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Do farmers' socioeconomic status determine the adoption of conservation agriculture? An empirical evidence from Eastern and Southern Regions of Cameroon

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A B S T R A C T

The African Union's Agenda 2063 and the Malabo Declaration recognize agricultural development as one of the most effective means of combating extreme poverty. Conservation Agriculture Practices (CAP) have been asserted to have the potential to boost agricultural output, improve livelihood and contribute to the conservation of natural resources. This study thus seeks to advance knowledge about Conversation Agriculture by assessing the factors determining the adoption and intensity of CAP among Cameroon's smallholder farmers. Data collected from 351 farmers in the South and East regions of Cameroon were used to study the social, economic, ecological and biophysical factors that determine the adoption of CAP. The study considered agroforestry, intercropping, crop rotation, cover crop, mulching, and zero-tillage as the CAP under investigation. According to the multivariate probit analysis employed, the results showed that gender, age, family size, extension services, use of modern farm technology, distance from house to farm, livestock owned, and infertile soil all significantly influenced CAP adoption. Results on adoption intensity revealed that gender, distance from house to farm, and the number of livestock owned were critical drivers of CAP adoption intensity. Promoting the adoption of CAP, policymakers and concerned stakeholders should consider farmer, institutional, socio-economic, ecological, biophysical aspects as well as relational values. However, already existing extension services need to be improved upon.

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Introduction

Agriculture has remained the bedrock of survival in the rural landscape in the developing world [13]. The World Bank reported that the agricultural sector provides jobs for over 1.3 billion farmers in rural settings and most of these farmers are smallholders [38]. Ironically, most hungry people globally, are found in rural areas in growing economies, with Sub-Saharan Africa (SSA) being among the most represented populations (Tsige et al., 2020; [18]). Smallholder farmers in SSA are known to be resource-poor with the use of rudimentary technologies. In addition, most of these farmers rely mainly on rain-fed agriculture which is vulnerable to climate change [5]. Curbing the climate change challenge has been the discourse of many global efforts including the Paris Agreement which seeks to limit the increase in global temperature to 1.5° or 2°C above preindustrial levels by reducing greenhouse gas (GHG) emissions (Masson-Delmotte et al., 2018). Anthropogenic GHG emissions from the agricultural sector are the second largest contributor to global warming. This means the need for Conservation Agriculture (CA) that limits GHG emissions.

On the heels of geometric population growth, it is imperative for SSA farmers to adopt innovative methods to improve productivity which does not compromise the environment. The current intensification through conventional (tillage-based) agriculture may compound poverty and food insecurity by degrading the ecosystem and reducing soil productivity (Mupangwa et al., 2016). Environmental challenges brought about by conventional agriculture have been attributed to changes in climate change due to an increase in greenhouse gas (GHGs) emissions [4]. Climate change has manifested in SSA through mid-season droughts, where SSA is experiencing low and inconsistent rainfall patterns, causing crop failure (IPCC, 2022). Based on the detrimental effects of conventional agriculture on the environment, conservation agriculture which is a resource-efficient production system is being heralded as a possible solution. Conservation agriculture is a set of plot-level practices bounded by the following three principles [12]; which are (a) reducing soil loss (minimal/zero tillage), (b) preserving everlasting soil cover (cover crops, intercrops, and mulching), and (c) diversifying crop rotations.

CA is recognized as a climate-smart agricultural practice because it can improve environmental sustainability by improving crops' resilience to climate change, mitigating greenhouse gases, conserving biodiversity, and improving crop productivity and consequently improving food insecurity and alleviating poverty [34]. Primarily it is geared towards improving yields and soil fertility. In addition, it has the potential to boost carbon-based soil. However, for a farming system to be CA, all three principles must be practiced simultaneously [19]. According to Giller et al. [16] farmers do not adopt all principles in practice due to limited resources and is therefore necessary to investigate the individual principles of the CA system. In addition, they indicate that the adoption of CA is an interaction of bio-physical, socio-economic, and cultural factors which makes adoption different from one place to another.

Africa now sees an increase in the promotion of CA as a sustainable farming practice to increase food production [9]. Although CA is widely practiced in other regions of the world, its adoption in SSA has been mediocre. The views on the adoption of new CA technologies in SSA vary including differences among farmers, context, riskiness, conflict with farmers' resources, and the perceived benefits (Mupangwa et al., 2016). As one of the SSA countries, Cameroon has agriculture as one of its primary sources of national income, which provides jobs to 70% of its population force [26]. Akamin et al. [1] further reaffirm that agriculture has remained the mainstay of Cameroon's economy though classified as Sub-Sahara Africa's fifth-biggest oil producer. Like most of the SSA countries, Cameroon is plagued by declining soil fertility and climate disruption, low productivity, and population growth, resulting to poverty and food insecurity [3]. Agriculture's sustainability in many regions of Sub-Saharan Africa is endangered by a loss of species diversity, a reduction in land, forest, and water resources, soil erosion, salinization, acidification, desertification, and environmental pollution [26]. This is because of continuous use of traditional farming techniques (slash and burn, shifting agriculture, and traditional mixed farming) that evolved over generations in constant interaction with local culture and ecology and have helped in increasing deterioration of land and poor yields. Therefore, it is imperative for CA to be the means for the nation to intensify its agricultural sector.

Adopting CA is expected to bring economic benefits to farmers by improving yields, enhancing food security and economic growth, and improving farmer welfare [21,27,37]. Furthermore, consumers will also enjoy the benefits CA adoption by consuming organic food free of chemical contamination. However, there is a paradox amid this appealing narrative: while proponents describe CA as being indisputably good for farmers, adoption has remained shockingly low in many poor countries, despite ongoing efforts to encourage CA adoption [24].

A substantial literature has arisen on the agronomic and economic implications of CA for smallholder farmers, as well as trends of CA adoption [9]. The benefits of CA, according to both critics and unbiased proponents, are very context-specific, dependent on elements such as location and seasonal variations, among others (Erenstein et al., 2012). Weeds, for example, are referred to as the "Achilles heel" of CA by Giller et al. [16], because CA (especially reduced tillage) increases weed pressure during the early years of CA adoption, and manually eradicating weeds is exceedingly labor demanding. He further cites competing uses for crop residues, limited labor availability, and access to physical inputs as significant barriers to CA adoption.

While some academics have studied smallholder systems and conservation agriculture in Africa and Cameroon [22], very few have investigated the extensive nature of its adoption [3,10]. Some studies have focused either on socio-economic aspects or a combination of socio-economic and biophysical aspects [3,10,22]. We move further to include ecological aspects in our analysis. This study thus supplements the sparse empirical evidence on technology diffusion by focusing on the nature of adoption and intensities of adoption in Cameroon's agriculture. In fact, some studies have called for a clearer understanding of the adoption and diffusion patterns of technologies in smallholder farming, and this study satisfies that need

(Muthoni, 2017). Cameroon is selected for this study because of the representative nature of its ecology and biodiversity within the Central African subregion. However, most CA studies [3,7,27] have relied solely on primary quantitative data, so the evidence they provide may be limited to patterns among large populations. Since qualitative data often gathers more in-depth insights on participant attitudes, thoughts, and actions, this study used triangulation in its sampling method by incorporating both quantitative and qualitative interviews. In terms of methodology, most previous studies on adoption have relied on inefficient and biased versions of the simple probit model, negative binomial model, and multinomial logit (e.g. Oduniyi and Chagwiza, 2022; [25]).

Thus, this research assesses the scope of CAP implementation and the intensity of CAP adoption. The hypothesis is that the socioeconomic status of farmers and their households may correlate positively with the adoption of conservation agriculture. The rationale for such a study currently is essentially to generate information to guide policy making towards resilient and productive agricultural systems. The primary data from farms and households in the South and East regions of Cameroon showed significant number of farmers engaged in conservation tillage, agroforestry, intercropping, crop rotation, cover crop and organic mulching. From the multivariate econometric analysis we observed that gender, experience proxied by age, family size, extension services availability, the use of modern farm technology and livestock ownership influenced CAP adoption. The adoption intensity is attributed to gender, distance from house to farm, and the number of livestock owned as critical drivers of CAP.

The observations of this study indict the extension services on its role in achieving national and continental visions such as the African Union's Agenda 2063 for the agricultural sector to become more financially viable and attractive to young people and women. The Malabo Declaration of 2014 further identified sustainable climate smart agriculture for its resilience and capacity to boost agricultural growth and transformation for greater economic and social well-being in the African continent. The current research effort also adds to the wealth of knowledge on the expected outcomes of the United Nations Sustainable Development Goal (SDGs), particularly SDG1, SDG2 and SDG8 by illuminating the niche area of CSA on which to focus investments. Steering farmer adoption of CA will have the triple win of improving food security, promote adaptation and mitigation to climate change as well as poverty eradication for the majority of rural dwellers who are gainfully employed in the agricultural sector.

Materials and methods

Study area

This study was carried out in some selected villages from the South and East regions of Cameroon (Fig. 1), based on the concentration of forests and active agricultural activities in this area. The South region is in the southwestern and south-central portion of the Republic of Cameroon. It shares borders with a portion of the Atlantic Ocean to the west, the Centre Region to the north, the Littoral Region to the northwest, the East region to the east, and Gabon, Congo, and Equatorial Guinea to the south. The South is the fourth largest region in the country, with a total area of 47,720km^2 [32]. The many Beti-Pahuin peoples, including the Ewondo, Fang, and Bulu, make up the principal ethnic groups. In addition, the South Region has a respectable amount of industry, with forestry, mining, and offshore oil drilling making up the bulk of its trade. In the South, commercial agriculture is also significant, with cocoa and rubber as the two main cash crops. Additionally, fishing and raising cattle are important economic activities. Subsistence farmers make up a large portion of the population. The South region has a Guinea-type climate. In the interior, there is a lot of humidity, and the coastal area has 2000-3000mm of precipitation annually compared to 1500-2000mm in the interior. Rainfall along the coast from north of Kribi to south of Ebodjé can reach 4000 mm annually [32]. Moreover, temperatures are high, averaging between 24 and 26°C from Kribi north along the coast. The Guinea-type climate offers alternating dry and wet periods in place of regular seasons. A protracted dry season that lasts from December to May ushers in the New Year. A brief dry season from July to October is followed by a modest wet season from May to June. Around October, a prolonged wet season starts and lasts through November.

On the other hand, Cameroon's southeast corner is occupied by the East Region. It shares borders with the Central African Republic to the east, the Congo to the south, Adamawa to the north, and the Centre and South Regions to the west. It is the most sparsely inhabited and largest region in the country, covering 109,002km^2. The Baka (or Babinga) pygmies were the original settlers, and the peoples of the East have been in Cameroon longer than any other ethnic group in the country's history. Also, the East region has virtually little industry; logging, wood, and mining make up much of its trade. Subsistence farmers make up most of the population. As a result, the region has minimal political significance and is frequently disregarded by Cameroonian politicians. This, together with the region's lack of growth, have earned it the nickname "*the forgotten region.*" The South Cameroon Plateau, which makes up the country's southeast, contains almost the whole land of the East region. Except for the lower-lying plains of 200 to 500m in the extreme southeast centred on the Dja, Boumba, Sangha, and Ngoko rivers, the elevation thus fluctuates between 500 and 1000m above sea level [14,32]. The topography is mostly composed of monotonous, slightly sloping hills, labelled as "half-oranges" after the fruit they resemble. Furthermore, the East has a wet equatorial climate, commonly referred to as a climate of Guinea type, which is characterised by high temperatures (24°C on average) and the absence of traditional seasons. Instead, there are four distinct seasons: a lengthy dry season (December to May), a light rainy season (May to June), a brief dry season (July to October), and a heavy wet

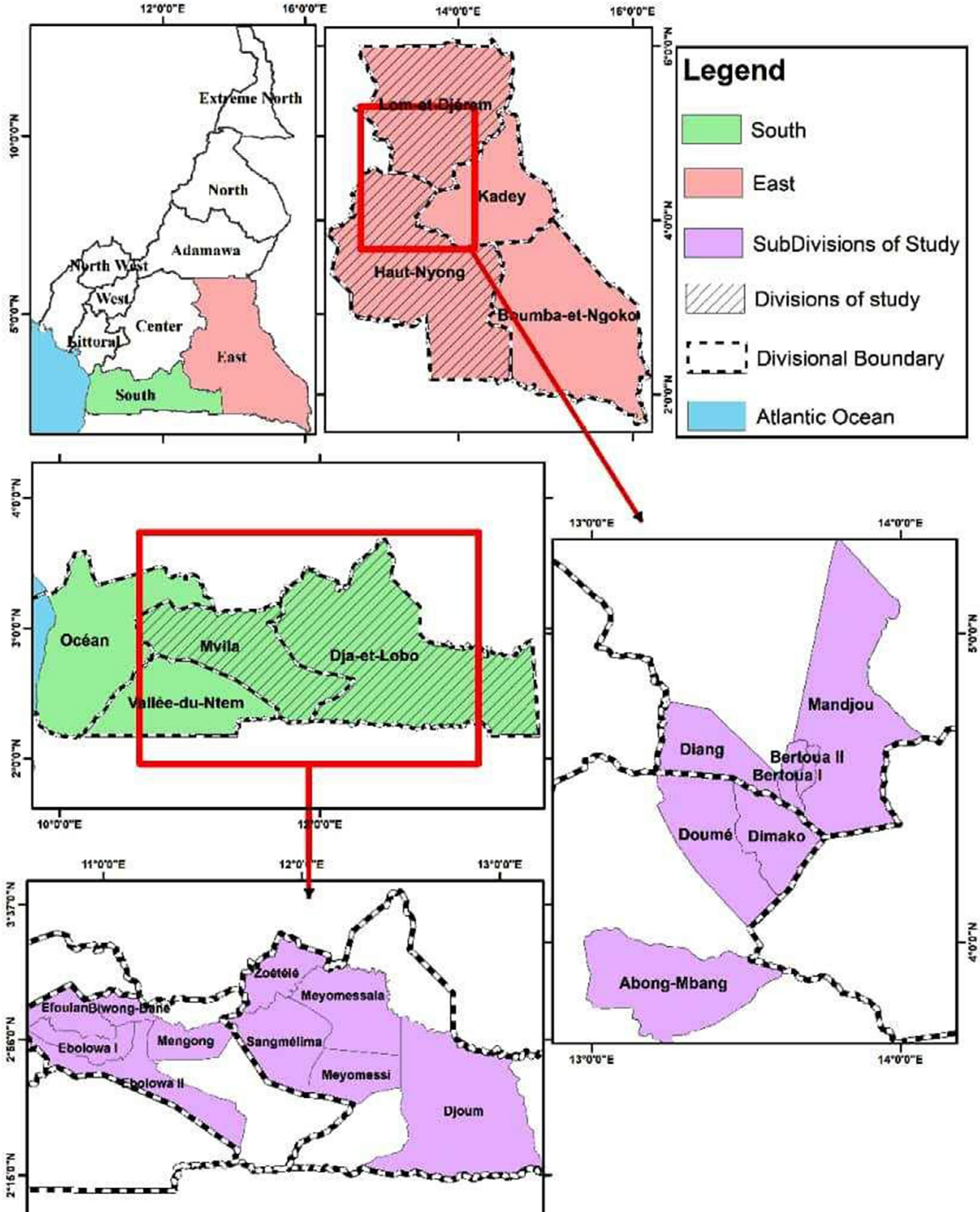

Fig. 1. Study area indicating villages under investigation (Source: Authors' Calibration, 2022).

season (October to November). Except for the extreme eastern and northern sections, where precipitation is slightly less, there is a fair amount of humidity, cloud cover, and precipitation, averaging 1500-2000mm annually [14,32].

Sampling and data collection

Principally, this study makes use of primary data. Data was gathered through face-to-face interviews with peasant household heads in Cameroon's South and East regions in the period of February and March. Additionally, field observations were conducted to capture the socioeconomic factors and daily activities, particularly farm techniques. The participants in this study were chosen using the two-stage sampling procedure. Since farmers are dispersed across a large geographic area, the population of farmers was divided into 4 clusters in the first stage (Dja et Lobo, Mvilla in the South region, and Nyong & Lom et Djerem in the East region). In addition, 20 farmers were chosen at random from each cluster in the second stage to create the study sample size (400). Data collection took place during the wet season, which presented certain field antics and made it difficult for researchers to access some isolated places. In the end, the researchers received 351 questionnaires with complete answers, although some incomplete questionnaires were eliminated to prevent erroneous findings. The sizes of main sampling units were reduced by using this technique.

Furthermore, descriptive statistics, and the multivariate probit econometric model were used in analyzing the primary data collected from the study area. The descriptive statistics was used in outlining the socio-demographic characteristics of smallholder farmers, as well as the adoption intensities of farming practices. In adoption studies on African farming systems, since most farmers adopt multiple technologies at once, Multinomial logit and probit models are typically used to estimate the equations separately. However, there are mathematical limitations with the negative binomial model, where the sum of the predicted values is not equal to the sum of the input values, indicating that the model does not preserve the constancy of sums. As a consequence, we rather employ for this study the ordered probit model and the multivariate probit (MVP) model to be able to correct for this bias and to be able to capture both the adoption process and the intensity of adoption of conservation agricultural technologies. Statisticians and econometricians view the multivariate probit model as an efficient generalization of the probit model used to estimate several correlated binary outcomes simultaneously (Greene, 2002). It is frequently believed that multivariate probit model is more accurate than multivariate logit model (MVL) since it does not presume the independence of irrelevant alternatives (IIA). In actuality, the error correlations should also be estimated by an MVP model in addition to the coefficients. Thus, it could seem that MVP is a more efficient statistical model than MVL.

Model specification

We employ the MVP to assess the determinants of CAP adoption since it is attractive for analyzing choice behaviour as it permits a flexible correlation structure for the unobservable covariates [17]. Furthermore, Teklewold et al. [36] revealed that estimates from the MVP vastly contrasted across all equations estimated. However, indicating the appropriateness of differentiating between practices as heterogeneity in adopting agricultural practices and analysis of each separate practice is supported rather than grouping the practices into a single variable (Teklewold et al., 2017).

In a single-equation statistical model, information on a farmer's adoption of one CAP does not alter the likelihood of adopting another CAP. However, the MVP approach simultaneously models the influence of the set of explanatory variables on each of the different practices while allowing for the potential correlation between unobserved disturbances and the relationship between the adoption of different practices. A source of correlation, in this case, is either complementarity or substitutability between different methods. The interrelationship between adopters' decisions with unobserved factors must be captured to avoid bias and inefficient estimates (Greene, 2000).

The observed outcome of CAP adoption is modelled following a random utility formulation. Consider the i^{th} farm household ($i = 1$, ……, N) facing a decision on whether or not to adopt the available CAP on plot p ($p = 1$,.., P). the benefits farmers get from traditional farm methods is represented by U_0, while the benefits they get from adopting the k^{th} CAP is denoted as Uk: where k denotes choice of agroforestry (A), intercropping (I), cover crop (C), crop rotation (R), mulching(M), minimum/zero tillage (T). The farmer adopts the kth CAP on plot p if $Y^*_{ipk} = U^*_K - U_0 > 0$. The net benefit ($Y^*_{ipk}$) that the farmer derives from the adoption of k^{th} CAP is a latent variable determined by observed household, plot, and location characteristics (X_{if}) and the error term (ε_{ip}):

$$Y^*_{ipk} = X'_{ip}\beta_k + \varepsilon_{ip} \tag{1}$$

When we used the indicator function, the unobserved preferences in Eq. (1) were translated to the observed binary equation for each choice as follows:

$$Y_{ipk} = \begin{cases} 1 \ if \ Y^*_{ipk} > 0 \\ 0 \ otherwise \end{cases} (k = A,\ I,\ C,\ R,\ M,\ Z) \tag{2}$$

In the multivariate model, where the adoption of several CAP is probable, the error terms mutually follow a multivariate normal distribution with zero mean and variance normalized to unity [20].

Where: µA, µI, µC, µR, µM, µZ ∼: MVN (0, Ω) and the symmetric covariance matrix X is given by:

$$\Omega = \begin{bmatrix} 1 & \rho AI & \rho AC & \rho AR & \rho AM & \rho AZ \\ \rho IA & 1 & \rho IC & \rho IR & \rho IM & \rho IZ \\ \rho CA & \rho CI & 1 & \rho CR & \rho CM & \rho CZ \\ \rho RA & \rho RI & \rho RC & 1 & \rho RM & \rho RZ \\ \rho MA & \rho MI & \rho MC & \rho MR & 1 & \rho RZ \\ \rho ZA & \rho ZI & \rho ZC & \rho ZR & \rho ZM & 1 \end{bmatrix} \quad (3)$$

The off-diagonal elements in the covariance matrix are of particular interest, representing the unobserved correlation between the stochastic components of the different types of CAP. This assumption means that Eq. (2) generates an MVP model that jointly represents decisions to adopt a particular farming practice. The use of non-zero off-diagonal elements in this specification allows for cross-correlation. The error terms of several latent equations, which represent unobserved characteristics that affect the choice of alternative CAP. When analyzing the determinants of adoption, we consider the influence of non-observable household characteristics on adoption decisions. For instance, there may be a correlation between plot-invariant characteristics (managerial ability) and the decision to adopt a particular CA technology. A pooled MVP model is consistent because unobserved heterogeneity is uncorrelated with observed explanatory variables. We exploited the multiple plot observations nature of our data and estimated Eq. (2) with and without Mundlak's [28] approach. However, this was to control for unobserved heterogeneity, including the means of plot-varying explanatory variables (e.g. average of plot characteristics, plot distance to the home of a farmer) as additional covariates in the regression model.

From our MVP model above, we conceptualized that before adopting one or more CAP, a farm household compares the net benefit of adopting and not adopting and only chooses to adopt the new CAP if the net benefit is more significant than non-adoption. Farm households tend to adopt more CAP if the household derives higher utility from the previous adoption. However, the MVP model is limited to estimating the intensity of the adoption of CAP. We, therefore, adopted the ordered probit model to evaluate the intensity of adoption. In addition, we considered assessing the extent of adoption by the numbers of CAP adopted at the household levels. This concept is related to a Poisson count distribution model; however, a Poisson distribution contradicts our assumption of the interdependence of CAP which renders it inappropriate. Usually, a standard analytical process of assessing the intensity of adoption considers the proportion of land area stipulated by some adoption studies [6]. As a result of data limitation on variables related to this, we treated our dependent variable as an ordinal variable that follows categories of ordered outcomes, for example, households that adopt one, two, or more CAP. Following Cameron and Trivedi [8], our ordered outcomes are modelled sequentially as a latent variable y^*, where y^* is an underlying unobserved measure of households' adoption of CAP in numbers, and it is specified as follows:

$$y_i^* = X_I' B + u_i \quad (4)$$

For a j^{th} farm household where normalization is that the regressors x do not include an intercept, for a low y^*, adoption of CAP is low, for $y^* > 1$, the number of CAP increases, for $y^* > 2$, adoption increases further, and this continues further. For m categories following a standard ordered probability model, the probability of observing outcome i corresponds to the following:

$$\Pr(outcome_{j=i} = \Pr(K_{i-1} < X_i'\beta + \mu_i \leq \alpha_i) \quad (5)$$

Where μ_i is assumed to be normally distributed with a standard normal cumulative distribution function. The coefficients $\beta_1 \ldots\ldots\ldots \beta_k$ is jointly estimated with the cutpoints $\alpha_1,\ \alpha_2, \ldots\ldots \alpha_{k-1}$, where k is the number of possible outcomes. The description of the outcome and control variables in the model are presented in Table 1.

Results and discussion

Social and economic statistics of the smallholder farmers

Average age of agricultural household heads is estimated at 44 years, with 18 years of farming experience (Table 1), thus indicating that heads of these households are still in their productive agriculture years. Age plays a vital role in driving household decisions to embrace agricultural novelties in many adoption studies since it might represent experience in farming methods and use. However, age is said to have a diverse outcome on CAP acceptance (Nigussie et al., 2017). Furthermore, many homes (about 45%) are headed by a woman. While this suggests that females play an important role in farming, it does not diminish the significance of male-heads, who may be land administrators impacting adoption preferences.

The average home size in the study area is seven, which implies a typical large family environment. Most agricultural settings in developing nations have large family sizes, signifying the potential for family labor use. The average farm size cultivated by many farmers is 2.42 hectares, demonstrating that the mainstream of farmers in this area are typical rural farmers. The size of a farm influences technological adoption. Larger farms size holders are more inclined to accept new methods because they can devote a section of their land to testing emerging innovations, whereas farmers with smaller farmlands are far less willing to do so (Gebremariam and Tesfaye, 2018).

Also, household size is a determining factor of CAP adoption especially at the household level for family farmlands [33]. The size of the household for example is very necessary in adopting soil and water-saving technologies, because they demand for additional labor requirements (Gebremariam andTesfaye, 2018). Household statistics revealed that 80 percent of

Table 1
Description of variables.

Variables	Calibration	Expected sign
Outcome Variables		
Agroforestry	Adoption of Agroforestry (Dummy, yes=1, No =0)	+
Intercropping	Adoption of Intercropping (Dummy, yes=1, No =0)	+
Cover Crop	Adoption of Cover crop (Dummy, yes=1, No =0)	+
Crop Rotation	Adoption of Crop rotation (Dummy, yes=1, No =0)	+
Mulching	Adoption of Mulching (Dummy, yes=1, No =0)	+
Zero/minimum Tillage	Adoption of zero/minimum tillage (Dummy, yes=1, No =0)	+
Control Variables		
Gender	Gender of farmhouse head (Dummy, female=1, male=0)	+/-
Age	Age of farmhouse head (years)	+/-
Land Size	Farmland size (hectares)	+/-
Farm Experience	Household head farming experience (Years)	+
Extension advises	Access to extension service (Dummy, yes=1, No= 0)	+
Agriculture Credit	Access to agricultural credit (Dummy, yes=1, No= 0)	+
Distance from Home to Farm	Distance from farm households to farmland (in kilometres)	-
Farms Cultivated	Number of farms cultivated (in numbers)	+/-
Household Size	Number of family members(count)	+/-
Marital Status	1 = single; 2 = common-law; 3 = married monogamous; 4 = married polygamous; 5 = widowed; 6 = Divorced/Separated	+/-
Education	Years of education of household head(count)	+
Land Ownership	Land ownership status (1= family, 2= owned land, 3= leased land	+
Perception of Soil Fertility	Perception of fertility status of soil (1=very fertile, 2=moderately fertile, 3= not fertile	+/-
Use of sustainable Farm Techniques	Modern farm technology (dummy, 1=yes, No =0)	+
Received Government Subsidies	Farmers who received government subvention (dummy, yes=1, No=0)	+
Perception of Climate Variability	If farmers perceive variability in climate (Dummy, yes=1, No=0)	+/-

(Source: Designed by authors, 2022)

Table 2
Description of socioeconomic variables.

Variables	Description	Average	Std Dev.	Min	Max
Household Factors					
Age	Age of house head (years)	44.52	14.31	19	90
Farm house Size	Number of members in the house (count)	7.26	4.79	1	35
Gender	Gender of house head (Dummy, female=1, male=0)	0.55	0.50	0	1
Marital Status	1 = not married; 2 = common-law; 3 = married monogamy; 4 = married polygamy; 5 = widow; 6 = Divorce	2.71	1.34	1	6
Education	Years of education of household head (count)	1.39	0.80	0	7
Economic Profile					
Farm Size	Farmland size(hectares)	2.42	2.64	1	28
Farms Cultivated	Number of farms cultivated (in numbers)	2.28	1.51	0	10
Land Ownership	Land ownership status (1= family, 2= owned land, 3= leased land	0.50	1.76	1	3
Farm Experience	Household head farming experience (Years)	17.79	14.23	1	70
Distance from Home to Farm	Distance from farm households to farmland (in kilometers)	56.39	50.43	1	260
Access to Extension	Contact with extension worker (Dummy, yes=1, No= 0)	0.36	0.48	0	1
Access to Credit	Available agricultural finance (Dummy, yes=1, No= 0)	0.18	0.38	0	1
Received Government Subsidies	Farmers who received government subvention (dummy, yes=1, No=0)	0.08	0.27	0	1
Use of sustainable Farm Tech	Modern farm technology (dummy, 1=yes, No =0)	0.63	0.48	0	1
Perception of Soil Fertility	Perception on fertility of soil (1=very fertile, 2=moderately fertile, 3= not fertile	1.27	0.67	0	3
Perception of climate Variability	If farmers perceive variability in climate (Dummy, yes=1, No=0)	1.03	0.19	0	1

(Source: Analysis from Survey data, 2022)

household heads had at least one year of formal training, implying that most household heads are uninformed and unable to understand best farming techniques and technical knowledge uptake.

The survey also reveals that about half of household heads are tenure secured, which is ascribed to difficulties in transferring tenure rights, as in most Central African countries [27]. While the role of extension service remains paramount to promote modern agriculture, only approximately 36% and 18% of farmers had a contact with an extension worker and farm financing, respectively. Contacts with extension advisers are critical for raising awareness, showcasing farm practical trials and techniques, while prompting sustained adoption. Paradoxically, access to extension services remains low, indicating a significant alleged risk of CAP adoption among farmers. Nevertheless, research has proven that farmer contacts with extension advisers have a favorable stimulus on uptake of innovative agricultural practices (Wekesa et al., 2017).

According to Wekesa et al. (2017) agricultural finance is a major driver of technological adoption. This study affirms this for only very few farmers had access to agricultural loans, a possible explanation to low adoption rates in this area. The

Table 3
Smallholder farming households' CAP.

Conservation Agricultural Practices	Percentage Adoption (%)
Agroforestry	61.82
Intercropping	49.86
Cover Crop	25.93
Crop Rotation	20.51
Mulching	17.38
Zero/minimum Tillage	33.90

(Source: Analysis from Survey data, 2022)

Table 4
Econometric estimates of factors influencing CAP adoption in rural farm households in Cameroon.

Parameters	Agroforestry		intercropping		Cover cropping		Crop rotation		Mulching		Zero -tillage	
	Coef	*Se*	*Coef*	*Se*	*Coef*	*Se*	*Coef*	*Se*	*Coef*	*Se*	*Coef*	*Se*
Gender	0.581***	0.158	0.239	0.157	-0.166	0.170	0.165	0.171	-0.148	0.185	0.210	0.167
Age	0.019**	0.007	-0.005	0.007	0.013*	0.007	-0.007	0.007	-0.007	0.009	0.015**	0.008
Land Size	0.047	0.035	-0.015	0.029	0.050*	0.030	0.008	0.034	0.028	0.031	-0.070	0.043
Farm Experience	-0.008	0.007	0.006	0.007	-0.008	0.007	-0.001	0.008	-0.005	0.008	0.003	0.007
Access to Extension	0.057	0.164	-0.166	0.165	0.423**	0.170	0.024	0.178	-0.446**	0.209	0.068	0.169
Agricultural Credit	0.217	0.212	-0.343	0.212	0.006	0.220	0.198	0.218	-0.006	0.245	-0.711**	0.226
Distance home-farm	0.003*	0.002	0.003*	0.001	0.001	0.002	0.000	0.002	0.003	0.002	0.003*	0.002
Number of farms	0.027	0.053	0.017	0.049	-0.038	0.060	-0.020	0.058	0.062	0.057	0.104*	0.057
Farm house size	-0.007	0.016	0.012	0.016	-0.008	0.017	-0.011	0.017	-0.005	0.018	-0.025	0.018
Marital status	0.014	0.060	-0.055	0.060	-0.079	0.066	0.025	0.065	0.044	0.072	-0.122*	0.066
Education	0.000	0.092	-0.022	0.091	0.089	0.094	-0.110	0.103	-0.055	0.119	0.155	0.095
Land ownership	-0.122	0.151	-0.181	0.152	0.349**	0.169	0.216	0.165	-0.004	0.177	-0.170	0.158
Soil fertility status	-0.003	0.108	-0.045	0.111	-0.089	0.122	-0.012	0.129	-0.439**	0.134	0.250**	0.116
Modern farm technique	0.075	0.160	0.310**	0.158	-0.327*	0.169	-0.173	0.174	0.803***	0.211	-0.857***	0.160
Government subsidy	0.127	0.304	0.145	0.295	-0.068	0.295	0.294	0.295	0.647**	0.337	0.052	0.317
Climate variability	0.265	0.360	0.706*	0.417	0.110	0.378	-0.573	0.496	0.216	0.434	-0.487	0.457
Livestock owned	-0.067***	0.018	0.098***	0.019	0.079***	0.021	0.061**	0.022	0.009	0.021	-0.026	0.019
Persistent soil erosion	0.168	0.160	-0.292*	0.158	0.269	0.166	0.175	0.171	0.055	0.188	0.142	0.163
_cons	-0.736	0.606	-1.174*	0.629	-2.256**	0.649	-0.691	0.713	-1.151	0.725	0.035**	0.660

N = 350 Log Likelihood = -1058.6109 Wald chi2 (114) = 252.23 Prob> Chi2= 0.000
*** 1%. ** 5%. * 10%.
Source: Computed from Field Survey (2022)

average years of farming expertise in this area is 18 years. This knowledge allows them to compare the performance of new and old farming technologies and gain confidence in taking farming risks which is a critical aspect to agricultural success.

Determinants of smallholder farmers' conservation agricultural practices

According to the findings, farmers in both regions adopt the following conservation agriculture practices: agroforestry (planting fruit trees in crops land), intercropping, cover crops, crop rotation, mulching, and zero/minimum tillage. Interestingly, Table 3 shows that agroforestry (fruit trees in cropland) was implemented by most smallholder farmers (61.82%), this is because of the economic benefits they get from fruits harvested from these trees. While mulching was the least popular conservation agriculture method (17.38%).

Table 4 displays the multivariate probit model's coefficient estimations. The correlation of CAP error terms suggests our six CAPs under consideration are interdependent. The findings showed that the model's log-likelihood ratio (LR) of -1058.61 and the Wald2 (114) = 252.23 is significant at (P0.00), indicating that the model is well-fitting. The significance of LR also implies that the decision to use several conservation farming strategies is interconnected. This relevance level is derived from the fact that identical unobserved home factors can influence the adoption of various CAP (Oyetunde-Usman et al., 2020).

Gender of household head has a beneficial consequence on agroforestry uptake. According to findings from this research, men were more likely than women to use agroforestry. This prediction backs up prior research that males control farming resources and, as a result, easily embrace practices that require more resources [31,33]. However, it contradicts Musafiri et al. [29], who showed that females are more likely to pursue agroforestry.

The findings show that old farmers use agroforestry, cover crops, and zero tillage more, whereas young farmers use more of intercropping, crop rotation, and mulching. The disparities in these practices could be attributed to young farmers' capacity to recognize the value of sustainable farming practices such as intercropping and mulching. These results conformed with those of Negera et al. [31] who explained that older farmers prefer to stick to the practices they already know than indulging in new exploits.

Farm size is significant (p= 0.01) only for driving cover cropping adoption, meaning that increase in farm size enhances the household chances of adopting cover crops as a conservation farming approach. As a result, a farmer with a larger farm size has more financial resources and greater area to devote to enhancing technology adoption. They can also purchase more advanced and sophisticated technologies, as well as the ability to bear risk if the equipment fails to function properly. Deininger et al. (2008) found that farm size was substantially connected to the likelihood of investing in conserving soil and water. However, Soutamenou and Parrot [35] contrast with such findings and further explained landsize as a relative measure that is specific to context and thus cannot be generalized. Correspondingly, Menale (2010) found that farm size was associated with the adoption of numerous CAP methods since it mirrors capital, which alleviates liquidity limitations in applying the practices. They discovered that farmhouses with large farms have greater chances to use current technology than farmers with smaller farm sizes.

Contact with extension agents had a considerable beneficial influence on cover crop uptake, whereas mulching had a negative influence. Extension agents are critical in raising knowledge of and showcasing new CAP technology. Fundamentally, the more contacts made, the more knowledge gained, because sustainable farming necessitates new abilities such as observation, monitoring, and risk assessment. The results relate to the necessity of knowledge on applying cover crop strategies rather than mulching. These results are in support with those of Gido et al. [15], who postulates that extension advice is important for developing institutional frameworks that facilitate the propagation and transfer of information. However, our findings, agree with Anang et al. [2], who emphasized the vitality of extension service in increasing new farm method acceptance.

Availability of loans for farming has a negative impact on zero tillage adoption and this is contradictory to the results of Lee and Gambiza [23]. Farmers with access to agricultural financing no longer see the need to use zero-tillage since they have more money to spend on inputs for other techniques. Furthermore, the distance between home and farm encourages the use of agroforestry, intercropping, and zero tillage. Shorter distances encourage farmers to adopt these strategies. The number of farmlands a farmer owns has a favorable influence on zero tillage adoption, and a farmer with more cultivable farms has the comfort of experimenting with various farming techniques on one of the farms. In contrast, marital status had a strong negative relationship on zero tillage adoption. Marriage generates family labor, and because women and children can assist in crop production, processing, and marketing, the household can engage in more labor demanding agricultural practices such as intercropping.

Land ownership also facilitates household decision to implement innovative farm methods. According to findings from this study, land security played a substantial role in increasing the use of cover crops. Sotamenou and Parrot [35] reported land ownership to be a major factor in the adoption of compost in the West regions of Cameroon. As a result, farmers who own their farms may employ intricate and resource demanding conservation methods. This consequence could be because land security permits farmers to explore complicated technologies, impacting cover crop use. Also, soil fertility had a considerable impact on zero-tillage adoption but had a negative impact on mulching adoption. This can be clarified further by stating that soil fertility is said to impact the uptake of recovery methods, and zero-tillage is a soil fertility recovery practice. As a result, a farmer with infertile soils will prefer zero-tillage to mulching. The discovery could boost soil fertility by utilizing minimal tillage, hence increasing livelihood and food security.

Furthermore, farmers may expect reduced output from infertile soils, resulting in a refusal to apply more costly strategies. This finding supports that of Musafiri et al. [29]. Furthermore, the coefficient for a farmer using modern farm technologies such as improved seeds is a significant promoter of adoption of intercropping and mulching as conservation farming methods. However, modern farm technology is a facilitator of farmer's uptake of cover crop and zero-tillage. Results from this research postulates modern agricultural techniques to be a predicting factor for the likelihood of farmers in Cameroon's South and East Forests using conservation farming strategies such as intercropping and mulching.

The number of animals owned has a favorable influence on intercropping, cover crop, and crop rotation adoption but has a negative influence on agroforestry adoption. The findings revealed that as animal ownership increased, so did the proclivity for intercropping, cover crops, and crop rotation. The larger requirement for animal manure for crop farms may explain the influence of livestock ownership on intercropping, cover cropping, and crop rotation. However, animal dung might potentially be used to boost soil fertility by being applied to agricultural land. Nonetheless, these outcomes align with Ndeke et al. [30], who indicates keeping livestock as a strong predictor of improved technology adoption.

CAP adoption intensity

Smallholder farmers must enhance their adoption intensity in order to improve agricultural yields and revenue while also reducing the effects of climate change [33]. From our findings the model used is significant, as indicated by the LR Chi^2 (18) = 41.36 and Prob $> \text{chi}^2 = 0.0014$. This degree of significance shows that the ordered probit model is trustworthy. Gender of household head indicated severity of CAP adoption (Table 5).

According to the findings, male-headed households improve their agricultural methods more than female house heads. This can be ascribed to the fact that men in this area have an edge over land and labor [20]. However, these results are contrary to those of Oyetunde-Usman et al. [33], which postulate female-headed families to boost sustainable farming methods, attributing this to a shortage of complementary inputs. They are, nevertheless, identical to Musafiri et al. [29]. Short distance

Table 5
Factors that influence intensity of adopting conservation agricultural practices.

Variables	Coefficient	Std Error	P-Value
Gender	0.2550**	0.1219	0.037
Age	0.0061	0.0055	0.268
Land Size	0.0114	0.0228	0.617
Farm Experience	-0.0035	0.0054	0.518
Access to Extension	0.0126	0.1264	0.921
Agricultural Credit	-0.0369	0.1611	0.818
Distance from home to farm	0.0026**	0.0011	0.022
Number of fields cultivated	0.0554	0.0395	0.160
Household size	-0.0123	0.0121	0.311
Marital status	-0.0291	0.0469	0.536
Education	-0.0185	0.0709	0.794
Land ownership	-0.0007	0.1180	0.995
Perception of soil fertility	-0.0168	0.0859	0.845
Use of modern farm techniques	-0.1317	0.1224	0.282
Government subsidy	0.3784*	0.2257	0.094
Perception on climate variability	0.0231	0.2815	0.935
Livestock owned	0.0742***	0.0148	0.000
Persistent soil erosion	0.1439	0.1223	0.239
Number of observations =350 LR Chi^2 (18) = 41.36 Prob > chi^2 = 0.0014			
Log Likelihood = -612.735 Pseudo R^2 = 0.0326			

*** p<0.01. **P<0.05. *p<0.1.
Source: Computed from Field Survey (2022)

from home to farmland affects CA adoption intensity positively and significantly, which is consistent with other findings [35]. Given that valuable equipment and materials are typically owned by households for security reasons, the closer the land is to the house, the greater the likelihood of storing and, as a result, adopting CAP.

Our results reject the claim that smallholder farmer adoption of more than one CAP increased with distance from the farm. This is attributed to the fact that, households that reside far from the farm, nevertheless, are more likely to use CAP. This conclusion explains why farmers will want to optimize the amount of time they spend on the farm and thus implement many farm technologies to ensure a satisfactory harvest if one way fails. Contrary to popular belief, access to farms that drive adoption may not be limited by distance and may rely on locally available information networks. The strong forecast of our results of government subsidies on multiple CAP adoption meant that smallholder farmers who got subsidies were more inclined to intensify agricultural methods. Receiving subsidies encourages the smallholder farmer to try a new farm practice, thus boosting their use of CAP.

Furthermore, livestock ownership has a considerable impact on CAP intensification, as shown in Table 5. This finding emphasizes the significance of animals in agricultural intensification, with the possibility that animal droppings are employed as manure. However, these outcomes align with results of Ehiakpor et al. [11], who ascribed cattle ownership to have a considerable impact on intensity of sustainable farming methods uptake. This fervor is ascribed to the likelihood of selling animals to buy farm need like agricultural chemicals, manures, and improved seeds.

Conclusion

This paper addresses the adoption of conservation agricultural methods in Cameroon by evaluating the scope of CAP implementation and the intensity of CAP adoption. Previous studies show that factors associated with the adoption of CAP are interwoven with social, demographic, and Institutional aspects. For our case study, the multivariate probit model (MVP) regression was used to estimate the factors that influenced the adoption of CA practices. The ordered probit model was then employed to analyze the intensity of adoption. From the MVP estimation, our study finds that gender, age of house head, family size, extension advise, usage of contemporary farm technology, distance from house to farm, animals owned, and infertile soil enhanced farmers' potential to adopt CA. Results of the ordered probit analysis on intensity of adoption attributes the respondent's gender, distance from home to farm, and animal ownership as important determinants of CAP adoption intensity.

This study has important policy implications that traverse through the African Union's Agenda 2063 to the Malabo Declaration. A better performing farm sector not only guarantees food security but also good nutrition, health, farm value, and protection of the continent's natural endowments. A resilient climate-smart agricultural sector would imply economic and socially resilient communities in the face of climate change. There are therefore gains for agricultural policy and investments that prioritize the adoption and applicability CSA. This research contributes to better understanding of gender, government subsidy, and livestock ownership as central factors in promoting adoption of climate smart agriculture. Policy that alleviates the challenges faced by women farmers, ensure properly tailored subsidy programmes and facilitates mixed farming whereby the livestock component would contribute to the promotion and development of sustainable agriculture which is climate smart. Therefore, not only does this study shed new light on the area or country under study, but also on the central

African countries that share similar ecological zones. Moreover, this study adds to the body of knowledge that intercropping, cover crops, and crop rotation are more likely to be adopted by farmers in areas where integrated crop-livestock farms are present than in areas where these practices are not.

Considering the foregoing, we recommend that policymakers develop pro-farmer policies that incorporate rural farmers own indigenous ideas of conserving land and their environment not only focusing on the obvious rational proven approaches. Given that a multitude of factors influence CAP adoption, planners should look outside the box when optimizing CAP adoption to address smallholder views on soil fertility, erosion, and climate variability. More importantly, attention should be directed to farmers who are able to timely perceive issues on fertility and erosion of soils, and climate variability to increase CAP implementation.

Data availability

The data used for this study is readily available upon reasonable request.

Declaration of Competing Interest

All authors declare that they have no known competing financial interests or personal ties that can influence material and results presented in this paper.

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