practices. The practical implication of this finding is that capacity building, access to infrastructure, market and production information, and agricultural inputs can foster the adoption of CSA practices. Further, Ibrahim et al. (2009) and Asante et al. (2017) conclude that institutional support

Table 6. Impact of certification on adoption of CSA practices

Variable	ATET		POM	
	Coeff.	**Std. Err.**	**Coeff.**	**Std. Err.**
Fertilizer use	−0.501***(50%)	0.167	0.694*** (69%)	0.189
Herbicide use	−0.376* (38%)	0.204	0.700*** (70%)	0.199
Pesticide use	−0.225** (23%)	0.110	0.939*** (94%)	0.103
Crop diversification	−0.295 (30%)	0.253	0.596*** (60%)	0.248

Notes: *, ** and *** represent statistical significance at 10%, 5% and 1% level respectively. Std. Err. Represents standard errors and Coeff. represents coefficients. ATET represents average treatment effects on the treated. POM represents the potential outcome mean. Coefficient multiplied by 100 yield percent estimates of the impacts of certification.

services such as extension services encourage farmers to diversify their crop production since they receive information that capacitates them to cultivate other crops to enable them to meet their nutritional demands from agricultural production. According to Kifle et al. (2022) and (Kassa & Abdi, 2022) an appreciation of these practices and their cumulative adoption can contribute to increased farm productivity, enhanced resilience, reduced emissions and food security.

After controlling for endogeneity, the study found that access to institutional support services such as extension services and credit as well as access to high-value markets and participation in farmer-based organizations enhance farmers' adoption of certification. These factors are the critical pathways through which an increase in the adoption of certification can be achieved. Specifically, access to credit increases the resource endowment of farmers which enables them to afford certification costs. Access to extension services is an avenue for training and capacity development which capacitates farmers to understand practices stipulated in sustainability standards. There are progremmes organized by development organizations such as GIZ and West Africa Competitiveness Programme that are geared towards training farmers to adopt good agricultural practices. These programmes have significantly contributed to farm productivity and the uptake of certification. High-value markets like industrial processors in the study area offer capacity development programmes to mango farmers in the study area. This support capacitates farmers to comply with voluntary sustainability standards.

The study area hosts strong mango producer groups. Given that mango production in the study are is predominantly on a small-scale, certification is done on a group level. Consequently, participating in farmer groups increases farmers' propensity of being certified. According to Praneetvatakul et al. (2022), access to farmer groups promotes access to group certification which intend enhances farmers' access to certification. Also, farmers who participate in high-value markets receive premium prices. It is expected that farmers would desire to continue to receive high prices which would induce them to comply with standards in high-value markets, hence the adoption of certification. This is consistent with Quartey et al. (2021). The findings on the drivers of certification imply that farmers are required to make significant adjustments and investments if they want to accelerate their adoption of certification. Accordingly, farmers require financial, institutional and technical support services to adopt sustainability certification.

The results of the study show that certification significantly reduces the use of inorganic fertilizers, herbicides, and pesticides. This corroborates with Raynolds (2012) who found that certification regulates the use of harmful agrochemicals such as pesticides. A recent study by Praneetvatakul et al. (2022) show that farmers are willing to pay for the various environmental attributes of certification such as integrated pest management and ecolabelling. This implies that farmers have positive perceptions the direct impacts of certification on the environment.

Also, since ecolabelling guarantees access to high-value markets to farmers, it can be inferred that certification directly influences responsible pest management which promotes environmental health. The study also found that certification does not matter for the adoption of crop diversification. The findings of the study show that the adoption of practices that exacerbate climate change would accelerate without certification. However, without certification, farmers are more likely to adopt mixed cropping which is a key climate change adaptation strategy that can build farmers' resilience against climate change. Consistent with the findings of Smith et al. (2019), certification can contribute to the reduction of greenhouse gas emissions, thereby contributing to the mitigation of climate change and its impacts.

The study has some limitations. Although there might be different certification schemes, the study focused on GlobalGAP certification which is the most popular in Ghana's mango sector. Also, geographically, the study focused on the Southern Belt of mango production in Ghana. Yet, there is the Northern Belt of mango production. Although mango farmers might adopt several CSA practices, the study focused on practices that are relevant to certification. Further studies are encouraged to analyze the environmental impacts of different certification schemes in Ghana's fruit sector.

6. Conclusion

Sustainability certification schemes seek to make agriculture economically viable, socially just and environmentally sustainable. The study sought to analyze how certification can achieve the goal of environmental sustainability by analyzing the role of certification in the adoption of CSA practices by mango farmers in Ghana. The study found that the main CSA practices that mango farmers adopt include weeding, crop diversification and the use of inorganic fertilizers, herbicides, and pesticides to accelerate productivity and control weeds and pests. Crop diversification and the use of inorganic fertilizer and herbicides were more common among uncertified farmers than certified farmers. Mango farmers combine pesticides and inorganic fertilizers and pesticides and herbicides. On the other hand, farmers substitute weeding with herbicides and weeding with inorganic fertilizers. The study concludes that farmers' adoption of different CSA practices is influenced by sociodemographic, technical and institutional factors in different ways.

The study found that membership in mango farmers' associations, and access to high-value markets and credit facilities encourage farmers' participation in sustainability certification schemes. Overall, certification discourages the adoption of inorganic fertilizer, pesticides and herbicides. On the other hand, certification enhances the adoption of weeding. Based on the study findings, we conclude that certification promotes environmental sustainability.

The implication of the study is that enhancing participation in certification schemes can enhance the adoption of CSA practices and consequently promote environmental health. Therefore, the study recommends that credit facilities are made more available to mango farmers. This can enhance farmers' adoption of approved inputs and also capacitate farmers to cover costs associated with certification. Also, efforts should be targeted at improving farmers' access to high-value markets such as the export markets and industrial processors. This can enhance the adoption of certification in two folds. First, given that these markets are remunerative, access to these markets implies high farm income for farmers which can translate to the adoption of approved inputs can ability to cover certification costs. Second, in the study area, buyers from these markets offer capacity development programmes which can enhance farmers' compliance with sustainability standards and increase their participation in certification schemes. Finally, since group certification is a major pathway to participation in certification schemes, it is important that mango farmers are encouraged to join farmer groups.

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Data available upon reasonable request.

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APPENDIX

Appendix A: Test of endogeneity

Model	Prob > chi2
Fertilizer	0.0165**
Herbicides	0.3992
Pesticides	0.2818
Crop diversification	0.1414

Note: **** denotes statistical significance at 5% level**