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Gender Dimensions in the Adoption of Climate-Smart Agriculture Technologies in Response to Climate Change Extremes in Benin

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Abstract

This study investigated the gender dimensions in the adoption of CSA technologies among smallholder farmers in Benin. A multistage sampling procedure was used in selecting 272 respondents for the study, comprising equal proportions of male and female-headed households. Focus group discussions, key informant interviews, and structured interviews were used to obtain responses from interviewees. Descriptive statistics, principal component analysis, and multivariate probit regression model were used in analysing the data. The results of the study showed that a higher percentage (89.0%) of women sourced information on CSA technologies from their family/peers compared to men (66.2%). Men adopted more CSA technologies than women. Specifically, the CSA technologies adopted by the respondents were crop rotation (92.7% women vs. 86.0% men), animal health services (44.9% women vs. 66.2% men), and organic fertilizer (46.3% women vs. 59.6% men), among others. These climate-smart agricultural technologies were further delineated into three broad packages namely: soil and water conservation practices (SWC); improved livestock management system (ILM); and improved crop production system (ICP). More men than women adopted SWC and ILM. On the other hand, women (94.9%) adopted ICP more than men (87.5%). Gender, age, farm size, land ownership, access to labour, project contact, climate change information, and livestock ownership are significant determinants of the adoption of CSA options among the respondents. The study reinforces the need to consider context-specific local factors and co-design gender-based solutions to extreme climatic threats with the local communities.

Keywords: Adoption, Benin, climate-smart agriculture, gender, multivariate probit model

Total number of words: 9935

1. Introduction

In sub-Saharan Africa, the agricultural sector remains a keystone for achieving the Sustainable Development Goals (SDGs) (Kofi & Adams, 2020). Benin is among the countries in sub-Saharan Africa that depend primarily on agriculture. The agricultural sector in Benin employs

40 more than 70 % of its workforce and contributes 25% to the GDP of the national economy
41 (World Bank, 2017). Small-scale farming systems dominate agriculture in Benin with many
42 communities heavily dependent on agricultural products for their livelihoods (Sossou et al.,
43 2021). However, climate change evident in form of rising temperature, precipitation and other
44 extreme weather events has threatened food production. For small-scale farmers, this will alter
45 the nutritional quality and reduce the availability of food thus leading to food insecurity (Amitav,
46 2019).

47 Due to their little adaptive capacity as a result of their limited material resources, small-scale
48 farmers will experience the most adverse effects of climate change (Jawid, 2020; Rahman &
49 Anik, 2020). Climate-smart agricultural practices (CSA) offer the possibility to increase the
50 adaptive capacity of small-scale farmers. Climate-Smart Agriculture (CSA) is an approach that
51 integrates the need for adaptation and the potential for mitigation into agricultural development
52 strategies to promote food security (Asfaw & Branca, 2018). Thus, it contributes to the joint
53 achievement of three defined objectives, including increasing productivity to achieve food
54 security, adapting and building resilience from the farm level to the national level, and reducing
55 greenhouse gases emissions (CCAFS, 2017).

56 The adoption of CSA technologies at the farm level is influenced by the contextual nature of
57 such technologies (Mwongera et al., 2017) and requires that diverse options are developed for
58 different contexts, including socially differentiated groups such as age and gender. It has been
59 documented that a gender gap exists in agriculture such that women, especially those in female-
60 headed households, have less access to advisory services, information, participation in
61 community governance and social organisation, financial capital and productive resources in
62 comparison with men (Cohen et al., 2016; Nelson & Huyer, 2016). In the context of climate-
63 smart agriculture, this gender gap places women in a disadvantaged position when compared
64 with men. Due to their different roles in the household and agriculture, women have different
65 abilities and capacities to respond and adapt to climate change impacts when exposed to climatic
66 shocks (Kristjanson et al., 2017; Huyer and Partey, 2020). Additionally, the different social
67 status, economic power and expectations of men and women could affect the adoption patterns
68 of agricultural technologies (Murage et al., 2015). This could reinforce inequalities in the
69 adoption and sustainability of climate smart-agriculture technologies. If implemented in a way
70 that the needs and circumstances of women are taken into consideration, climate-smart
71 agriculture technologies could be beneficial to women and thus bridge the gender gap.

72 Economic models of agricultural technology adoption often analyze the decision to adopt a
73 single technology/practice, with little attention paid to analyzing multiple technologies whose
74 adoption and economic impacts are potentially linked and which may perform better when
75 adopted together (Ruzzante et al., 2021). In that sense, limited attention has been given to
76 analyzing the adoption of multiple CSA technologies from a gender perspective in a constrained
77 environment under extreme climate change effects (Bryan et al., 2021; Oyawole et al., 2020).
78 Often, adoption studies fail to control for the interdependence of technologies, which may result
79 in underestimating or overestimating the influence of various factors on the adoption decision
80 (Khanna, 2001; Wu & Babcock, 1998) and the impacts of adoption.

81 Therefore, the goal of this study is to investigate the gender dimensions of the adoption of
82 multiple CSA technologies in Benin. Benin provides a good case study because women are
83 responsible for 60 – 80% of the agricultural activities in Benin (Dah-gbeto and Villamor, 2016)

84 and are more vulnerable to the adverse impacts of climate change than their male counterparts
85 (Dossou-Cadja & Akimabera, 2020). Thus, the analysis of the gender dimension of climate-
86 smart agriculture in Benin could improve the design and implementation of climate-smart
87 agriculture interventions (World Bank et al., 2015). The paper is organised as follows: the
88 conceptual framework is presented in section two. In section three, we present the study area,
89 sampling procedure and data collection. The results and discussion are presented in section four.
90 Finally, we conclude the paper with some policy recommendations in section five.

91 **2. Conceptual framework**

92 The concept of gender is constantly evolving to meet the changing norms resulting from human
93 interaction within societies (Reckelhoff, 2023). What is meant by the term “gender” often differs
94 from society to society, each with unique characteristics in terms of shared values, beliefs, and
95 cultures. Broadly, the term “gender” is associated with roles and social constructs, as opposed to
96 the biological sex of male and female (Garofalo & Garvin, 2020). In theory, it refers to the
97 different roles, responsibilities, and power relations between men and women in a given society
98 (Hove & Gweme, 2018; Kristjanson et al., 2017; Tsige et al., 2020). Accordingly, in the agrarian
99 society of northern Benin, women and men are expected to play different roles which shape their
100 decision to adopt new technologies. Building on the above definition, this study conceptualizes
101 “gender” as the social roles played by men and women and the power relations between them,
102 which have a profound effect on the adoption of climate-smart agricultural technologies.
103 Moreover, while we acknowledge that the terms “sex” and “gender” are distinct concepts, their
104 influence often overlaps as important determinants of innovation adoption literature in
105 agriculture (Brown et al., 2017; Hirpa Tufa et al., 2022; Lokonon & Mbaye, 2018; Teklewold,
106 2023; Yahaya et al., 2018). Therefore, this study also uses sex-disaggregated data of farmers as a
107 proxy to measure gender outcomes in the adoption of climate-smart agricultural technologies in
108 northern Benin.

109 The process of undertaking a gender analysis of climate-smart agriculture technologies adoption
110 is particularly crucial for achieving a sustainable world free of hunger and poverty. Indeed,
111 gender-related factors are likely to affect various components of the food system, including food
112 production, consumption, and distribution processes (Njuki et al., 2022). This study, given its
113 scope and purpose, focuses on the food production system. Increasingly, changes in climate
114 variability, including the frequency and severity of extreme events, pose significant threats to the
115 food production system (Filho et al., 2022; Kumar et al., 2022; Mirón et al., 2023), resulting in
116 lower crop yields, frequent pests and diseases, and high livestock mortality (Amouzou et al.,
117 2019; Tonnang et al., 2022; Wing et al., 2021). While both women and men working in
118 agriculture are affected by climate change, women are affected differently, making them more
119 vulnerable to climate change than men. Numerous studies in Benin report situations in which
120 women growing the same crops as men in their households, but on different plots, have
121 significantly lower yields (Gbetondji & Nonvide, 2019; Osei-Adu et al., 2015). Structural
122 barriers, including lack of access to and control over productive resources and agricultural
123 services, time constraints resulting from unpaid domestic chores, inequality in decision making,
124 and restricted mobility, all frequently account for gender gaps in crop productivity.

125 Moreover, gender also interacts with other forms of social differentiation categories (e.g., region,
126 ethnic group, age, economic class, or religion) to define the extent to which women and men are
127 vulnerable to climate change impacts. As such, how gender plays out in relation to vulnerability
128 and resilience to climate change in Benin could be context-specific and nuanced. According to
129 Dossou-Cadja and Akimabera (2020), women in Benin are about 1.1 times more vulnerable to
130 climate change than men. They are particularly vulnerable to productive resources, including
131 access to land, and education. In the Niger Basin of Benin, female-headed households invest
132 relatively less than male-headed households in agriculture and livestock (Lokonon, 2019), while
133 in the coastal areas of Benin, women face enormous challenges in conducting income-generating
134 activities due to coastal hazards, which increases their vulnerability to livelihoods (Yantikoua et
135 al., 2023). Gender also influences youth participation in agriculture, with young men being more
136 likely to invest in agriculture or agribusiness than their female counterparts (Akrong & Kotu,
137 2022). Furthermore, Fulani women, and allotochnes in northern Benin face greater
138 marginalization in access to land than autochtones and other ethnic groups (Bidou et al., 2018).

139 Efforts to increase the adaptive capacities of vulnerable groups in agriculture across the world
140 have accelerated in recent years and have resulted in the adoption of climate change adaptation
141 strategies. More recent efforts of governments and civil society organizations have emphasized
142 “climate-smart agriculture” technologies. By definition, the climate-smart agriculture approach is
143 based on three main pillars including (i) sustainably increasing the productivity and profitability
144 of agriculture thereby ensuring food security, (ii) adapting and building resilience to climate
145 risks, and (iii) mitigating greenhouse gas (GHG) emissions. While it is recognized that there are
146 trade-offs between these three pillars of the CSA that contribute, in a broader sense, to the
147 Sustainable Development Goals, it does not take into account the “higher level” trade-offs
148 between the CSA and gender equality (SDG 5). Yet, gender inequalities can be reproduced in the
149 way men and women access and benefit from CSA technologies use (Bryan et al., 2017; Tsige,
150 2019). For example, evidence shows that women have less access to climate information in
151 comparison to men. Yet, when women have access to information on climate-smart agriculture,
152 they are more likely to adopt the practices (Twyman et al., 2014). Some CSA technologies, such
153 as soil and water conservation, are less adopted by women due to increased labour requirements
154 (Beuchelt & Badstue, 2013a; Nelson & Stathers, 2009). This underscores the need to design or
155 (re)adapt CSA technologies to meet women's labor capacities. Participatory identification of
156 women's needs for CSA technologies can provide a roadmap for gender-responsive and climate-
157 smart agriculture. Therefore, gender mainstreaming in CSA is paramount to improving the
158 livelihoods of both men and women in rural areas. Moreover, for CSA to have a positive impact
159 on men and women, gender equality targets must be deliberately introduced at the prioritization,
160 design, planning and implementation stages of climate adaptation programs (Roy et al., 2022).

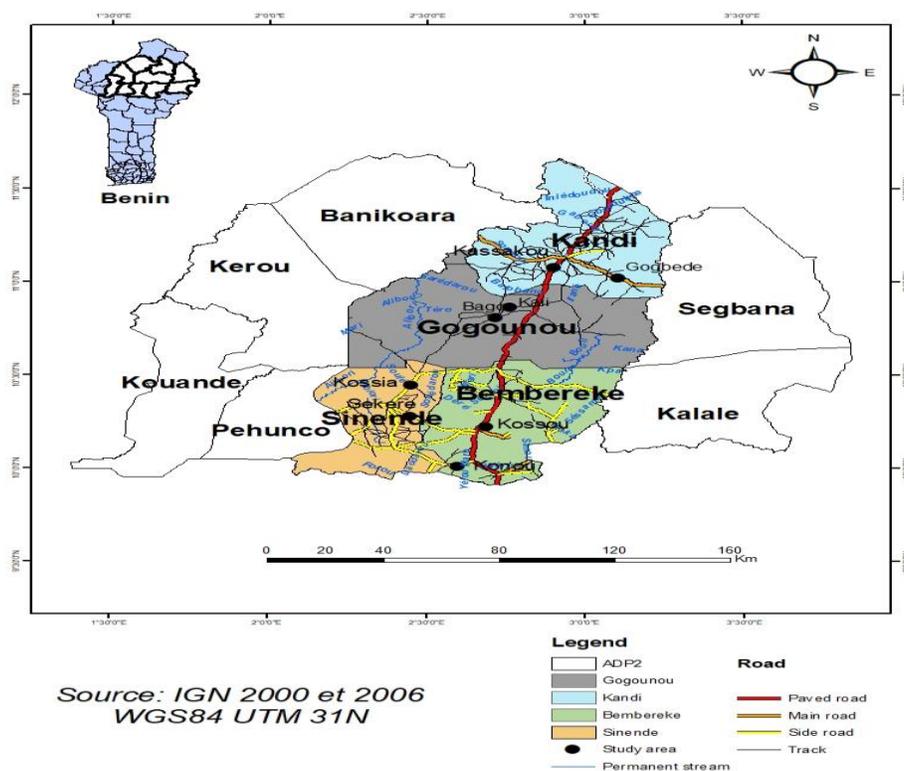
161 **3. Material and Methods**

162 *2.1. Study site description*

163 Benin is a West African country located in the tropical zone between the equator and the Tropic
164 of Cancer. Its latitude ranges from 6°30' N to 12°30' N and its longitude from 1° E to 3°40' E.
165 Its total area is 112,622 km². The total population of Benin was estimated in 2013 to be 9.9
166 million, of which more than 50% are women. The country has 77 municipalities and seven
167 agricultural development poles (ADP). Each ADP is administered by the Territorial Agricultural
168 Development Agencies (ATDA). Indeed, the ADP is a framework for the development of

169 various agricultural projects and programs in the country. It represents a development territory
 170 organized based on a limited number of priority agricultural sectors and municipalities to
 171 promote economic development in the territory. Small-scale farmers in Benin operate mostly
 172 (93.56%) on family farms. Such farms are characterized by high use of family labour (94.15%)
 173 and manual tools and equipment (80.3%), i.e., hoes, cutters, etc. The average farm size is $4.89 \pm$
 174 2.20 ha.

175 The study was carried out in Northern Benin. This region represents 73% of the country in terms
 176 of land area. Out of the seven ADPs in Benin, the Northern part of the country covers three
 177 ADPs including (1) Niger Valley; (2) South Alibori-Borgou North-2KP and (3) West Atacora.
 178 More precisely, the study was carried out in ADP 2 (South Alibori-Borgou North-2KP). ADP 2
 179 covers 10 municipalities, while ADP 1 and 3 cover 2 and 3 municipalities, respectively. Besides,
 180 a decline in agricultural production in this pole 2 has been reported, owing to the loss of land
 181 fertility because of climate change. In particular, ADP 2 is among the sub-catchments that are
 182 severely vulnerable to climate change. Some climate change effects observed in ADP 2 are
 183 delayed rainfall, increased temperatures, droughts and floods. Between 1990 and 2019,
 184 projections in the ADP2 indicated that the sub-catchments areas were vulnerable to climate
 185 change effects.



186

187 Figure 1: Agricultural Development Pole (ADP) 2 showing the study area

188 2.2. Sampling procedure and sample size

189 The studied population comprised all small-scale farmers in Northern Benin. A multistage
 190 sampling procedure was used to collect data from the respondents through a structured interview.

191 The Agricultural Development Pole 2 covers the municipalities of Kandi, Banikoara, Segbana,
192 Gogounou, Kouandé, Kérou and Péhunco. Sinendé, Kalalé and Bembéréké. In the first stage,
193 four out of the 10 municipalities were randomly selected (Gogounou, Kandi, Sinendé and
194 Bembéréké). In the second stage, in each of the four selected municipalities, two town
195 communities were purposively selected. The purposive selection was based on the intensity of
196 agricultural production activities and adverse climatic events (floods, soil erosion, droughts) over
197 the past ten years. In the third stage, one village was randomly selected in each of the eight
198 selected towns. The selected villages were Bagou-Yagbo, Kale, Kassakou, Gogbede, Konou,
199 Kossou, Kossia and Serekè-Marou. In each village, 34 farm household heads were randomly
200 selected. This gave a total of 272 respondents (comprising 136 male and female-headed
201 households each).

202 2.3. *Data collection*

203 This study employed a mixed-method approach and relied on a combination of quantitative
204 (structured interview) and qualitative (Focus Group Discussion and key informant interviews)
205 data collection methods (Creswell & Clark, 2017). The use of a mixed method reinforces the
206 rigour and enriches the analysis and the results (Wisdom & Creswell, 2013). Moreover, it helps
207 to improve data reliability and validity through data triangulation. Focus Group Discussions
208 provided qualitative data to explain the gender roles and adoption of climate-smart agriculture
209 technologies in the study area. In total, 16 FGDs were conducted - two FGDs per village, with
210 separate discussions held with women and men. The FGDs were recorded with the consent of the
211 participants. The findings from the FGDs were triangulated with results from the key informant
212 interviews to validate the conclusions of the study. The data from FGDs and key informant
213 interviews complemented and informed the development of the structured interview instrument
214 for collecting in-depth data on small-scale farmers. The interview of respondents from the study
215 areas was conducted using a structured questionnaire. The objective was to collect gender-
216 disaggregated information on the socio-economic and institutional characteristics of the
217 respondents, their adoption of climate-smart agriculture technologies and the sources of
218 information on CSA technologies. Prior to collecting structured interview data, ethical approval
219 was obtained from the Department of Agricultural Extension of the University of Nigeria
220 Nsukka. Participants provided a written informed consent to participate in the study. In addition,
221 written informed consent was obtained from all participants for specific data to be used in an
222 open access publication. Data were collected in face-to-face interviews with the help of
223 experienced and trained research assistants from the National Agricultural Research Institute of
224 Benin (INRAB). All interviews were audio recorded and then transcribed into French language.

225 2.4. *Study hypotheses and variables specification*

226 The hypotheses of the study were that: i) there is no significant relationship between the gender
227 of the household head and the socio-economic and institutional variables and, ii) the socio-
228 economic and institutional variables do not significantly influence the choice of CSA options
229 adopted by the respondents. Because a smallholder farmer can therefore use several CSA options
230 simultaneously, our dependent variable is polytomous and represents CSA options including (i)
231 soil and water conservation practices; (ii) improved livestock management system; and (iii)
232 improved agricultural production system in response to climate extremes. Independent variables
233 were selected based on theoretical background from the literature, expert consultations and
234 experiences of local farmers (Falco et al., 2011; FAO, 2010; Kassie et al., 2010). The model

235 variables assumed to influence the choice of CSA options by small-scale farmers are included in
236 Table 1.

237 **Table 1:** Variables influencing farmers' adoption decision

Variables	Description of the variables	Expected sign
Dependent variables		
Soil and water conservation practices	Dummy=1 if farmer adopted, 0 otherwise	
Improved livestock management system	Dummy=1 if farmer adopted, 0 otherwise	
Improved crop production system	Dummy=1 if farmer adopted, 0 otherwise	
Independent variables		
Age	Age of the farmer in years	+/-
Education	Dummy=1 if farmer is literate, 0 otherwise	+
Household size	Number of people eating in one pot	+
Cooperative membership	Dummy= 1 if farmer belongs to a cooperative, 0 otherwise	+
Access to credit	Dummy= 1 if farmer has access to credit, 0 otherwise	+
Extension contact	Dummy= 1 if farmer has contact with extension services, 0 otherwise	+
Project contact	Dummy= 1 if farmer has contact with projects, 0 otherwise	+
Access to climate information	Dummy= 1 if farmer has access to climate information, 0 otherwise	+
Farm size	Total land size in hectares	+
Livestock ownership	Dummy = 1 if farmer owns livestock, 0 otherwise	
Access to hired labour	Dummy= 1 if the farmer have access to labour, 0 otherwise	+
Land ownership	Dummy = 1 if farmer owns land, 0 otherwise	+
Off-farm income	Dummy = 1 if farmer has an off-farm source of income, 0 otherwise	+

238 *2.5. Data analysis*

239 Descriptive statistics (frequencies, percentages and means), nonparametric chi-square (X²) tests
240 for two-way categorical associations, and t-tests were performed. A Chi-Square was also
241 conducted to determine whether there is a significant difference between the use of CSA
242 practices and the gender of the farmer and t-tests were used to test the relationship between
243 gender and farm characteristics. Qualitative data were analysed using thematic analysis while
244 quantitative data were analysed using Stata version 16.

245 *2.6. Model specification and estimation strategy*

246 In this study, a farmer is considered to be adopting a CSA practice if he or she had used the
 247 practice at least one planting season before the interview and was still using it at the time of the
 248 interview. In total, 13 CSA technologies were considered and they were measured using dummy
 249 variables. In other words, if a small-scale farmer has adopted a CSA technology, he/she is scored
 250 1, otherwise 0 ([Appendix A](#)). The selection of technologies before was guided by the CSA
 251 country profile for Benin. This was documented as part of the collaborative effort between the
 252 International Center for Tropical Agriculture (CIAT), the lead centre of the CGIAR Research
 253 Program on Climate Change, Agriculture and Food Security (CCAFS), the International Crops
 254 Research Institute for the Semi-Arid Tropics (ICRISAT), and the Food and Agriculture
 255 Organization of the United Nations (FAO) to identify country-specific baselines and entry points
 256 for scaling out CSA in West Africa.

257 In specifying the empirical model of the study, the CSA technologies used in Northern Benin
 258 were first identified and their adoption rates estimated. Next, Principal Component Analysis
 259 (PCA) was used to identify the number of, and the climate-smart technologies, which constitute
 260 CSA technologies “option/combinations” adopted by small-scale farmers. The components were
 261 rotated so that a smaller number of highly correlated technologies would be placed under each
 262 component to facilitate the interpretation and generalization of a CSA option. In this study, PCA
 263 with oblique rotation (Oblimin) was used as it combines CSA technologies that are correlated,
 264 unlike PCA with orthogonal rotation (varimax or quart max) (Duong & Duong, 2008). Besides,
 265 the results of PCA with oblique rotation are more accurate for research involving human
 266 decision-making as it provides results that can be easily interpreted (Williams *et al.*, 2010).
 267 Oblique rotation is chosen over varimax rotation when the observed correlations from the factor
 268 correlation matrix are at least 0.32 (Tabachnick *et al.*, 2007). The result of the rotation yielded 3
 269 principal components with eigenvalues > 1 by criterion. PCA was useful in reducing the
 270 dimensionality of the data without losing much information. This approach is superior to using a
 271 convenient grouping of technologies that would make it difficult to conclude about a group in
 272 cases where few practices could represent the entire group (Wekesa *et al.*, 2018). Based on
 273 Filmer & Pritchett (2001), the general model for principal component analysis with oblique
 274 rotation for a set of n number of random CSA technologies is expressed as follows.

$$\begin{aligned}
 275 \quad PC_1 &= a_{11}X_1 + a_{12}X_2 + \dots + a_{1n}X_n \\
 276 \quad PC_2 &= a_{21}X_1 + a_{22}X_2 + \dots + a_{2n}X_n \quad (1) \\
 277 \quad PC_{13} &= a_{131}X_1 + a_{132}X_2 + \dots + a_{13n}X_n
 \end{aligned}$$

278 Where a_{1n} represents the coefficient (weight/factor loadings) for the first principal component of
 279 the n^{th} number of random CSA technologies. The order of the components ensures that the first
 280 principal component explains the greatest possible amount of correlation of the variables in the
 281 original data..

282 After grouping the CSA technologies, a Multivariate Probit (MVP) regression model was used to
 283 capture the factors that influence small-scale farmers' decision-making process for the adoption
 284 of CSA technologies combination/option. The MVP model was used because it models the
 285 influence of all explanatory variables on each CSA option by simultaneously estimating a set of
 286 binary Probit models while allowing the error terms of these models to be correlated (Greene,
 287 2008). Several factors that may influence farmers' decision to adopt a CSA option were
 288 considered, including the socioeconomic and institutional characteristics of small-scale farmers

289 and their assets. In the estimation of the factors affecting the adoption of each CSA option, the
 290 dependent variable is coded as 1 = Use and 0 = Non-use. The MVP model for multivariate choice
 291 problems can be represented by two systems of equations. First, a system of equations with latent
 292 (unobservable) dependent variables is described by a linear function of a set of socioeconomic (i)
 293 and institutional (j) characteristics of small-scale farmers as well as productive (k) resources
 294 (X_{ijk}) and normally distributed multivariate stochastic terms (ε_{ijk}). The empirical model for the
 295 Multivariate Probit regression is represented as shown below:

$$296 \quad Y_{ijkm}^* = \beta_m X_{ijk} + \varepsilon_{ijk} \quad \text{Where } (m=\text{SWC, ILM, ICP}) \quad (2)$$

297 where Y_{ijkm}^* denotes the latent dependent variables that can be represented by the expected level
 298 of benefit and/or utility from using the CSA option Soil and Water Conservation practices
 299 (SWC), Improved Livestock Management (ILM), and Improved Crop Production (ICP),

300 ε =Error term; i =Socio-economic characteristics of the small-scale farmer; j =Institutional
 301 characteristics of the small-scale farmer, k = Assets of the small-scale farmer.

302 The second system of equations describing the observable dichotomous household choice
 303 variables is as follows.

$$304 \quad Y_{ijkm} = \begin{cases} 1 & \text{if } Y_{ijkm}^* > 0 \\ 0 & \text{otherwise} \end{cases} \quad (3)$$

305 Where Y_{ijkm} is the adoption of the m th CSA option for the ijk th small-scale farmer.

306 **3. Results and discussion**

307 *3.1. Socio-economic and institutional characteristics*

308 Table 2 shows the descriptive statistics of the socio-economic and institutional characteristics of
 309 the respondents differentiating between male and female-headed households. Results from the t-
 310 test suggest that there are statistically significant differences for eight out of thirteen variables
 311 examined, namely age, education, cooperative membership, extension contact, access to climate
 312 information, farm size, livestock ownership and land ownership.

313 From the table, the average age of male-headed households was about 42 years while that of
 314 female-headed households was 37 years. Previous studies reveal that the age of the farmers
 315 positively influences the adoption of new technologies, with younger farmers adopting more
 316 technologies (Marescotti et al., 2021; Paustian & Theuvsen, 2016), arguably because of their
 317 risk-taking attitude (Ayinde, 2016; Spicka, 2020). Our findings revealed that more men than
 318 women were literates. It is expected that the variable education positively influences the adoption
 319 of climate-smart agriculture technologies. Many authors have reported that farmers' education
 320 levels significantly influence the adoption of CSA technologies (Nyang'au et al., 2021;
 321 Onyeneke et al., 2018; Sardar et al., 2021). The average household size in the study area is about
 322 ten people the female-headed households and eleven in male-headed households, above the
 323 average household size of seven in northern Benin (Bidou et al., 2018). This further implies that
 324 family farm labour will be relatively available for farm activities in the study area, potentially
 325 increasing the likelihood of adopting CSA technologies. Likely, soil and water conservation may
 326 require additional labour from the farmer, which is often provided by household members.

327 More male-headed households belong to a cooperative organisation and have access to credit
 328 than female-headed households do. In addition, men have access to extension services more than
 329 women, although both, most women and men farmers have been in contact with different
 330 development projects in the past five years. Moreover, both men and women mostly discuss
 331 climate change and adaptation issues with their peers.

332 On average, women respondents (household heads) cultivate 3.11 hectares of land, while men
 333 cultivate 4.88 hectares of land. The majority of men and women rear livestock in addition to crop
 334 production. Regarding their accessibility to labour, the majority of respondents have access to
 335 labour with more women having access to labour than men. Most of the respondents own the
 336 land they cultivate and off-farm employment complements the revenues of the majority of the
 337 small-scale farmers.

338 **Table 2:** Socioeconomic and institutional characteristics of the respondents

Variables	Female-Headed Household (N=136)		Male Headed Household (N=136)		t-statistic (sig)
	Mean	SD	Mean	SD	
Socioeconomics					
Age	37.33	11.18	41.79	13.26	-2.9912***
Education	0.24	0.43	0.34	0.47	-1.8681*
Household size	9.68	5.55	11.14	6.87	-1.9114
Institutional					
Cooperative membership	0.51	0.50	0.65	0.47	-2.3529***
Access to credit	0.38	0.48	0.44	0.50	-0.9837
Extension Contact	0.39	0.49	0.55	0.50	-2.6983***
Project contact	0.54	0.50	0.60	0.49	-0.9789
Access to climate information	0.95	0.21	0.99	0.086	-1.9206**
Assets					
Farm size	3.11	1.81	4.88	2.05	-7.5730***
Livestock ownership	0.65	0.47	0.84	0.36	-3.7191***
Access to labour	0.73	0.45	0.70	0.46	0.5346
Land ownership	0.74	0.44	0.87	0.33	-2.8053***
Off-farm income	0.78	0.41	0.74	0.44	-0.8466

339 Significance *at the 10% level, **at the 5% level, ***at the 1% level of t-test estimates of mean
 340 comparisons

341 3.2. Sources of information on climate-smart agriculture technologies

342 Overall, peers, family and friends were the main sources of information on climate-smart
 343 agriculture technologies (Figure 1). The majority (89.0%) of women and men (66.2%) use their
 344 peers, family and friends to obtain information on climate-smart agriculture technologies,
 345 probably because they are easily accessible. Focus group discussions with men and women
 346 revealed that the exchange of information between peers and friends was a way to legitimize and
 347 verify the effectiveness of CSA technologies. This means that information the farmer receives

348 from other sources may not be fully accepted if it is not clarified by their peers, family and
349 friends. Results from our work are in line with the work of Kalungu and Filho (2016) in Kenya
350 who found that most smallholders tend to receive information about technologies from other
351 farmers. Complementarily, it was reported in the work of Nguyen *et al.* (2021) in Vietnam that
352 women were more willing to disseminate knowledge within communities through formal and
353 informal channels than men. The finding also corroborated with the work of Weyessa (2017) in
354 Ethiopia who found that farmer-to-farmer knowledge sharing contributed significantly to
355 technology adoption by facilitating adopting farmers' access to a credible and reliable source of
356 information on new technologies and access to improved seeds. As argued by Isaac *et al.* (2007),
357 peer-to-peer knowledge exchanges have stronger effects in actively seeking agricultural
358 knowledge. Already, the fact that the majority of CSA technologies are rooted in traditional local
359 knowledge implies that farmers will be more familiar with certain CSA practices and will look to
360 their peers for confirmation and updates of their current practices. However, given the
361 complexity of knowledge and the fact that individuals who receive CSA knowledge from their
362 peers have different capacities to absorb the knowledge they receive, realizing CSA learning
363 outcomes may sometimes be difficult (Pratiwi & Suzuki, 2017). As a key rule, successful
364 knowledge transfers require a level of mutual understanding between the knowledge givers and
365 receivers, which in turn requires reciprocal exchanges between the actors for successful learning
366 to occur (Burt, 2004).

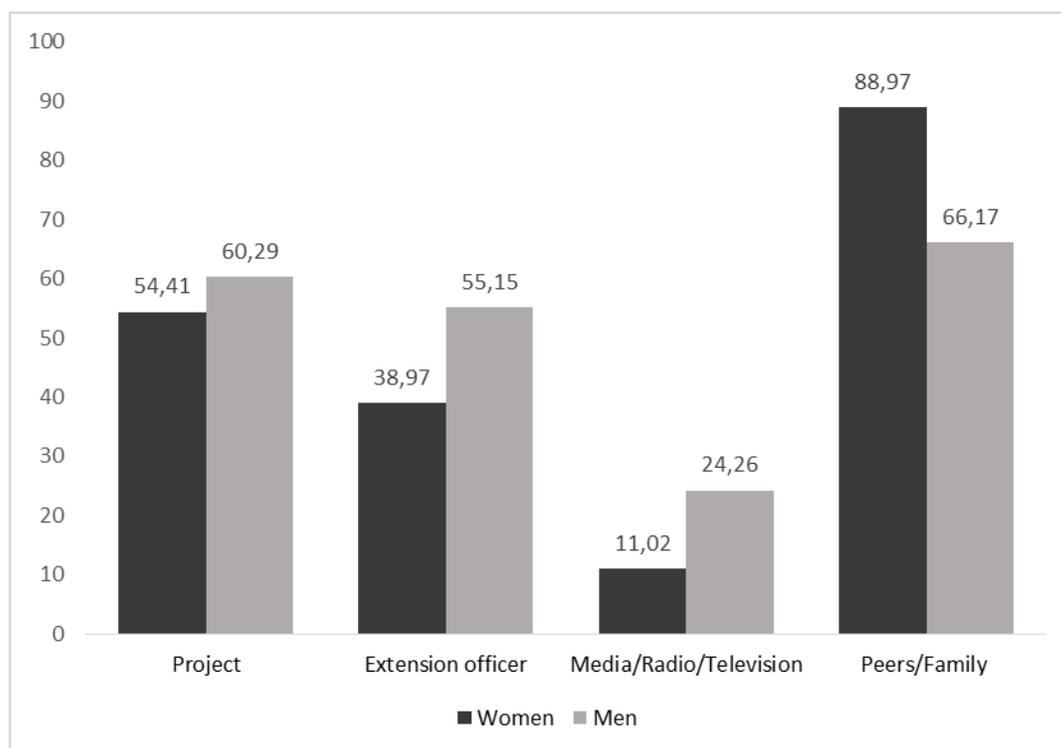
367 Nevertheless, as much as 60.3% of men and 54.4% of women also source information on
368 climate-smart agriculture technologies through development projects. Development projects in
369 the area often provide training and disseminate practices on how to adapt to climate change
370 impacts. However, relying solely on development projects for the dissemination of CSA
371 technologies to farmers may be unsustainable since these projects are time-bound. Extension
372 workers were the third most important source of information on CSA technologies, although the
373 proportion of women (39.0%) who received information from extension agents was lower than
374 the proportion of men (55.2%). Gendered institutional biases in extension service delivery have
375 contributed to women's limited access to CSA information from extension agents. Also, we
376 observed that women receive little attention from extension workers, probably due to their role in
377 the household. Duffy *et al.* (2020) equally elaborated that although both male and female farmers
378 obtained information on CSA through traditional extension, the gain was less for women,
379 however women farmers who interacted with farmers' leaders increased their knowledge on
380 CSA. This result also strengthens those of Waaswa *et al.* (2021) among potato farmers as very
381 few women rely on extension agents for awareness of CSA technologies. Innovative extension
382 services that target both men and women in the study area should therefore be designed and
383 delivered. On the other hand, relying solely on extension agents would not achieve wide
384 dissemination of CSA technologies to small-scale producers. Extension agent-based approaches
385 should often be complemented by farmer-led extension approaches. This because, effective
386 extension services require road infrastructure, the lack of which may prevent extension agents
387 from reaching farmers in the most remote areas. Most farming communities are far from the
388 district capital where most extension agents live. Extension agents therefore need transportation
389 to reach these communities. Unfortunately, many of them do not have their own transportation.
390 In addition, the high ratios of extension agents to farmers lead to an increased workload for
391 extension agents. When extension agents have too many farming communities to manage, the
392 frequency of visits becomes lower and more irregular, which can reduce the effectiveness of
393 extension advice. It is therefore important to improve the ratio of extension agents to farmers. At

394 the same time, female extension agents need to be promoted if effective CSA learning outcomes
 395 for small-scale women farmers are to be achieved. Experiences have shown that women farmers
 396 feel more comfortable with female extension agents, since they are freer to discuss their
 397 problems with them and they can accommodate their meeting time preferences better than with
 398 male extension agents (Ragasa, 2014).

399 Moreover, 11% of women and 24.3% of men rely on the media, including television, radio, and
 400 cell phones, to learn about CSA technologies. While acknowledging the role of the media in
 401 shaping smallholder farmers' knowledge of climate adaptation, as shown by Comoé and Siegrist
 402 (2015), many challenges remain limiting equitable access to CSA information. The low rate of
 403 media use could be explained by the fact that the media has limited coverage of CSA-related
 404 information that is specific to each socio-cultural context (Comoé & Siegrist, 2015). Often,
 405 media tend to give general information. Also, gender inequalities in asset ownership, including
 406 radio and television, often result in women having limited access to agricultural information
 407 (Singh *et al.*, 2018). There is a need for the media to design more programs in indigenous
 408 languages, especially for CSA-oriented content delivery. More efforts should be made to
 409 promote the organization of community media to complement the work of commercial
 410 broadcasting stations.

411

412



413

414 **Figure 1:** Small-scale farmers' sources of information on CSA technologies

415

416 *4.2 Adoption of CSA technologies*

417 Table 3 presents the results of the adoption of CSA technologies by small-scale farmers. Overall,
418 men adopted ten out of thirteen CSA technologies considered, more than women. On the other
419 hand, women adopted two technologies more than men. More men than women adopted some
420 technologies, such as agroforestry (52.2% men vs 41.2% women) and the use of organic
421 fertilizers (59.6% men vs. 46.3% women). However, women adopted some technologies more
422 than men, including crop rotation (92.7%) and mulching (55.2%). Our findings suggest that there
423 are gendered differences in the use of CSA technologies in northern Benin, with men adopting
424 more CSA technologies. This finding contends with those of Kalungu and Filho (2016) who
425 found that male-headed households had higher technology adoption levels compared to female-
426 headed households. However, the findings contradict those of Bernier *et al.* (2019) in Kenya and
427 Oyawole *et al.* (2020) in Nigeria, who found that female-headed households are more likely to
428 adopt CSA technologies than their male counterparts.

429 Our result further contradicts the findings of Oyawole *et al.* (2020) that men are more likely to
430 adopt crop rotation than women and that women are more likely to adopt green manure and
431 agroforestry than men. The relatively low adoption of agroforestry among women may be
432 because women have small plots of land compared to men. Dhakal & Rai (2020) identified the
433 limited landsize as the main constraint to agroforestry adoption by smallholders. On the other
434 hands, men are more likely to engage in agroforestry than women. This is due to the patriarchal
435 rights intrinsically linked to land tenure security (Anugwa *et al.*, 2020).

436 The study found a low proportion of women adopting organic fertilizer as compared to men, with
437 a Chi-square test revealing significant difference ($p = 4.7813$). This difference may be attributed
438 to the small number of cattle owned by women. FGDs revealed that cattle manures were most
439 available for men than women. Besides, women buy organic fertilizer and complement it with
440 waste and small ruminant dung. This result is consistent with those of Abebe and Debebe (2019)
441 and Avane *et al.* (2021). However, it contradicts the findings of Daadi and Latacz-Lohmann
442 (2021) in Ghana who found that female-headed households are more likely to adopt organic
443 fertilizer than male-headed ones.

444 Though men tend to adopt water management practices, such as contours ploughing, cover crops,
445 or drainage ditches, more than women, the pace of adoption is relatively low for both men and
446 women farmers, and the differences in adoption between men and women are not statistically
447 significant. As in other areas, the low adoption of such practices may be due to the poor technical
448 knowledge of farmers (Diptesh & Chauhan, 2016; Saidur Rahman & Gupta, 2015). Other
449 reasons for the low adoption rate mentioned during FGDs include the labour-intensive
450 requirements and high costs associated with these practices. Moreover, both women and men
451 declared that stones are not always available for use and most of them used water management
452 practices on the upper slopes.

453 Though the livestock-based CSA technologies were not highly adopted, there was a statistically
454 significant difference between women and men in the use of all climate-smart livestock
455 technologies. This implies that men adopted more climate-smart livestock technologies than
456 women. Among livestock management practices, the use of animal health services/use of
457 vaccines recorded a relatively high rate of use for men (66.18%) than women (44.85%). The high
458 rate of animal health services/use of vaccines may be traced to the availability of veterinary
459 extension services in the study area. During FGDs, women reported they received less veterinary
460 extension services than their male counterparts. On the other hand, seasonal livestock mobility

461 recorded the lowest adoption rate for both men (39.7%) and women (19.9%). This result
 462 complements those of Mujeyi *et al.* (2019) in Zimbabwe that livestock-based practices were not
 463 widely adopted among smallholders. This is because the unfavourable perceived effectiveness or
 464 the costs associated with its implementation.

465 **Table 3:** Adoption of climate-smart agriculture technologies among small-scale farmers

CSA technologies	Women	Men	Total	Chi-square
	(n=136)	N=136)		
	%	%		
Improved crops varieties/drought-tolerant crops	47.8	50.0	48.9	0.1324
Crop rotation/crop diversification	92.7	86.0	89.3	3.1264
Agroforestry/planting trees	41.2	52.2	46.7	3.3224
Mulching/crop residues management	55.2	53.7	54.4	0.0593
Organic fertilizers (Compost/manure)	46.3	59.6	53.0	4.7813***
Contours ploughing	43.4	51.5	47.4	1.7841
Contour stone bunds	33.1	33.1	33.1	0.0000
Cover crops	48.5	55.2	51.8	1.1928
Drainage ditches	28.7	31.6	30.2	0.2793
Constitution of food reserves for the dry season	36.0	51.5	43.8	6.5882***
Pasture management and supplementary feedings	24.3	35.3	29.8	3.9558***
Seasonal movement of the livestock	19.9	39.7	29.8	12.8168***
Animal health services/use of vaccines	44.9	66.2	55.5	12.5199***

466 Fieldwork, 2021

467 *** *Significant at 5% level*

468 4.3 CSA technologies combination using principal component analysis

469 The principal component analysis of the different CSA technologies shows that the three
 470 principal components explained 59.78% of the total variability in the data set (Table 4). The first
 471 component explained 39.24% of the variance and is correlated with six CSA technologies:
 472 mulching/crop residues management, organic fertilizers, cover crops, contours ploughing,
 473 contour stone bunds and drainage ditches all with positive effects (component loadings). Thus,
 474 this component was named “*Soil and water conservation practices*”. Components 2 and 3
 475 accounted for 11.28% and 9.26% of the variance, respectively. The second component was
 476 positively associated with four practices: the constitution of food reserves for the dry season,
 477 pasture management and supplementary feeding, the seasonal movement of the livestock, and
 478 animal health service/use of vaccines. Component 2 was named “*Improved livestock*
 479 *management*”. The last component was positively associated with improved crop varieties, crop
 480 rotation and agroforestry and it was named “*Improved crop production system*”.

481 **Table 4:Principal Component Analysis of different CSA technologies**

CSA technologies	Comp1	Comp2	Comp3	Communalities
Improved crops varieties/drought-tolerant crops	0.215	-0.164	0.453	0.504
Crop rotation	-0.07	0.098	0.621	0.562
Agroforestry/Planting trees	0.041	0.202	0.391	0.459

Mulching/crop residues management	0.436	0.019	-0.263	0.647
Organic fertilizers (Compost/manure)	0.391	0.117	-0.255	0.665
Cover crops	0.346	-0.072	0.233	0.562
Contours ploughing	0.41	-0.176	0.128	0.549
Contour stone bunds	0.402	0.018	0.047	0.654
Drainage ditches	0.344	0.069	0.033	0.551
Constitution of food reserves for the dry season	-0.006	0.52	0.036	0.73
Pasture management and supplementary feedings	-0.063	0.426	0.166	0.499
Seasonal movement of the livestock	-0.009	0.525	0.021	0.730
Animal health services/use of vaccines	0.179	0.377	-0.146	0.660
Eigenvalues	5.1	1.466	1.20	
% of variance explained	39.24	11.28	9.26	
Cumulative %	39.24	50.52	59.78	

482

483 Table 5 presents the descriptive statistics of each component (% of people who adopted at least
 484 one of the components in the group). The most commonly used component was the improved
 485 crop production system with 94.9% of women and 87.5% of men using at least one unit of this
 486 component. The second most used component was soil and water management practices with
 487 75.7% of women and 81.6% of men using at least a unit of this component. Finally, the least
 488 used component comprised improved livestock management, which includes the constitution of
 489 food reserves for the dry season, pasture management and supplementary feeding, the seasonal
 490 movement of the livestock and animal health services/use of vaccines and was used by 53.7% of
 491 women and 75.0% of men.

492 **Table 5: CSA technology combinations**

Group of CSA	Components	Women	Men	Total
		(N=136)	(N=136)	
		%	%	%
Improved crop production practices	Improved crops varieties	94.9	87.5	91.2
	Crop rotation			
	Agroforestry/Planting trees			
Soil and water conservation practices	Mulching/crop residues management	75.7	81.6	78.7
	Organic fertilizers			
	Cover crops			
	Contour ploughing			
	Contour stone bunds			
	Drainage ditches			

	Constitution of food reserves for the dry season			
Improved Livestock management	Pasture management and supplementary feeding	53.7	75.0	64.3
	Seasonal movement of the livestock			
	Animal health services/use of vaccines			

493 Fieldwork, 2021

494 *4.4 Determinants of the adoption of different CSA technologies*

495 The factors influencing the use of identified CSA options are presented in Table 6. The results of
 496 the Multivariate Probit model show that gender, age, household size, farm size, contact with a
 497 project, livestock ownership, access to labour and land ownership significantly affected the
 498 adoption of different CSA options in the study area.

499 **Improved Crop Production (ICP)** practices are implemented by women ($z = -2.61$), older
 500 people ($Z=2.23$), farmers in contact with projects ($z = 3.53$), those who have less access to
 501 climate change information ($z=-9.23$), and land owners ($z = 2.37$). The tendency for women to
 502 adopt improved crop production practices more likely than men is because of the ease women
 503 have in implementing such practices and the quick return on investment they can get compared
 504 to their men counterparts. Besides, women are often allocated low-fertility land in the study area,
 505 thus making them more inclined to adopt improved crop production practices. A woman
 506 discussant affirmed, "*Already the land we are given is very impoverished, and we have no other*
 507 *choice than to practise crop rotation so as not to tire the land too much. We have understood*
 508 *that the land too, is like a man who breathes and when he works he needs rest*". In addition, due
 509 to their household chores and mobility restriction, women are often allocated lands close to
 510 settlements. Such lands are low-fertile which increases their tendency to use an improved crop
 511 production system option (Patel *et al.*, 2014). This result further shows the potential of this
 512 option in promoting and empowering marginalised women as it not only offers a better synergy
 513 between productivity and adaptation but it is also beneficial in terms of financial and resource
 514 use efficiency (Mutenje *et al.*, 2019; Oyawole *et al.*, 2020; Sain *et al.*, 2017).

515 The finding also reveals that being in contact with development projects has significantly
 516 increased the probability of an improved crop production system. It was found that households
 517 who participate in a project or agroforestry initiative were more likely to adopt agroforestry
 518 when compared to households who do not participate (Jha *et al.*, 2021). Though efforts to
 519 promote sustainable agriculture have been made in the study area by various development
 520 organizations, there is still a need to continuously and vigorously support interventions through
 521 various innovation support services (extension, financial, inputs etc.) if we are to increase the
 522 pace of adoption of CSA technologies. We also found that small-scale farmers with no access to
 523 climate change information were less likely to use improved crop production practices ($z=-9.23$).
 524 This further shows the extent to which weather and climate information drive the adoption of
 525 CSA technologies in the region (Djido *et al.*, 2021; Tran *et al.*, 2020). Our results further show
 526 that land ownership positively influences the use of an improved crop production system ($z =$
 527 2.37). Evidence indicates that female land ownership promotes women's wealth and decision-

528 making authority, which could be the pathways through which their land fertility is influenced
529 (Chakrabarti, 2018; Jha et al., 2021).

530 **Soil and Water Conservation (SWC)** practices are most likely to be implemented by younger
531 people ($z = -2.22$), living in larger households ($z = 3.94$), with contact with projects ($z = 4.81$)
532 with more livestock ($z = 2.00$) and less access to labour ($z = -2.44$). Soil and water conservation
533 practices are labour intensive (Anuga et al., 2019; Moges & Taye, 2017) and as such younger
534 farmers as well as larger households could provide the necessary farm labour to implement
535 labour-intensive activities such as contour stone bunds, contour ploughing and drainage ditches.
536 Similar findings have been found by Belachew et al. (2020) in Ethiopia and Moriaque et al.
537 (2019) in Benin. Moreover, there is a higher tendency for larger households to use mulching and
538 organic fertilizers than smaller households (Mwaura et al., 2021). Furthermore, livestock
539 ownership also significantly influences the use of soil and water conservation. This result
540 contends with those of Amare & Simane (2017) who also found that livestock ownership
541 significantly influences the use of soil and water conservation practices as well as agronomic
542 practices. Small-scale farmers with more livestock are likely to access organic manure which
543 could increase their adoption of practices such as organic fertilizers (Getahun et al., 2021;
544 Mairura et al., 2021). However, our finding that small-scale farmers with less access to farm
545 labour were more likely to use soil and water conservation practices is surprising when compared
546 to a previous study which found the opposite (Belachew et al., 2020). The probable reason might
547 be that practicing some of the SWC technologies such as contour ploughing needs less demand
548 of labor and requires a relatively low complexity approach to operate. Thus, CSA policy
549 interventions to increase the adoption of SWC practices should target younger farmers, living in
550 larger households, with more livestock and should also provide training/information on less
551 complex practices requiring low labor demand.

552 Finally, **Improved Livestock Management (ILM)** practices were implemented by households
553 with bigger farms ($z = 2.70$), less access to climate information ($z = -2.72$), and more livestock ($z =$
554 7.58). The finding is further consistent with those of Kifle (2021) in Ethiopia who also found that
555 farm size positively influences the adoption of improved livestock feed. However, the finding
556 contradicts findings by Njarui et al. (2017) in Kenya who found that households that owned
557 larger pieces of land were more unlikely to adopt improved livestock feeding system with forage
558 than households that had smaller pieces of land. The results further demonstrate the extent to
559 which small-scale farmers valued climate information concerning managing climate risks in
560 livestock production. The provision of climate information does not alone guarantee its
561 integration in farm production decisions (Gitonga et al., 2020). Other forms of institutional
562 support such as extension services, reliability of network connectivity and communication
563 infrastructure should be complementary. Households with more livestock would likely generate
564 additional income needed to engage in improved livestock management practices. Hence, in
565 order to increase the probability of adoption of ILM practices, CSA programs and policies
566 should focus on providing information to farm households with more livestock and large farm
567 sizes. While the provision of climate information to farmers is necessary, the provision of
568 extension services and other forms of institutional support is important to encourage the adoption
569 of ILM practices.

570 **Table 6: Determinants of climate-smart agriculture options by small-scale farmers**

Variables	SWC			ILM			ICP		
	Coef.	Std.Err.	Z	Coef.	Std.Err.	z	Coef.	Std.Err.	z
Gender	0.089	0.229	0.39	0.139	0.219	0.64	-0.697	0.267	-2.61***
Age	-0.017	0.008	-2.22**	0.013	0.009	1.39	0.026	0.012	2.23**
Education	-0.071	0.215	-0.33	0.054	0.254	0.21	0.061	0.243	0.25
Household size	0.079	0.02	3.94***	0.024	0.016	1.49	0.036	0.03	1.22
Farm size	-0.048	0.056	-0.87	0.152	0.056	2.70***	0.024	0.058	0.42
Cooperative membership	-0.061	0.28	-0.22	-0.126	0.304	-0.42	-0.464	0.326	-1.43
Access to credit	-0.027	0.228	-0.12	0.048	0.217	0.22	0.058	0.224	0.26
Extension contact	0.253	0.277	0.91	-0.071	0.249	-0.29	-0.323	0.394	-0.82
Project contact	1.236	0.257	4.81***	0.346	0.246	1.41	1.051	0.298	3.53***
Climate change information	0.806	0.575	1.40	-1.023	0.377	-2.72***	-3.504	0.38	-9.23***
Livestock ownership	0.531	0.265	2.00**	2.568	0.339	7.58***	0.173	0.294	0.59
Access to labour	-0.663	0.272	-2.44***	0.303	0.223	1.36	0.328	0.26	1.26
Land ownership	-0.491	0.284	-1.73	0.288	0.253	1.13	0.742	0.314	2.37***
Off-farm employment	-0.2	0.244	-0.82	0.3	0.249	1.20	0.382	0.263	1.45
Constant	0.274	0.73	0.38	-2.822	0.657	-4.3***	2.597	0.57	4.55***

Wald chi2(42) = 61
 Prob> chi2=0.0000
 Likelihood ratio test of rho21 = rho31 = rho32 = 0: chi2(3) = 8.20008 Prob> chi2 = 0.0421

571 *** *Significant at the 1% level, ** significant at the 5% level*572 **SWC:** Soil and water conservation practices573 **ILM:** Improved livestock management system574 **ICP:** Improved crop production system

575 **5 Conclusion and policy implications**

576 The study reveals that the rate of CSA adoption in northern Benin is still low, with a lower
 577 proportion of women implementing CSA technologies than their male counterparts. In addition,
 578 women farmers have implemented CSA technologies that require little capital, which may be
 579 explained by their limited financial resources. Improved crop production systems were the most
 580 prevalent CSA technologies among both male and female farmers, possibly due to their low cost.
 581 Our results suggest that there is a need to empower farmers to gradually move to more capital-
 582 intensive practices. Gender, in particular, significantly influenced the use of the improved crop
 583 production system in this set of variables. This suggests that CSA programs and policy
 584 interventions should focus on improving equal access to CSA information and empowering
 585 women in household decision-making. This can be achieved by establishing policy measures that
 586 would enhance women's access to formal education and extension services. The existence of
 587 trade-offs and complementarities between CSA technologies suggests that policy and
 588 programmatic efforts on climate change adaptation affect the adoption of gender-sensitive CSA
 589 technologies. The contextual nature of these findings reinforces the need to consider local factors
 590 and design gender-responsive solutions in collaboration with local communities. This would
 591 include ensuring equitable access to CSA information and capacity building initiatives, as well as
 592 using transformative gender approaches to address cultural barriers to CSA technology adoption.
 593 Specifically, knowledge and information dissemination channels that design and deliver
 594 contextually relevant climate/seasonal forecast information that addresses the specific needs of
 595 rural and marginalized women should be established. Other measures include facilitating the
 596 creation of social networks among women in the community so that they can help each other in
 597 times of need.

598 The findings of this study should however be interpreted with some caution since we relied
 599 mainly on cross-sectional survey data and self-reported measures of gender differentiated
 600 adoption of climate-smart agricultural technologies. A cross-sectional data limits us from
 601 rigorously providing a dynamic effect of gender differentiated adoption of CSA technologies on
 602 risk exposure. Future research using panel data can help provide a more rigorous estimates of the
 603 dynamic effects of gender-differentiated adoption of CSA technologies. Additionally, our limited
 604 sample size of 272 households does not capture every farm household in northern Benin.
 605 However, our data collection approach of a random selection of farm household heads in the
 606 study communities that have experienced adverse climate extremes and the mixed method
 607 research design improved the reliability of the study . Despite these shortcomings, we do not
 608 expect systematic bias in our study. Our study contributes to available literature on gender
 609 dimensions on the adoption of CSA technologies.

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