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Small-scale Farmers' Adoptions of Climate-smart Agricultural Practices in the Guinean Savanna's Agroecological Zones

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ABSTRACT

Purpose: *The Guinean Savanna is the largest agro-productive area in Guinea and the most vulnerable to climate-induced hazards that challenge farming practices and cause crop failures. Subsequently, small-scale farmers have recently lent themselves to climate-smart agricultural practices (CSAPs) as alternatives to maintain food security. Developing such practices has led this study to identify farmers' know-how of CSAPs and the factors motivating these practices.*

Research Method: *Methods including household surveys, focus group discussions, key informant interviews and field observations were used to collect data from a purposive random sample of 1,500 small-scale farmers in nine agroecological zones susceptible to drought and flood. A multivariate probit model was used to determine factors influencing small-scale farmers' adoption of CSAPs.*

Findings: *Results show that adoptions of CSAPs were influenced by farmers' socio-economic characteristics including access to income sources from non-farm activities, holding of livestock and/or a plantation, perceived impacts of climate change, and membership to a farm-based organization. Other factors such as farming experience, educational level, gender and age were also motivating farmers to adopt CSAPs. On the contrary, household size was not significant in adopting CSAPs in the Guinean Savanna.*

Research Limitations: *This study only covers 9 of the 17 agroecological zones that make up the Guinea Savanna.*

Originality/value: *Being the first study that showed an interest in CSAPs in the study area, it provides information that could enhance food security and communities' resilience.*

Keywords: *climate change adaptation, climate-smart agricultural practices, resilient farming systems, sustainable livelihood*

INTRODUCTION

The projected impacts of climate change (CC) on Africa's agricultural production systems will profoundly affect its food security, especially in small-scale farmers' systems with low adaptive capacity and heavily dependent on rainfed agriculture (Hlophe-Ginindza and Mpandeli, 2020) Up-to-date, Africa's nutritional profile shows that it is the most food-insecure region of the world where undernourishment is expected to increase by 33% by 2025 while Sub-Saharan

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Africa's (SSA) population is expected to increase by 33.6% in the same year, which is higher than the average growth of 10.5% in other developing countries (OECD and FAO, 2016). Given this situation and in the face of increasing disruption of current climatic conditions, climate-smart agriculture (CSA) aims to boost agricultural systems' capacity to sustain food security by integrating CC adaptation and mitigation strategies into the agricultural development agenda and related policies (FAO, 2013). It appears to be an important determinant of Africa's food security as well as its economic take-off (Barasa *et al*., 2021). Hence, building resilient farming systems to CC and variability is an urgent African development need due to its significant contribution to food security, poverty alleviation and its heavy reliance on natural resources (FAO, 2021).

Agriculture is one of the most contributing sectors to greenhouse gas (GHG) emissions highly dependent on weather and climate conditions (Lynch *et al*., 2021) To reverse this trend, CSA seems to be very promising and refers to agricultural practices that sustainably increase productivity and resilience while reducing GHG emissions (Partey *et al.*, 2018; Torquebiau *et al*., 2018) Thus, farmers' ownership of CSA has the potential to reduce adverse impacts of CC on livelihood sources as well as to reduce GHG productions in traditional farming systems which involves the majority of Africa's agricultural force heavily dependent on natural resources as basic assets (Wekesa *et al.*, 2018). Seemingly, 95% of Africa's agricultural activities are rainfed-dependent (Hlophe-Ginindza and Mpandeli, 2021) Therefore, moving small-scale farmers beyond existing subsistence farming to sustainable livelihoods and food security requires innovative approaches to climate-resilient infrastructure development, awareness-raising activities, and funding programmes (Phiri *et al*., 2021). Nowadays, factors such as poor access to climate information, lack of agricultural inputs, poor delivery of agricultural extension services, little access to microcredit and insurance, production infrastructure gaps, and low literacy level of farmers, hamper the uptake of CSA and the production of climate-resilient livelihoods in SSA (Kaptymer *et al*., Jellason *et al*., 2021). These factors isolate poor small-scale farmers from the mainstream economy as well as from significant agricultural value-chains in the African continent (Makate *et al*., 2016) as they did not yet get adequate attention in their long-term challenges amidst climate-induced disasters (Mbuli *et al*., 2021).

Both agriculture and mining are major sectors contributing to Guinea's economic progress as they each contribute to 20% of the national gross domestic product (GDP) (World Bank, 2018). Agriculture alone employs nearly 80% of the economically active population, mainly driven by rural small-scale farmers strongly dependent on rain-fed agriculture (Guinean government, 2018). Factors such as land-use changes associated with unsustainable agricultural practices as well as mining companies' negative impacts on the natural environment are major sources of GHG production in Guinea (Dimé, 2021). Therefore, the increase in agriculture-based climate-smart agricultural practices (CSAPs) becomes an opportunity to reduce GHG production, improve farmers' productivity and income and build resilience in farming systems (Barasa *et al*., 2021). To this end, the Guinean Savanna's agroecological zones (AEZs) which are home to most of the country's farmers who derive their livelihoods mainly from rain-fed agriculture and livestock (USAID, 2017) could significantly contribute to scaling up Guinea's food security with CSAPs.

The Guinean Savanna's AEZs remain largely untapped despite their great agricultural potential and market opportunities, and CSAPs tend to improve this recently (International Fund for Agricultural Development, 2018). Made up of crucial rural areas for agriculture-dependent livelihoods, small-scale farmers are involved in several crops production over 70,000 km^2 of cultivable land, and practicing other livelihood activities such as fishery, livestock rearing, forestry, small-scale mining, gathering wild fruits, and wildlife hunting (Holt, 2016). Despite these numerous assets, the agricultural sector is still unsuccessful in meeting households' food and nutrition needs (African Development Bank Group, 2018). Factors including farmers' poor access to social basic services, lack of technical assistance, limited access to agricultural inputs, institutional barriers, and financial challenges seem to be impediments to the widespread adoption of CSA in this region (MacNairn, 2017). Such conditions have constrained farmers to remain focused only on their experiences, skills, and knowledge gained over time, while CSA without institutional support may not have significant impacts on farmers' well-being (Alare *et al*., 2018). Incorporating such experiences, knowledge, and skills into agricultural technology development has the potential to help small-scale farmers make a smooth transition to CSAPs (Weniga Anuga *et al*., 2019) Moreover, identifying current determinants of CSAPs among small-scale farmers could inform decision-makers on appropriate policy formulation that enhances food production and builds the resilience of farmers.

Broadly, several scholars (Njuguna *et al*., 2019; Issahaku and Abdulai, 2020; Nyang'au *et al*., 2020; Zakaria *et al*., 2020) have already undertaken studies about factors influencing the adoption of CSAPs by farmers. However, factors influencing farmers' decision to adopt various combinations of CSAPs to deal with climate constraints remain poorly explored by researchers and are site-specific, socio-economic, environmental, physical and institutional factors (Dinesh and Vermeulen, 2016) This constitutes a gap in an effective understanding of factors that promote or inhibit the adoption of CSA. Additionally, to the best of our knowledge, limited evidence exists about factors driving CSAPs in the study areas, which adds value to the study. These have led to conducting this study for informed decision-making to improve food production and strengthen farmers' resilience.

This allowed us to:

- Explore small-scale farmers' know-how of CSAPs in the Guinean Savanna's AEZs
- Examine factors influencing farmers' decision to adopt various combinations of CSAPs to deal with climate constraints in the Guinean Savanna's AEZs.

MATERIALS AND METHODS

The Study Sites

The Guinea Savanna, a sparsely vegetated zone composed of woodland-grassland is the third national geographic region of Guinea after Lower and Middle Guinea, the last being Forest Guinea. Covering 39% of the country's total area, it is prone to a wide range of human and natural-induced hazards including bushfires, drought and flood (Dara, 2013). Its location on the western edge of River Niger's vast basin offers small-scale farmers suitable conditions for agricultural production across floodplains. It is made up of 17 agroecological zones with 70,000 km^2 (71%) of cultivable land (Institut de Recherche Agronomique de Guinée, 2001) where farmers are practicing rain-fed agriculture (Figure 01). Productions are primarily used for subsistence and the surplus is sold in the local market to purchase other needs. As a very fragile area, the whole region will continue to be impacted by the new climatic conditions combined with rapid population growth which is causing greater pressure on renewable resources (Kante *et al*., 2019).

Sampling Frame and Size

The multistage sampling technique was used in selecting study areas and sample sizes. First, seventeen (17) AEZs that make up the Guinea Savanna were identified based on the guidelines of the Guinean Institute for Agronomic Research (IRAG). Among these seventeen AEZs, nine (Bassando, Dion-Niandan Inter-River, Fié Basin, Foutanian Piémont, Kolokalan High Valley, Middle Plateau, Solima's High Plateau, Soudanese Plateau and Woulada Plateau) containing mainly rural communities (RCs) most affected by drought and flood episodes were purposively selected (Table 01) based on guidance from local environmental bodies and humanitarian affairs coordinators. Within each selected AEZ, RCs at higher risk were retained. As a result, the most affected RCs with 548,153 individuals were considered as the study population. From 548,153 individuals, a purposive sample of 1,500 households was chosen, and for a population of over 150,000 inhabitants, a purposive sample size of 1,500 households is required (Neuman,1991). To ensure a reasonable distribution of the sample and to minimize inaccuracies due to the shrinkage or growth of some communities, the probability proportional to size (PPS) sampling procedure was applied by using Equation 1.

$$S_i = \frac{N_i}{Total\ population\ of\ the\ selected\ AEZs} 1{,}500 \quad (1)$$

Where determines the number of households selected by AEZ and represents each AEZ's total population.

Data Collection

Closed-ended and open-ended questions were used to collect data from respondents made up of males and females. Sampled households were chosen systematically by starting from the first randomly selected household to the last according to the sample size in each selected community. Within each household, the household's head either male or female was selected and responded to questionnaires. Questionnaires were raised on farmers' know-how of CSAPs as well as their sociodemographic characteristics, and economic conditions.

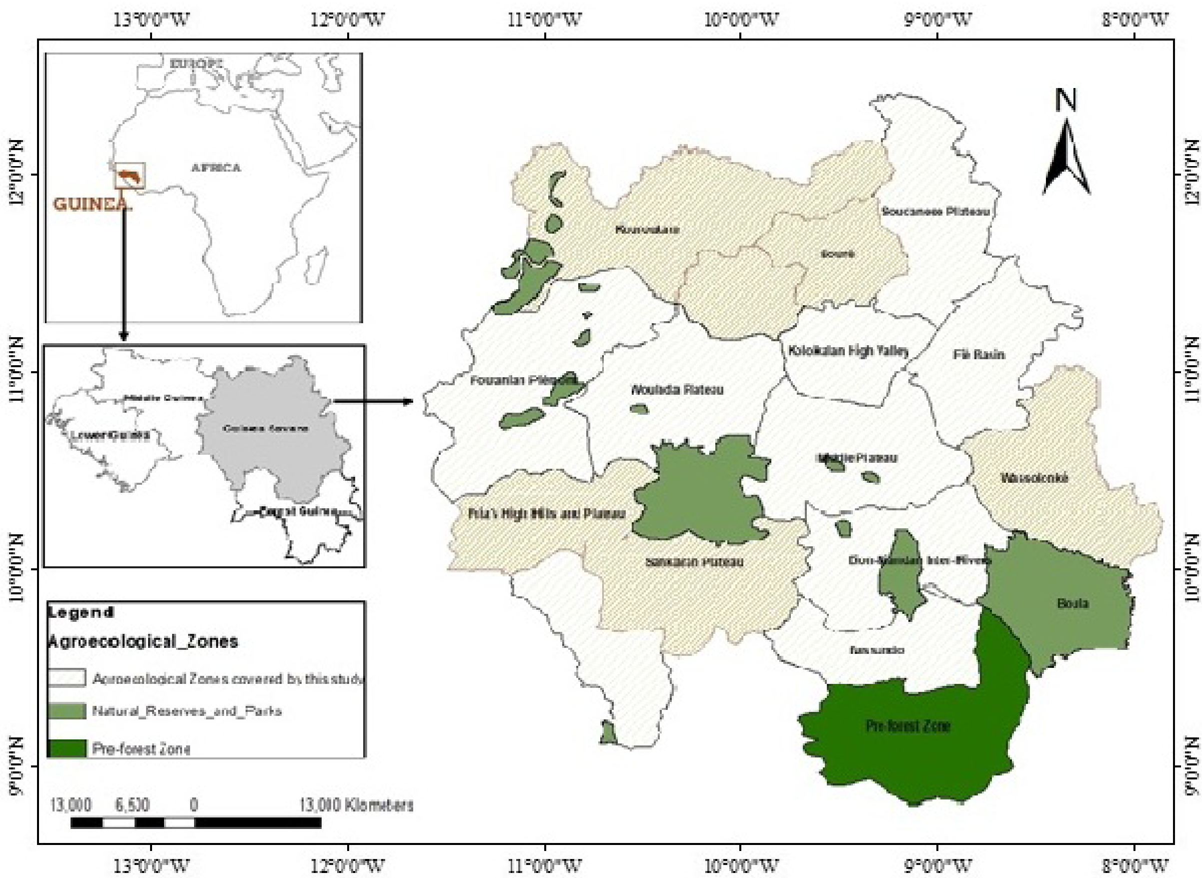

Figure 01: Map of Guinea Savanna showing the Agroecological Zones

Table 01: Sampled households' distribution by Agroecological zones

AEZs	Sample size
Bassando	41
Dion-Niandan inter-river	108
Fié basin	153
Foutanian Piémont	188
Kolokalan high valley	306
Middle plateau	374
Solima's high plateau	50
Soudanese plateau	215
Woulada plateau	65
Total	1,500

Moreover, focus group discussions (FGDs) and key informant interviews (KIIs) were used to collect substantial information that couldn't be obtained from household surveys. The corresponding members were purposely selected based on their in-depth agricultural experience and knowledge of their surrounding environment. FGDs members included 8-12 participants per community and were made up of different community members including, farmers, religious leaders, communities' kings, farm-based organizations, and school teachers. Two targeted farmers based on their significant and relevant contributions to the debates on issues raised during FGDs were used for KIIs in each community.

From the centre to the northern part of the study area, the local language Maninka was used to collect data while the Djallonka language was used to collect data in the southern part. Additionally, direct field observations were also conducted for supplementary information on farmers' land-use types and changes, farm-based activities, and existing resources.

Data Analysis

Sources and description of variables used in the analysis: Explanatory variables including farmers' socio-demographic characteristics, perception of climate risks, and economic capital which describes differences in wealth among small-scale farmers (Table 02) were selected through explorations of published papers (Ozor *et al*., 2011; Apata, 2012; Weniga Anuga *et al*., 2019and exacerbating the risks associated with farming. Smallholder farmers, especially from developing countries, have been identified as the most vulnerable to climate hazards due to prevalence of low adaptive measures. Climate Smart Agriculture (CSA; Nyang'au *et al*., 2020) and which were appropriate to the study area. Dependent variables used in this study encompass small-scale farmers' CSAPs namely agroforestry intercropping (AFI), crop diversification (CD), cultivation of improved crop varieties (CICVs), use of early maturing varieties (EMVs), changing the timing of planting (CTP), and livelihood diversification (LD). Practices that were not viable or did not fall into the CSA framework were not considered in this study. Such CSAPs were realized either by combination or by substitution by small-scale farmers in selected AEZs of the Guinea Savanna.

***Descriptive analysis of data*:** Respondents' socio-demographic data were subject to descriptive statistical analysis using Microsoft Excel (version 2019) and a Statistical Package for the Social Sciences (SPSS version 21.0) to generate frequency tables, the mean and standard deviation for analysis purposes.

***Econometric analysis of data*:** The multivariate Probit (MVP) model was used to examine factors influencing farmers' decision to adopt various combinations of CSAPs in dealing with climate constraints in the Guinean Sarvanana's AEZs. The MVP model was preferred to account for the independence amongst practices as farmers might adopt various practices regarding climate change conditions (Kangogo *et al*., 2021). It includes a set of six binary dependent variables representing viable CSAPs of farmers in the study areas and nine independent dummy variables (Table 02) influencing CSAPs.

Following Kangogo *et al.* (2021), the MVP model used is as follows:

$$Y_{ik} = X_i \beta_k + \varepsilon_i, \qquad k = 1, \ldots\ldots 6 \quad (2)$$

$$Y_k = \begin{cases} 1 & if \quad Y^*_{ik} > 0 \\ 0 & otherwise \end{cases} \qquad k = 1, \ldots\ldots 6 \quad (3)$$

Where k represents existing CSAPs including livelihood diversification, crop diversification, uses of early maturing varieties, agroforestry intercropping, changing the timing of planting, and cultivation of improved crop varieties, practiced by i^{th} farm household. Y_{ik} is the latent variable determined by unobserved explanatory variables X_1, X_2, X_3... X_i. Then, ε_i and β_k are respectively the error term and the vector of parameters to be estimated.

Table 02: Description of the Variables

Dependent variables	Description		SD
Livelihood diversification (D)	1 if applied 0 if not applied	0.26	0.44
Crop diversification (D)	1 if applied 0 if not applied	0.52	0.5
Early maturing varieties (D)	1 if applied 0 if not applied	0.40	0.49
Agroforestry intercropping (D)	1 if applied 0 if not applied	0.13	0.33
Changing the timing of planting (D)	1 if applied 0 if not applied	0.47	0.49
Cultivation of improved crop varieties (D)	11 if applied 0 if not applied	0.05	0.21
Explanatory variables			
Age (C)	Years	61	11.5
Gender (D)	1 for Female and 0 for Male	0.89	0.3
Educational level (C)	Years	1.87	3.30
Household size (C)	Number of household members	12.64	5.38
Farming experience (C)	Farmers' farming experience (in years)	18.32	9.92
Income source from non-farm activities (D)	1 if the farmer participates in a non-farm activity, and 0 if otherwise	0.25	0.43
Holding of livestock and /or plantation (D)	1 if the farmer possesses livestock and/or plantation, and 0 if otherwise	0.49	0.50
Perceived impact of climate change (D)	1 if the farmer is aware of changes, and 0 if otherwise	0.87	0.33
Membership to a farm-based organization (D)	1 if the farmer is a member of an agricultural-based group, and 0 if otherwise	0.15	0.35

In the context of multiple CSAPs, the error term jointly follows a multivariate normal distribution with zero conditional mean and variance and symmetric covariance matrix Ω is given by equation 4:

$$\Omega = \begin{bmatrix} 1 & \rho_{12} & \rho_{13} & \rho_{14} & \rho_{15} & \rho_{16} \\ \rho_{21} & 1 & \rho_{23} & \rho_{24} & \rho_{25} & \rho_{26} \\ \rho_{31} & \rho_{32} & 1 & \rho_{34} & \rho_{35} & \rho_{36} \\ \rho_{41} & \rho_{42} & \rho_{43} & 1 & \rho_{45} & \rho_{46} \\ \rho_{51} & \rho_{52} & \rho_{53} & \rho_{54} & 1 & \rho_{56} \\ \rho_{61} & \rho_{62} & \rho_{63} & \rho_{64} & \rho_{65} & 1 \end{bmatrix} \quad (4)$$

Where, ρ is the correlation between the error terms.

Data from FGDs and KIIs were analyzed through Content Analysis (CA) (Bengtsson, 2016). CA aims to turn a lot of raw data into usable evidence through data reduction methods (Hawkins, 2013). The overall collected information from field observations in addition to those obtained from FGDs and KIIs were integrated into the discussion and were also used to comment on the results of the study.

RESULTS AND DISCUSSION

Respondents' Socio-Demographic Characteristics

The results showed that 10.7% of the 1,500 respondents were women while men made up 80.3% of respondents. The ages ranged from 40 to 87 years old. 60.3% of households had between 10 and 20 members; 8.7% had up to 20 members, and 31% had fewer than 10 members (Table 03). These large households might be related to mining activities and polygamy. This consolidates the findings of Drammeh *et al.* (2019) and Nyangasa *et al.* (2019) who assert that large households are the leading factor of malnutrition in Africa.

Main Crops Produced in Agroecological Zones of the Guinean Savanna

Results reveal that small-scale farmers were involved in several crop productions, mainly rice as Guinea's staple food. Rice production covers two-thirds of cultivated land across the country (World Bank, 2018). However, other crops were particularly grown based on certain climatic conditions and soil quality. This was the case with the yam particularly adapted in the Dion-Niandan inter-River zone, the cotton especially in the Soudanese Plateau, and the sorghum in the Fié Basin (Table 04).

Crop production was also related to the diet which constitutes an important factor that influences food production in the Guinean Savanna. This was the case with cassava and maize which often serve to prepare a kind of meal named "Too" in the local language, a food largely consumed in the northern part of the country notably in the Sudanese and Middle plateau. Rice production covers the entire region but was dominant in the southern part of the study area notably in Bassando and Solima's high plateau. Harvests were largely used for household food consumption and seeds for the following season, while they did not even cover some households' food needs.

Farmers' Know-how of CSAPs in the Guinean Savanna's AEZs

Farmers' core perceived impacts of CC: Results show that 87.33% of respondents had noted changes in climate conditions while 12.67% of respondents were undecided about noticing a change. These results are inferior to those noted by Abdureman Omer and Hassen (2020) in the Oromia Region, Kurfa Chele District in Ethiopia, where almost all respondents (97.4%) were aware of climate change.

Despite emerging weather disruptions, a lack of formal education has prevented some small-scale farmers from noting meaningful changes in their environment. Among those who perceived changes in climate conditions, 25.40% noted changes in crop yield, 16.33% noted changes in rainfall, 4.07% noted temperature changes, 28.87% noted increased drought episodes and 12.67% noted increased flood episodes (Table 05).

These results are consistent with several scholars' findings who have shown that farmers are aware of changing weather and climatic conditions (Le Dang *et al*., 2014; Callo-Concha, 2018; Adjebeng-Danquah *et al*., 2020). However, awareness-raising processes should continue to be promoted in rural areas where a large part of people with no formal education make their living.

Farmers' CSAPs: Results show a low level of adoption of CSAPs in the Guinean Savanna with averages not exceeding 50% except for crop diversification (Table 06). CSAPs were mainly motivated by farmers' socio-economic conditions. Viable CSAPs were agroforestry intercropping (13.1%), changing the timing of planting (47.1%), crop diversification (52,3%), use of early maturing varieties (40.3%), livelihood diversification (26.4%), and cultivation of improved crop varieties (5.1%).

Table 03: Sociodemographic characteristics of respondents

AEZs	Total respondents	Gender		Age		
		M	F	Average	Min	Max
Bassando	41 (3%)	36	5	59	44	79
Dion-Niandan Inter-River	108 (7%)	94	14	60	40	83
Fié Basin	153 (10%)	141	12	60	40	85
Foutanian Piémont	188 (13%)	164	24	60	40	83
Kolokalan High Valley	306 (20%)	277	29	61	40	87
Middle Plateau	374 (25%)	336	38	61	40	83
Solima High Plateau	50 (3%)	42	8	65	40	85
Soudanese Plateau	215 (14%)	192	23	62	40	81
Woulada Plateau	65 (4%)	57	8	58	40	84
Total	1500	1339	161	60.77	40	87

Table 04: Main crops produced in agro-ecological zones by ethnic groups

AEZs	Main ethnic groups	Varieties of crops produced
Bassando	Maninka, Kouranko	Rice, Cassava, Groundnut
Dion-Niandan Inter-River	Maninka, Wassolonka	Yam, Rice, Cotton, Cassava
Fié Basin	Maninka, Wassolonka	Rice, Maize, Sorghum, Groundnut, Cotton, Casava
Foutanian Piémont	Fulani, Tukulor	Rice, Groundnut, Cassava, Maize
Kolokalan High Valley	Maninka	Rice, Maize, Cassava, Groundnut, Cotton
Middle Plateau	Maninka	Rice, Maize, Cassava, Potato
Solima High Plateau	Djallonka, Maninka, Lele	Rice, Cassava, Fonio, Maize, Tomato
Soudanese Plateau	Maninka	Maize, Cotton, Groundnut, Sorghum, Rice, Casava
Woulada Plateau	Maninka, Djallonka, Fulani, Tukulor	Rice, Maize, Groundnut, Cotton, Casava

Table 05: Small-scale farmers' core perceived impacts of climate change

Farmers' Perceived Impact of CC	Frequency	Percentage
Change in crops' yield	381	25.40
Change in rainfall	245	16.33
Change in temperature	61	4.07
Do not know	190	12.67
Increased drought episodes	433	28.87
Increased flood episodes	190	12.67
Total	1,500	100

Little interest in CSA was also reported by Abdureman Omer and Hassen (2020) in the Kurfa Chele District in Ethiopia where agroforestry was adopted only by 19.28% of farmers against 13.1% in the Guinean Savanna, and 14% in Bungoma County, Kenya (Njuguna *et al*., 2019). This could be explained by the poor provision of basic social services to people in the study area notably in terms of support for subsistence farming.

Agroforestry intercropping: Results show that few farmers were involved in AFI (13.1%) as CSA practice. Limited access to information about the potential of agroforestry in improving soil quality and enhancing food security could explain its low uptake. Observations show that farmers holding cash crop plantations such as cashews, avocado trees, lemon, orange trees, etc., were able to meet their family's urgent needs compared to non-owners. Njuguna *et al*. (2019) also found 14% of farmers practicing agroforestry in Bungoma County, Kenya.

Changing the timing of planting: 47.1% of respondents were making changes in the cultivation calendar, which was also observed by Kangogo *et al*. (2021). Respondents claimed that emerging climatic conditions were the main factor driving late or early farming practices in the Guinean Savanna. Hence, respondents were either rushing one agricultural activity or delaying another one. However, they agreed that May 15th was the starting point of agricultural activities without any disturbances in weather or climate conditions. As a symbol, they believed that at this particular point in time, it was likely to find water droplets in any container spilled on the floor in the open area for a minimum of 24 hours. So, finding water bubbles at the bottom of a container placed on the ground indicated that agricultural activities may start. Much often-used mortar for this experiment. Although this knowledge existed, observations have shown that there was an urgent need for agricultural extension services or advisory support.

***Crop diversification*:** Results reveal that CD was well practiced by a significant fraction of the Guinean Savanna's farmers (52.3%). However, this result is inferior to the finding of Nyang'au *et al*. (2020) in Kenya where 87.3% of farmers were practising CD. In the Guinean Savanna, many varieties of crops with the same or different species were grown by farmers. These usually included a mixture of grasses, legumes and vegetable crops like cassava or potato. For example, in wooded areas, farmers liked growing for the first time rice and other compatible crops on new lands, followed by cassava which has no proper roots but tubers that could easily be developed in an already fertile and flexible area. Fonio and okra came after the cassava, which grows in a very flexible and well-prepared land. Farmers were cultivating fast-growing crops alongside slow-growing crops on the same soil so that the first one that reaches maturity is harvested to make room for the second which takes time. Moreover, they often plant low crops such as pepper, pineapple, eggplant, etc., under tree crops, while cereals like rice, maize, sorghum, Fonio, etc., were cultivated in the open sky because of their high demand for solar light for photosynthesis.

Use of early maturing varieties: 40.3% of respondents were using EMVs. Based on their opinions, the use of EMVs was an option to counter hostile weather and climate conditions but also to avoid food shortages as subsistence farming was far from ensuring large households' food needs within a farming year. Some farmers complained about labor shortages or technical equipment required to perform such practices. On the contrary, those who had family labor or owned an animal-drawn plough found it easy to engage in early seeding operations. The early maturing varieties' utilization is improving as Ogada *et al*. (2020) found an increase in the number of farmers using it (40 to 70%), between 2013 and 2016.

Livelihood diversification: Farmers' access to income-generating activities in addition to agricultural activities was low (26.4%). This result is consistent with that of Akrofi-Atitianti *et al*. (2018) in Ghana (38%), although lower than that of Onyeneke *et al*. (2018) in Nigeria where farmers diversified activities from farm to non-farm activities 50%. The farmers of the Guinean Savanna were deriving their livelihood mainly from hand hoe as a large part of them were illiterate. Apart from farming, other farmers were involved in off-farm activities such as small-scale mining, fishery, and small trade heavily depending on crop products and wild foods. However, such activities were also getting serious issues as an interviewee in Fié Basin asserted this:

> *"I used to send my older sons to work in mining zones as a livelihood alternative following the crop failures, and if God helps us, they can bring back home some money to resolve pressing family needs. But nowadays, these alternatives are getting worse due to the scarcity of gold and high population pressure over such resources*.

Cultivation of improved crop varieties: 5.1% of respondents had access to improved crop varieties in the Guinean Savanna which is largely inferior to those found by Martínez and Pachón (2021) in Colombia (60.6%). This means that poor farmers in developing countries remain less involved in CSAPs. The improved rice varieties used by farmers were interspecific hybrids named Nerika or New rice for Africa as a result of a cross between an Asian variety (*Oryza Sativa* L.) and an African variety (*Oryza glaberrima* Steud.). Interviewees clearly show that their low access to improved varieties was due to their limited access to extension services, and financial issues. Moreover, farmers ascertained that improved varieties of seeds were purchased mainly from the informal sector and a few from official agro-dealers. Consequently, farmers' production gains were driven mainly by the enlargement of cultivated area and the use of fertilizers rather than their access to improved crop seeds which were highly accessible to people with improved sources of income. Rice varieties such as *Sika, Kologbè*, *Chinese,* and *Dissibakhoulén*, were widely used by farmers to deal with hostile climatic conditions. But recently, farmers argued that emerging weather conditions were likely to exceed the tenacity of these aforementioned varieties.

As underlined above, farmers' know-how of CSAPs in the Guinean Savanna has not yet evolved technically and practices were strongly linked to their economic status and experiences. Limited access to agricultural extension services as well as technological and institutional gaps have led farmers to remain focused on their skills and experiences acquired over time. According to the investigation made, extension services were weak and unproductive, agents were few (1 agent for 10,000 farmers) and were faced several financial issues that prevented them from moving from administrative centers towards rural communities where their services were most needed. Farmers on their side were mostly based on chemical fertilisers' utilization which was the basis of intense crop production and the inability to obtain fertilizers was detrimental to households' food gain. Hence, the provision of fertilizers was the most needed input of farmers. However, the greatest obstacle was that the government was unable to provide a sufficient quantity that could cover this wide geographic zone but was just delivering to accessible areas. According to farmers, the little that the government used to send was also diverted to the profit of the traders who still resold to the farmers at a high price and utilization was also ineffective and inefficient.

Factors Influencing Adoptions of CSAPs among Small-scale Farmers of the Guinean Savanna's AEZs

A Multivariate Probit (MVP) model was used to identify factors influencing numerous adoptions of CSAPs. This model has confirmed that CSAPs in the Guinean Savanna's AEZs are not mutually exclusive as the likelihood ratio test [chi2(15) =85.55; Prob > chi2 = 0.000] rejects the null hypothesis, meaning that the covariance of the error terms across equations is not correlated. Moreover, estimates show that the model used fits adequately the data as the Wald test [Wald chi2(54) = 1143.39; Prob > chi2 = 0.000)] rejected the null hypothesis.

Globally, results show that farmers' adoptions of existing CSAPs were influenced by farmers' socio-economic characteristics notably holding of livestock and/or plantation, access to income sources from non-farm activities, the perceived impacts of CC, and membership to a far-based organization (Table 07). Hence, these results highlight that wealthier small-scale farmers were more likely to embrace CSAPs compared to poor small-scale farmers. On the contrary, household size was not significant in the adoption of CSAPs in the Guinean Savanna's AEZs. Other factors such as gender, age, farming experience, and educational level have also contributed to the adoption of CSA.

Gender: Gender and LD are significantly associated. This shows that LD options were gender-differentiated, implying that LD decisions were more likely to be of men resort within the household than women in the context of the Guinean Savanna. This demonstrates the place of females as household keepers and men as providers of expenditures and decision-makers on livelihood options. Contrary to our results, Maguza-Tembo *et al.* (2017) and Abegunde *et al*. (2020) found that gender was not significant in CSAPs in the drought-prone districts of Malawi and King Cetshwayo District municipality of South Africa. This confirms that adoptions of CSAPs are site-specific and related to socio-economic characteristics.

***Age*:** Farmers' age has a significant negative correlation with CSAPs such as CD and growing EMVs. This highlights that older farmers were less likely to practice CD and cultivating EMVs than younger farmers as these activities require intensive labor and energy expenditures which were not suitable for older farmers. Scholars such as Aryal *et al*. (2018) and Ogada *et al*. (2021) also found them significant in CSAPs respectively in the Gangetic plains of Bihar in India and Lushoto, in Tanzania.

Table 06: Small-scale farmers' CSAPs

CSA practices	Yes (%)	No (%)
Agroforestry intercropping	13.1	86.9
Early or late planting operations	47.1	52.9
Crop diversification	48	52
Early maturing varieties	40.3	59.7
Livelihood diversification	26.4	73.6
Improved crop varieties	5.1	94.9

Table 07: Coefficient estimates of the MVP model

Variables	LD		CD		EMVs		AFI		CTP		CICVs	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Gender of household head	0.373**	0.153	0.024	0.111	-0.115	0.114	0.133	0.150	0.244*	0.109	-0.000	0.206
Age of household head	-0.000	0.005	-0.017***	0.004	-0.016***	0.004	0.010	0.005	-0.004	0.004	0.007	0.007
Farming experience of the household head	0.021***	0.005	0.035***	0.004	0.050***	0.004	0.004	0.005	0.023***	0.004	0.014	0.007
Perceived impact of climate change	0.675***	0.157	1.392***	0.140	0.691***	0.138	0.650***	0.196	0.520***	0.123	0.469	0.296
Household size	-0.008	0.007	-0.005	0.006	-0.005	0.006	0.002	0.008	-0.008	0.006	0.006	0.012
Educational level	0.094***	0.012	0.068***	0.012	0.010	0.011	0.095***	0.012	0.005	0.010	0.122***	0.014
Holding of livestock and /or plantation	0.892***	0.088	0.201***	0.074	0.648***	0.076	0.355***	0.098	0.282***	0.072	0.044	0.145
Income source from non-farm activities	0.917***	0.092	-0.001	0.089	-0.001	0.088	0.551***	0.102	0.099	0.084	0.704***	0.149
Membership in a farm-based organization	0.243**	0.105	0.024	0.097	0.289***	0.097	0.096	0.118	0.090	0.093	-0.174	0.192
Number of observations	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500

*Notes: Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho61 = rho32 = rho42 = rho52 = rho62 = rho43 = rho53 = rho63 = rho54 = rho64 = rho65 = 0: chi2(15) =85.55 Prob > chi2 = 0.0000. Wald chi2(54) = 1143.39. Log-likelihood = -4032.95. Significance level: *** P < 0.01, ** P< 0.05, * P< 0.1. LD stands for livelihood diversification. CD: Crop diversification. EMVs: Early maturing varieties. AFI: Agroforestry intercropping. CTP: Changing the timing of planting. CICVs: Cultivating of improved crop varieties, and SE: Standard error.*

Farming experience: Results show that CSAPs including LD, CD, EMVs, and CTP are positively motivated by farmers' experiences. This shows that experienced farmers were more likely to adopt such aforementioned practices when they noticed changes in weather and climate conditions than inexperienced farmers. These results corroborate the findings by Abegunde *et al*. (2020) who asserted that the higher the farming experience the higher the likelihood of accumulation of social and physical capital.

Educational level: Farmers' educational level is positively correlated with LD, CD, AFI and CICVs. This result proves that education enables farmers to diversify livelihoods and choose better options to reduce climate change impacts on farm-based livelihood sources such as using improved crop varieties or practicing LD, CD, and AFI. The study suggests that educated farmers were more likely to search for information than illiterate farmers. Zakaria *et al*. (2020) also found farming experience significant in CSAPs among rice farmers in Northern Ghana. On the contrary, the educational level did not influence EMVs and CTP. This could be linked to a lack of climate-based agricultural information and a lack of contacts with extension services or agricultural advisors.

Perceived impacts of climate change: Results reveal that engagement of farmers in EMVs' cultivation, CTP as well as practicing AFI, CD, and LD was motivated by farmers' perceived impacts of CC. Farmers who perceived changes in weather or climate conditions were more likely to engage themselves in CSAPs rather than inattentive farmers. This confirms the finding of Zakaria *et al*. (2020) in northern Ghana where farmers' perceptions about changes in rainfall and temperature have influenced numerous CSAPs such as the cultivation of EMVs and drought-tolerant varieties.

Holding livestock and/or plantation: Farmers' possession of livestock and or plantation significantly influences LD, CD, EMVs, AFI, and CTP. These results demonstrate that the ownership of livestock or plantation as household resources was a discriminant social privilege that helped farmers to meet the aforementioned activities. For example, households holding animal-drawn ploughs had opportunities to adopt numerous CSAPs and it was a significant source of income as livestock-dependent households traded their livestock to respond to urgent livelihood needs. Kurgat *et al*. (2020) also found ownership of livestock positively correlated with agroforestry practice but not correlated with CD. The positive relationship between holding livestock/plantation and CD in the Guinean Savanna context could be explained by its practical relationship with agricultural means such as an animal-drawn plough enabling soon or late planting operations but also as sources of cash to purchase various seeds of crops.

Income source from non-farm activities: Farmers' diversity of income has a significant effect on CSAPs including the LD, AFI, and the CICV as they were motivated by farmers' access to cash incomes from non-farm activities such as traditional mining or salaried jobs. The study suggests that supplementary income fosters the adoption of CSAPs by enabling farmers to purchase improved crop varieties, diversify livelihood sources and practice AFI. Hence, farmers' engagement in CSAPs was also associated with the reliability of their income sources. Scholars such as Oyawole *et al*. (2019) in Nigeria and Zakaria *et al*. (2020) in Ghana, found that farmers with additional income sources from non-farm activities were likely to practice agroforestry. Likewise, Sani *et al*. (2016) showed that non-farm income increases the uptake of the CICVs in the Assosa district, Ethiopia.

Membership in a farm-based organization: Farmers' participation in farm-based organizations significantly influences the LD and the use of EMVs. This result highlights that social cohesion among farmers was an important driver of livelihood diversification as well as access to EMVs. Household head that participates in one or more farm-based organizations are likely to create a different portfolio of livelihood sources and be able to access and cultivate EMVs through their membership in the local organizations. This corroborates the findings by Roy and Basu (2020) amongst coastal farming communities in Bangladesh. Moreover, Mwungu *et al.* (2020) in Tanzania showed that farmers' membership in a social group has a positive impact on the CICVs.

CONCLUSIONS

This study used a multivariate probit (MVP) model to test the association between selected socio-economic factors and climate-smart agricultural practices (CSAPs) among small-scale farmers of the Guinean Savanna. Respondents' farmers were essentially dealing with climate-induced shocks and stress through practices including agroforestry intercropping, changing the timing of planting, crop diversification, the use of early maturing varieties, livelihood diversification, and the cultivation of improved crop varieties.

From the results of the MVP model, it has been found that economic essence was a key factor that motivated adoptions of CSA in the Guinean Savanna notably the income source from non-farm activities, the fact of holding livestock and/or plantation, a membership to a far-based organization and the perceived impacts of climate change. These were found to significantly enhance small-scale farmers' adoptions of existing CSAPs. On the contrary, household size was found to be not significant in the adoptions of CSAPs. Concerns were about the few farmers with resourceful knowledge of CSAPs under hostile climatic conditions and limited access to advisory services.

Since socio-economic conditions and institutional systems were still far from delivering adequate services needed by farmers, particular attention must be paid to farmers' experience, knowledge and socio-economic conditions towards farm-based livelihood sustainability under changing climate as small-scale farmers were the backbone of Guinea's economy.

Based on this study's findings, managers and decision-makers ought to support farmers' access to agricultural equipment and inputs, extension services, agricultural-based climate information, and a supportive environment for livelihood diversification.

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Conflict of Interest

The authors declare no conflict of interest.

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