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Gendered perceptions and adaptations to climate change in Ghana: what factors influence the choice of an adaptation strategy?

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Climate change poses a significant threat to various sectors, including agriculture, affecting men and women unevenly. Although gender-based perceptions of climate change have been studied, there remains a gap in understanding how these perceptions influence the adoption of adaptation strategies among men and women smallholder farmers in the production of leguminous crops in sub-Saharan Africa. This study investigated the gender differences in the adoption of climate change adaptation strategies among bean and cowpea farmers in Ghana. The findings revealed that socioeconomic and institutional factors significantly influenced the choice of adaptation strategies, with notable differences between men and women. Higher levels of education, farming experience, marital status, access to credit, and education determined the choice of adaptation strategies. On the other hand, women farmers, despite having lower levels of formal education, showed a higher utilization of extension services, possibly due to targeted efforts to reach out to more women farmers. Larger households were less likely to adopt mixed cropping and changing cropping patterns, while married individuals were less likely to use crop rotation. Training and access to credit significantly increased the likelihood of adopting crop rotation, changing cropping patterns, and using improved seeds. The study also found that [f]armers perceptions of the impacts of dry spells and delayed onset of rains influenced the use of climate change adaptation strategies. Furthermore, farmers who participated in climate change planning were more likely to use diverse adaptation strategies, underscoring the importance of a locally focused, inclusive planning process. However, gender differences were observed in the determinants of the use of these strategies. For instance, while access to extension services was found to be more influential for women, men's decisions were more influenced by their marital status, access to credit, and education. Policy makers and local institutions need to encourage and facilitate farmers' involvement in climate change planning processes to enable designing of effective, context-relevant, inclusive, and sustainable climate change adaptation strategies. Distinct differences in the factors underlying the use of adaptation strategies by men and women demand creation of and implementation of gender-sensitive programs that effectively reach and benefit both women and women.

KEYWORDS

adaptation, climate change, gender, intersectionality, perception, smallholder farmer

1. Introduction

Climate change has emerged as a pressing phenomenon of global concern (Bonnot et al., 2018; IPCC, 2022) with agriculture among the most vulnerable sectors (Cooney, 2012; Falaki et al., 2013). Climate induced events, such as droughts, and floods are among the major causes of reduced agricultural productivity globally (Thornton et al., 2014; Horton et al., 2016). Numerous studies in sub-Saharan Africa have provided evidence supporting farmers' perceptions of erratic climate variability in recent decades (Mertz et al., 2008; Sultan et al., 2014; Ndamani and Watanabe, 2015; Ayanlade et al., 2017; Cuni-Sanchez et al., 2019; Rapholo and Diko-Makia, 2020; Oluwatimilehin and Ayanlade, 2021). West African countries are particularly vulnerable to climate change not only due to their high reliance on rain-fed agriculture, but also due to their limited economic and institutional capacity to respond to climate change (Sultan et al., 2014). Therefore, smallholder farmers in West Africa need to adapt to the changing climatic conditions to safeguard their livelihood and food security (Asare-Nuamah and Amungwa, 2021).

In Ghana, agriculture contributes significantly to the national gross domestic product (GDP), foreign exchange earnings, and food security (World Bank, 2018). Smallholder farmers who heavily rely on rain-fed agriculture dominate the agricultural sector in Ghana, making them highly vulnerable to the impacts of climate change (Karl, 2021). The sector employs over 50% of the country's population and, therefore climate change directly impacts the growth of the sector and its contribution to national GDP (Chemura et al., 2020). Increased incidence of extreme climatic events, such as drought, mean changes in rainfall variability, temperatures, and floods, are projected to affect food production, hindering progress toward food security and rural development (Nelson et al., 2010).

Though understanding climate change and its effects is crucial for adaptation in agriculture, translating this knowledge into effective decision-making involves various factors that influence the process (Nelson et al., 2010; Cui and Xie, 2021). However, the process is not always straightforward as smallholder farmers lack the necessary knowledge and resources to identify and implement climate change adaptation measures. For instance, climate extremes vary across temporal and spatial scales, with resource-poor farmers with less adaptive capacity being the most vulnerable group (Govind, 2022). In addition, climate change impacts differ across agroecological zones and among households because of intersectional factors such as gender, wealth, age, experience, ability, education, networks, and education (Codjoe et al., 2012). These factors influence adaptive capacity of smallholder farmers, suggesting possible differences in individual and household capacities to adapt to climate change.

Integrating gender in climate change adaptation is helpful in planning and developing interventions and strategies for greater resilience (Ampaire et al., 2019). Although there may be overlap of men and women farmers' perceptions of climate change, differences in resource endowment, opportunities, and characteristics may affect their adaptative capacities (Mishra et al., 2018). This is because men and women perceive climate-related changes based on their social roles and responsibilities (Goli et al., 2020). For example, in Ghana, men predominately undertake land clearing and plowing, while women undertake planting, weeding, and harvesting (Diawuo et al., 2019). In this particular situation, women will be more concerned with the start and end of rain to ease planting and harvesting, while men will be more concerned with the start of rain for land preparation. Thus, the division of labor not only influences gender perceptions of climate change but may also affects their abilities to take action in response to it. These differences contribute to the increased vulnerability of some women to the adverse effects of climatic events compared to men (Eastin, 2018; Chidakwa et al., 2020).

In addition, research attributes gender inequalities in climate change adaptation to women's lack of access to economic resources and safety nets as well as socio-political exclusion, resulting from restrictive cultural norms and beliefs (Eastin, 2018; Alhassan et al., 2019; Assan et al., 2020). Addressing disparities in climate change adaptation is critical for promoting gender equity, which in turn builds women's resilience to the effects of extreme climatic events. There are two interconnected aspects to consider: integrating gender in adaptation interventions (adaptation for gender equality) and addressing gender inequities to improve adaptive capacity (gender equality for adaptation). This study defines gender as the socially constructed characteristics of men and women farmers (Codjoe et al., 2012). It goes beyond sex, to look at systematic structures that institutionalize men's power over women on various scales that are socially, economically, and culturally determined. The study acknowledges that gender is a critical determinant of vulnerability to climate change, as it interacts with institutional and socio-economic variables, resulting in varying degrees of vulnerability and adaptive capacity for male and female farmers.

While numerous studies have studied how the choice of climate adaptation strategies among smallholder farmers is influenced by perception, socio-economic, cultural, and institutional factors (Codjoe et al., 2012; Fosu-Mensah et al., 2012; Kisauzi et al., 2012; Kusakari et al., 2014; Ali and Erenstein, 2017; Ngigi et al., 2017; Adzawla and Kane, 2019; Mangheni et al., 2019; Ylipaa et al., 2019; Assan et al., 2020; Lawson et al., 2020; Adeagbo et al., 2021; Atube et al., 2021; Mwinkom et al., 2021; Awiti, 2022; Muluneh et al., 2022; Nuhu and Matsui, 2022) there are gaps in understanding factors that influence the choice of climate change adaptation strategies among men and women farmers in the production of multiple crops such as cowpeas (*Vigna unguiculata* L.) and common beans (*Phaseolus vulgaris* L.). These legumes are the most widely grown in sub-Saharan Africa and are often considered "women's crops" due to women's traditional roles in production, harvesting, and post-harvest activities. Also, most studies on adaptation to climate change in Ghana (e.g., Aniah et al., 2019; Chemura et al., 2020; Addaney et al., 2021; Antwi-Agyei and Nyantakyi-Frimpong, 2021) are either not crop-specific or predominantly focus on cereal and cash crops, with legume crops receiving limited attention. This study aims to fill this research gap by providing insights into gender-specific adaptation strategies for common bean and cowpea production, as well as examining the factors that underpin gendered differences in adaptation. By doing so, the study contributes to a more comprehensive understanding of gender differences in climate change adaptation in the context of these important legume crops.

Three research questions answered by the study are: (a) How do men and women smallholder cowpea/common bean farmers perceive climate adaptation? (b) How do men and women smallholder cowpea/common bean farmers adapt to climate change variability? (c) What gender-based factors influence the choice of adaptation strategies among smallholder cowpea/common bean farmers?

2. Materials and methods

2.1. The study area

The study was conducted in Ejura-Sekyedumase and Atebubu-Amantin municipalities due to the predominant production of leguminous crops in the region. Ejura-Sekyedumase lies in the transitional zones of the semi-deciduous forest, while Atebubu-Amantin falls within the interior wooded savanna or tree savanna zones. The annual rainfall for the municipalities varies between 1,200 and 1,800 mm and occurs in two seasons. Temperature ranges between 21 and 30°C. The climate in Ejura-Sekyedumase and Atebubu-Amantin is favorable for cereal, root and tubers, leguminous crop, and tobacco production (Ghana Statistical Service, 2014a). Agriculture plays a vital role in these municipalities, employing about 70% of the labor force (Ghana Statistical Service, 2014b). Figure 1 presents the map of Ghana showing the study areas.

2.2. Sampling and data collection

The two municipalities, Ejura-Sekyedumase and Atebubu-Amantin, were purposefully selected because they are common bean and cowpea growing hubs. The two municipalities are also intervention areas of the Pan-African Bean Research Alliance (PABRA) and the Council for Scientific and Industrial Research (CSIR)-Crops Research Institute common bean value chain activities in Ghana. Following sampling methods applied by Mwinkom et al. (2021), 16 farming communities were randomly selected from the two municipalities because there was no record of the number of legume farmers in two sites. A proportionate sampling technique was used to determine the number of farmers selected from each municipality and farming community as presented in Table 1. 160 respondents were

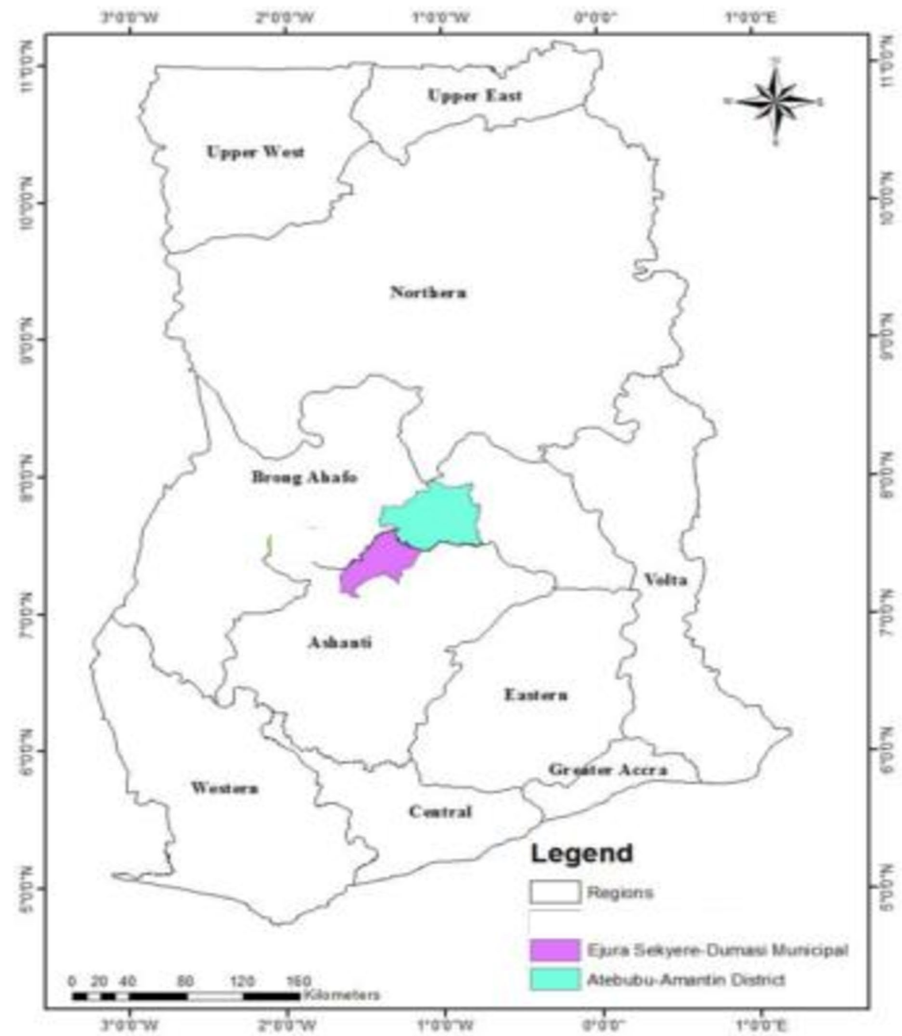

FIGURE 1
Map of the study area.

TABLE 1 Socioeconomic characteristics of bean and cowpea farmers by gender.

Variable	Pooled	Women	Men	*p* value
Average age of respondent	42.88	41.34	43.92	0.220
Marital status (%)				0.007
Single	11.04	8.06	13.04	
Married	82.47	77.42	85.87	
Divorced	1.95	4.84	0	
Widowed	4.55	9.68	1.09	
Education level (%)				0.000
None	44.81	67.74	29.35	
Basic	41.56	30.65	48.91	
Secondary	9.09	0	15.22	
Tertiary	4.55	1.61	6.52	
Average years of education completed	5.34	2.69	7.12	0.000
Household size	8.21	6.98	9.04	0.013
Average farming experience	18.72	15.87	20.65	0.007
Main income source—crop production (%)	98.04	95.16	100.00	0.065
Land ownership	70.13	74.19	67.39	0.366
Farm size	4.08	3.44	4.52	0.022

purposively selected from the 16 communities. Due to incomplete data, questionnaires of six respondents were discarded and 154 were admissible in the analysis. Smallholder farmers were defined as farmers who owned or could access five acres of land or less [Ministry of Food and Agriculture (MOFA), 2006].

A household survey was conducted to gather primary data from the 160 respondents. The data were gathered through face-to-face interviews using a semi-structured questionnaire. The questionnaire was administered to men and women cowpea and common bean smallholder farmers. The data collected included sociodemographic characteristic, such as age, sex, education level, main occupation, and household size. In addition, the study collected data on institutional information, including farmers' access to extension, credit, training, and climate information other information collected was cowpea and common bean production, farm characteristics, climate change perceptions and adaptation strategies.

2.3. Data analysis and econometric model specification

The collected data were analyzed using both descriptive analysis and regression model. Descriptive analysis involved use of frequencies, percentages, means, and standard deviations. Systematic differences between men and women responses were tested using chi-square test of independence for binary and categorical variables, and independent samples *t*-test for numerical continuous variables. Multivariate probit model was applied to analyze factors that determined use of adaptation strategies to climate change.

Determinants of climate change adaptations have been analyzed using discrete choice regression models, such as probit or logit regression (Fosu-Mensah et al., 2012) and multinomial probit (To et al., 2021). Farmers are most likely to use a combination of adaptation measures to deal with climate risks. However, the interrelationships among various strategies are not often considered by most analytical approaches (Yu et al., 2012). This occurs because farmers are faced with alternatives that may encourage the adoption or dis-adoption of multiple adaptation measures either simultaneously or sequentially as complements, substitutes, or supplements (Tesfaye and Seifu, 2016). While some studies on climate change adaptations assume that farmers consider several possible practices and choose a bundle of practices that maximize expected utility (Yu et al., 2012; Tesfaye and Seifu, 2016), it is important to recognize that not all studies share this assumption. Indeed, a substantial body of literature on gender and social differences directly challenges this assumption, emphasizing the influence of various socio-economic factors, including gender, on farmers' choices and adaptation strategies (Lawson et al., 2020). Thus, the adoption decision is intrinsically multivariate, and using univariate modeling excludes useful information about possible interdependencies that inform adoption decisions. Therefore, this study adopted the multivariate probit econometric approach to simultaneously model the influence of a set of explanatory variables on use of climate change adaptation strategies. The dependent variables are the choice of adaptation options, and they include use of crop rotation, mixed cropping, changing cropping patterns, and use of improved seeds that were co-identified during the implementation of PABRA activities in Ghana. Following Tesfaye and Seifu (2016), the multivariate probit econometric approach for this study is given by a set of n binary dependent variables y_{hpj} such that:

$$y*_{hpj} = x'_{hpj}\beta_j + \mu_{hpj} \qquad j = 1, 2 \ldots, m. \tag{1}$$

$$y_{hpi} = \begin{cases} 1 & if \;\; y^* hpj > 0 \\ 0 & otherwise \end{cases} \tag{2}$$

Where $j = 1,2\ldots, m$ denotes the climate change adaptation strategies available, $x'hpj$ is a vector of explanatory variables, βj denotes the vector of the parameter to be estimated; and μhpj are random error terms distributed as a multivariate normal distribution with zero means and unitary variance.

The assumption is that a rational *hth* farmer has a latent variable; $y*_{hpj}$ which captures the unobserved preferences associated with the *jth* choice of adaptation strategy. This latent variable is assumed to be a linear combination of observed farmer and other characteristics that affect the adoption of adaptation strategy, as well as unobserved characteristics captured by the stochastic error term. The variable $y*_{hpj}$ is latent and thus, the estimation is based on the observable variable y_{hpi} which indicates whether a farmer adopts a particular climate adaptation strategy. As the adoption of several adaptation strategies is possible, the error terms in equation (1) are assumed to jointly follow a multivariate normal distribution, with zero conditional mean and variance normalized to unity (Tesfaye and Seifu, 2016). The off-diagonal elements in the covariance matrix represent the unobserved correlation between the stochastic component of the *jth* and *mth* type of adaptation strategies. This assumption means that equation (2) gives a multivariate probit model that jointly represents decisions to adopt a particular adaptation strategy (Tesfaye and Seifu, 2016). This specification with non-zero off-diagonal elements allow for correlation across the error terms of several latent equations, which represent unobserved characteristics that affect the choice of alternative adaptation strategies. Gender and intersectionality factors are represented in the model as explanatory variables, allowing for the analysis of their influence on farmers' choices of climate change adaptation strategies and accounting for the complex interplay between different socio-economic factors that shape decision-making.

3. Results and discussion

3.1. Descriptive results

3.1.1. Socioeconomic factors

The data presented in Table 1 provide potential socioeconomic predictors of gender differences in climate change adaptation strategies in the context of beans and cowpea. The average age of farmers was 43 years, with the difference in age between the two men and women ages not statistically significant. This result indicates that age may not be a significant determinant of differences choice of climate change adaptation strategies between men and women farmers. However, the data showed a significant ($p < 0.001$) difference in marital status between men and women farmers. While significantly higher proportion of men farmers were married (86%) than women (77%), higher percentage of women farmers were either widowed (10%) or divorced (5%) than men. This result suggests that marital status might impact the selection of climate change adaptation strategies for men and women in distinct ways.

Furthermore, a significantly ($p < 0.001$) higher percentage of men farmers had secondary (15%) and tertiary (7%) education, while higher percentage of women farmers had no formal education (70%) with about 31% of them having basic education. The significant difference in education level between men and women farmers was further reinforced by statistically significant ($p < 0.001$) difference between average number of schooling years completed by men (7) and women (3). Therefore, educational attainment could possibly indicate potential gender differences in engagement in learning about climate change, resulting in differences in choice of climate change adaptation strategies used by men and women (Alonso-Tapia et al., 2023).

Men farmers reported statistically significantly larger-sized households (nine members) compared to women (seven members). Larger households may have higher labor availability that enable implementation of certain climate change adaptation strategies compared to small-sized household (Mume et al., 2023). The difference between the average number of years of farming experience of men (21) and women (16) was statistically significant ($p < 0.001$). Experience maybe associated with a better understanding of climate change impacts and potential adaptation strategies (Batungwanayo et al., 2023), thereby explaining possible gender differences in choice or use of climate change adaptation strategies. The results also showed that almost all farmers (98%) in the study area relied on crop production as their main income source. There was a marginally ($p < 0.1$) higher percentage for men (100%) than women (95%) who has had crop farming as the main income source, suggest that the principal source of household income may or may not be associated choice of climate change adaptation strategies by men and women farmers.

Further analysis of socioeconomic data revealed that a slightly higher percentage of women (74%) than men (67%) farmers own land, but this difference was not statistically significant ($p = 0.366$). Land ownership in the context of this study referred to an individual who made most of the decision about land allocation to common bean and cowpea, which we recognize that occurs within wider land allocation dynamics. Thus, the variables may not potentially affect men and women use of climate change adaptations strategies. This assertion is further supported statistically significantly high average farm size is owned/accessed by men farmers (4.5 acres) compared to women (4.4 acres). Thus, farmers with larger farms may have more resources and flexibility to implement certain strategies (Batungwanayo et al., 2023), thereby accounting for potential gender differences in climate change adaptation strategies.

3.1.2. Institutional factors

Several studies have shown that climate change adaptation strategies are embedded in the heterogeneous social and institutional conditions that have a ramification not only their use by how they are used. The social and institutional characteristics of farmers who participated in the study are presented in Table 2. The results indicate that 66% of the farmers had access to extension services, 18% attended training in bean and cowpea production, 14% had access to credit, and 49% belonged local social associations. More women (71%) than men (63%) had access to extension, while more men (20%) than women (15%) attended training in common bean and cowpea production. About 22% of men and 19% of women had access to credit. The data also showed that women (50%) and men (48%) were members of farmers associations. While there were some differences in the institutional characteristics of sampled women and men farmers, the disparities were not statistically significant, which implies that, regardless of gender, farmers had similar opportunities and constraints in access to social and institutional support necessary for adaptation to climate change.

However, specific types of training that farmers receive impact the choice and use of climate change adaptation strategies differently.

TABLE 2 Institutional characteristics of bean and cowpea farmers by gender.

Variable	Pooled	Women	Men	*p* value
Access to extension services	66.01	70.97	62.64	0.286
Attended training on bean/cowpea production	17.53	14.52	19.57	0.419
Type of training received				
Agronomic practices	17.53	14.52	19.57	0.419
Pest and disease control	15.58	11.29	18.48	0.228
Post-harvest practices	10.39	11.29	9.78	0.764
Climate-smart agriculture	13.64	12.9	14.13	0.828
Access to credit	20.78	19.35	21.74	0.721
Group membership	48.70	50.00	47.83	0.791
Receive climate change advisory from extension officers	66.23	75.81	59.78	0.039
Involvement in climate change planning	38.96	37.1	40.22	0.697
Use extension information in climate change adaptation	62.34	67.74	58.7	0.256
Taken proactive measures in climate change adaptation	44.16	41.94	45.65	0.649

Therefore, farmers who received training in common bean and cowpea production were further asked to state types of trainings they received. The results presented in Table 3 show that 18, 16, 10, and 14% of the farmers reported that themselves or household members received training in agronomic practices, pest and disease control, post-harvest practices, and climate-smart agriculture, respectively. Like access to social and institutional support, no significant differences ($p > 0.05$) in the type of training received were reported by gender, suggesting that both men and women had similar opportunities to receive and learn about agronomic practices, pest and disease control, post-harvest practices, and climate-smart agriculture. These training are critical in equipping farmers with knowledge and skills on how to manage their crops effectively and enabling them to understand climate change, manifestation and infestation of pests and diseases, and implementation of effective climate adaptation strategies (Batungwanayo et al., 2023; Kwambai et al., 2023).

Access to climate information/advise from extension officers and farmers involvement in climate change planning strong precursors/pathways of choice of climate change adaptation strategies. The results in Table 2 show statistically significant ($p < 0.05$) difference in percentages of men (60%) and women (76%) who received climate change information/advisory from extension officers. A higher percentage of women farmers receiving extension information could be as a result gender targeted efforts in delivery of extension services designed to reach out to more women due to deep-rooted cultural and gender barriers that prevent them from accessing services (World Bank, 2013; Lee et al., 2023).

However, no significant differences were observed between men (39%) and women (37%) involvement in climate change planning. In addition, no gender disparities were reported regarding the proportion on men (58%) and women (69%) who used of climate information, as well as between men (46%) and women (42%) who reported to have taken proactive measures in climate change adaptation. The no significant differences between men and women in terms of involvement in climate change planning and active use of climate information suggests that both genders are possibly equally affected by climate change as demonstrated by the perceptions of climate change (Table 3) or effectiveness of extension services in delivery of climate change information.

3.1.3. Climate change perceptions

Perceptions of climate change also plays a crucial role in not only shaping farmers choice of and willingness to implement climate change adaptation strategies. But also their understanding of climate change related risks and impacts, as well as their information seeking behavior, including engagement with training programs, extension services, and other forms of support aimed at promoting climate-smart agriculture (Limantol et al., 2016; Batungwanayo et al., 2023). The data in Table 3 provide insights into the farmers' perceptions of climate change, disaggregated by gender. The results reveal that 84% of farmers were aware of climate change, with the proportion women (79%) who were knowledgeable of climate change being lower than that of men (88%). However, no significant ($p = 0.131$) difference was observed. About 73% of the farmers perceived the occurrence of extreme climate change regardless of gender. 95% reported that temperatures had shifted upwards, but no significant differences were reported between men and women perceptions in temperature changes.

There were also no significant gender differences in perceptions on change in temperature and rainfall patterns, with 59 and 46% of both men and women indicating that temperature and rainfall were fairly high, respectively. About 64% of farmers, gender notwithstanding, perceived that the impact of delayed onset of rains had large (33%) and severe (31%) effect on crop production and therefore needed to be planned for or considered. The percentage of farmers with perception that river flooding had had moderate to severe effects on crop production (50%) was higher than those that reported no effect (21%) and minimal effect (22%). Similarly, perception of moderate to severe impacts of short rain duration on crop production and need to be planned for or considered (82%) was higher than those that indicated no effect (1%) and minimal effect (12%). In addition, about 82% of the farmers reported that dry spells had moderately to severely impacted crop production. However, no statistically significant gender differences in perceptions of the impact of climate change on crop production were reported.

TABLE 3 Farmers perceptions of climate change disaggregated by gender.

Variable	Pooled	Women	Men	*p* value
Climate change knowledge/awareness	84.42	79.03	88.04	0.131
Perceptions of occurrence of extreme climate change	72.73	72.58	72.83	0.973
Perceptions about change in temperature	94.81	95.16	94.57	0.589
Farmers' knowledge on change in temperature patterns				0.647
Fairly high	59.09	62.9	56.52	
High	10.39	8.06	11.96	
Moderate high	30.52	29.03	31.52	
Farmers' knowledge on rainfall patterns				0.500
Fairly high	46.1	51.61	42.39	
High	14.94	14.52	15.22	
Moderate high	38.96	33.87	42.39	
Knowledge on climate change effects				0.174
Fairly high	61.04	67.74	56.52	
High	9.74	4.84	13.04	
Moderate high	29.22	27.42	30.43	
Perceptions on impact of delayed onset of rains				0.109
No effect	1.95	0	3.26	
Little effect-no or minimal planning required	12.34	11.29	13.04	
Moderate affect that should be planned for	16.88	9.68	21.74	
Large effect that should be strongly considered	33.12	38.71	29.35	
Severe effect that needs to be planned for	31.17	32.26	30.43	
Do not know	4.55	8.06	2.17	
Perceptions on impact of river flooding				0.341
No effect	21.43	19.35	22.83	
Little effect-no or minimal planning required	22.08	16.13	26.09	
Moderate affect that should be planned for	23.38	20.97	25	
Large effect that should be strongly considered	22.08	29.03	17.39	
Severe effect that needs to be planned for	5.19	6.45	4.35	
Do not know	5.84	8.06	4.35	
Perceptions of impact of short rain duration				0.510
No effect	1.3	0	2.17	
Little effect-no or minimal planning required	12.34	9.68	14.13	
Moderate affect that should be planned for	20.13	17.74	21.74	
Large effect that should be strongly considered	28.57	27.42	29.35	
Severe effect that needs to be planned for	33.77	38.71	30.43	
Do not know	3.9	6.45	2.17	
Perceptions on impact of dry spell				0.933
No effect	3.25	3.23	3.26	
Little effect-no or minimal planning required	12.34	11.29	13.04	
Moderate affect that should be planned for	16.88	14.52	18.48	
Large effect that should be strongly considered	32.47	33.87	31.52	
Severe effect that needs to be planned for	31.82	32.26	31.52	
Do not know	3.25	4.84	2.17	

TABLE 4 Strategies taken by farmers to adapt to climate change.

Variable	Pooled	Women	Men	*p* value
Change in planting dates	48.70	46.77	50.00	0.694
Change in cropping patterns	40.91	41.94	40.22	0.832
Crop rotation	42.21	40.32	43.48	0.697
Mixed cropping	31.17	30.65	31.52	0.908
Certified/improved seed	21.43	19.35	22.83	0.607
Irrigation	19.48	22.58	17.39	0.425
Compost	16.23	11.29	19.57	0.172
Insecticides	34.42	30.65	36.96	0.419
Fertilizer	27.92	24.19	30.43	0.397
Agroforestry	19.67	32.97	27.63	0.072

The results in Table 3 reveals no significant differences in men and women perceptions of climate change and impacts on crop production. This could be linked to the Pan African Bean Research Alliance (PABRA) inclusive climate change interventions in Ghana. Ghana is one of the PABRA beneficiary countries that received training in use of Digital AgroClimate Advisory (DACA), an application that helps farmers manage climate change risks via provision of context-specific agro-climate advisories (Kagabo et al., 2020). Second, PABRA's promotion of community-based bean value chain businesses in Ghana could also have contributed to equalization of climate change perceptions among men and women farmers. Besides PABRA interventions, similar exposure to climate change effects, shared experiences, knowledge and information, and similar roles in farming activities by both men and women could also have led to similar perceptions of climate change and its impacts on crop production.

3.1.4. Climate change adaptation strategies

The results presented in Table 1 through Table 3 are critical to understanding the drivers of climate change adaptation strategies. We now profile strategies that farmers identified as climate change adaptation strategies. Table 4 shows 10 climate change adaptation strategies reported by farmers. About half (49%) of both men and women respondents reported changing planting dates as a climate change adaptation strategy, suggesting that farmers adjusted farming calendars in response to climate changes related occurrences. Second, 40% of them changed cropping patterns, which may have involved crop diversification, planting of climate-smart (drought-tolerant or early maturing) varieties or changing the sequence or combination of crops planted (Mwinkom et al., 2021; Lamichhane et al., 2022; Dittmer et al., 2023).

Crop rotation and mixed cropping were practiced by about 42 and 31% of the sampled farmers, respectively. Crop rotation and mixed cropping may have been used by farmers to reduce pest and disease incidence, enhance soil fertility, and crop productivity, and improve resilience to climate variability, which are important objectives of climate change adaptation as evidenced by Volsi et al. (2022), Mengesha et al. (2022) and Chidawanyika et al. (2023). 21% of farmers reported using certified or improved seed of common bean and cowpea varieties to adapt to climate change. Improved varieties offer higher yields and increased resilience to climate stressors (Laidig et al., 2022). Furthermore, about 20% of the farmers reported practicing irrigation, 16% used compost manure, 34% applied insecticides, and 28% used fertilizer as climate change adaptation strategies. Also, 20% of the farmers practiced agroforestry, possibly to enhance soil fertility, increase biodiversity, or as sequester carbon to reduce agriculture environmental footprint.

3.2. Regression results

3.2.1. Full regression

Table 5 presents coefficients of a multivariate regression analysis of the full model that estimated the determinants of use of four different climate change adaptation strategies: crop rotation, mixed cropping, changing cropping patterns, and use of improved seeds of common bean or cowpea varieties. Change of planting dates, agroforestry, and irrigation were not included in the regression model because they were highly collinear due to data limitations. Compost, insecticides, and fertilizer were not considered as climate adaptation strategies and therefore not included in model.

Model diagnostics show the overall fit of the model. The Wald chi-square (χ^2) test was statistically significant, meaning that that variables included in the regression analysis were jointly statistically significant in determining farmer use of climate change adaptation strategies. In addition, the likelihood ratio test was statistically significant, meaning that multivariate probit regression better predicted use of climate change adaptation strategies than univariate probit regression. The correlation coefficients (rho) were positive and statistically significant albeit at different levels. This shows that the four strategies are correlated and complement each other. Household size, marital status, training, access to credit, climate change planning, and farmers perceptions of the impact of climate change significantly predicted farmers use climate change adaptation strategies.

The coefficients for household size were negative and marginally statistically significant for mixed cropping and changing cropping patterns, suggesting that larger households have a lower probability of using the mixed cropping and changing cropping patterns as climate change adaptation strategies. Potential explanations for this result could be that large-sized household have more mouths to feed and may prioritize high-yielding monocultures or cash crops over more diversified systems. Mixed cropping and change in cropping patterns may require additional investments which may be a constraining

TABLE 5 Multivariate regression results of determinants of use of climate change adaptation strategies—full model.

Variable	Crop rotation		Mixed cropping		Cropping pattern		Improved seed	
	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Age	−0.020	0.015	−0.005	0.013	−0.003	0.014	−0.003	0.013
Education in years	−0.001	0.022	0.008	0.020	−0.005	0.023	−0.001	0.022
Household size	−0.024	0.024	−0.041*	0.025	−0.043*	0.023	0.037	0.023
Farming experience	0.014	0.017	0.001	0.016	−0.008	0.017	0.002	0.017
Marital status	−0.563*	0.311	−0.311	0.307	−0.334	0.316	−0.300	0.315
Farm size	0.016	0.038	0.031	0.036	0.049	0.041	0.003	0.043
Access to extension	0.363	0.257	0.919	0.261	0.270	0.243	−0.103	0.265
Training	0.798**	0.331	0.089	0.265	0.733**	0.304	0.577*	0.323
Access to credit	0.591**	0.295	0.677**	0.311	0.648**	0.306	0.123	0.328
Climate change planning	1.279***	0.261	1.023***	0.245	1.153***	0.243	0.939**	0.265
Impact of dry spell	1.711***	0.609	1.141**	0.572	1.220**	0.477	0.248	0.578
Impact of delayed onset of rains	−2.326***	0.711	−1.752**	0.697	−2.059***	0.639	0.394	0.691
Impact of short rain duration	0.644	0.655	0.951	0.638	0.841	0.658	−0.377	0.663
Constant	−0.112	0.594	−1.499**	0.636	−0.486	0.624	−1.538**	0.669
Wald χ^2	282.38***							
LR test	180.322***							
rho21	0.942***							
rho31	0.971***							
rho41	0.244*							
rho32	0.973***							
rho42	0.249*							
rho43	0.235*							

*, **, and *** denote significance at $p < 0.1$, $p < 0.05$, and $p < 0.01$, respectively.

factor for large-sized households. For instance, Shiferaw and Holden (1998) indicated that the relationship between household size and climate change adaptation is multifaceted. In relation to the results reported in this study, Shiferaw and Holden (1998) opined that large-sized households may have higher number of dependents, compelling them to rely on daily laborer (outsiders). Consequently, large-sized households in the context of the current study may have had poor perception on use of mixed cropping and changing cropping patterns as climate change adaptation strategies.

Second, coefficient for marital status was negative and statistically significant for crop rotation. This result indicates that married farmers were less likely to use crop rotations as a climate change adaptation strategy. Crop rotation involves allocation or reallocation of resource among crop enterprises, a process that involves decision-making and gender dynamics. Men and women concern about climate change vary due to differences in decision-making power which affects the crop rotation as climate change adaptation strategies. In the context of the study areas, men are commercially oriented and engage in rice and yam production, while women are largely involved in food crop production such as legumes and vegetables. Therefore, decision-making processes on allocation of land to crops on a rotational basis possibly hindered the adoption of crop rotation in response to the impact of climate change. The results align with findings of Ojo and Baiyegunhi (2020) who reported that being married reduced chances of adoption of adaptation strategies by smallholder rice farmers in south-west Nigeria.

Furthermore, training had significant positive relationship with use of crop rotation, changing cropping patterns, and improved seeds. These results indicate that farmers who attended trainings had a higher probability of using the three climate adaptation strategies than those did not receive the training holding other factors constant. The result confirms findings reported by Amankwah (2023) in a study conducted in Nigeria. The study found that access to credit was a significant factor influencing the adoption of sustainable agricultural practices (SAPs). In this study, trainings could have introduced and demonstrated implementation of crop rotation, changing cropping patterns, and improved seeds, thereby increasing technical ability of farmers about the three adaptation strategies. Consequently, this could have increased farmers confidence to use the strategies.

Credit was another important institutional factor that positively and significantly influenced use of crop rotation, mixed cropping, and changing cropping patterns. This finding aligns with Fosu-Mensah et al. (2012) and Belay et al. (2023) who reported that training was a key component of climate-smart agriculture that enabled farmers to adapt to climate change in Sekyedumase district in Ghana and Southern Ethiopia, respectively. Access to credit possibly increased farmers access to cash flow that allowed them to purchase inputs like improve seeds and fertilizers that are critical in implementation of crop rotation, mixed cropping, and making changes in cropping patterns. The positive association between credit and farmers use of crop rotation, mixed cropping, and making changes has a firm foundation in climate adaptation literature as demonstrated by Gbetibouo (2009) and Deressa et al. (2009).

Farmer's perceptions of the impact of dry spell and delayed onset of rains on crop production had mixed effects on use of crop rotation, mixed cropping, and change in cropping pattern as climate change adaptation strategies. The statistically significant coefficient for these variables suggests that farmers' perceptions of the impact of climate change influence their use of adaptation strategies. While perception of dry spell on impact crop production increased the likelihood of farmers using crop rotation, mixed cropping, change in cropping patterns, perception of the impact on delayed onset of rains made farmers less likely to use the three practices.

Dry spells usually have immediate and visible impacts on crops, possibly increasing the likelihood of farmers perceiving climate change as a serious threat to farming systems and livelihoods. Therefore, perception of higher impact of dry spells on crop production possibly compelled farmers to use crop rotation, mixed cropping, and changing cropping patterns as strategies for diversifying crop production and enhancing resilience of farming systems. The results conform to findings reported in literature. For instance, Joshi et al. (2017) found that perception on the increased incidence of dry spell during rainy season increased the probability of use of water conservation technologies/practices by farmers in mountain districts of Nepal. Tesfaye and Seifu (2016) also found that perceptions of effects of unreliable rainfall on agricultural production was significantly associated with planting different crop varieties, mixed farming, and use soil and water conservation as climate change adaptation measures in three districts of East Hararghe zone in Ethiopia.

The negative relationship between perception of delayed onset of rains and decreased use of crop rotation, mixed cropping, and change in cropping pattern as climate change adaptation strategies could be linked to the nature of climate change phenomenon. Unlike other aspects of climate change, such as dry spells, onset of rains is less predictable and controllable, suggesting that farmers may feel less able to adapt to delayed rains. This perception makes them less likely to adopt adaptation strategies in response to delayed onset of rains. The perception of delayed onset of rains could also reflect the cost and risk involved in changing cropping systems in response to uncertain climate changes. This assertion correlates with findings of Deressa et al. (2011) who showed that uncertainty in climate change outcomes influenced climate change adaptation strategies used by farmers in the Nile basin of Ethiopia.

The critical finding of this study was the effect of farmer participation in climate change planning on use of climate change adaptation strategies. Participation in climate change planning increased the likelihood of farmers using crop rotation, mixed cropping, cropping pattern, and improved seed. Specifically, farmers who participated in climate change planning, especially during the prototyping and testing of DACA, had higher likelihood of using all the climate change adaptations strategies. Participation strongly increased the likelihood of farmers adopting mixed cropping as an adaptation strategy possibly because it not only increased farmers' awareness of climate change and their understanding of different adaptation strategies, but also enabled tailoring the adaptation strategies to local contexts and to the specific needs and circumstances men and women farmers. This finding reinforces the importance of adaptation planning process to help farmers understand climate change and its potential impacts, and the importance for their involvement in designing of adaptation strategies to meet specific needs and circumstances of farmers (Bryan et al., 2009; Vincent et al., 2014).

3.2.2. Reduced regression results

Table 6 present probit coefficients of factors influencing use the different climate change adaptation strategies by gender. Reduced models were estimated using probit model because multivariate probit did not fit the data well. We provide significance levels to provide insights into how different factors influence the choice of climate change adaptation strategies for each gender.

Farming experience significantly influenced the use of rotation among women ($p < 0.1$), while access to extension services was significant for both genders but stronger for women ($p < 0.01$ for women and $p < 0.1$ for men). Climate change planning was significantly related to the use of rotation for both genders ($p < 0.01$). Marital status and access to extension services significantly affect men's use of mixed cropping ($p < 0.05$ and $p < 0.1$, respectively), and access to extension services significantly affects women's use of this strategy ($p < 0.01$). Men's use of mixed cropping was also significantly affected by their access to credit and their climate change planning ($p < 0.01$). Farming experience and training significantly influence women's use of this strategy ($p < 0.05$ and $p < 0.1$, respectively), and climate change planning significantly affects both genders ($p < 0.01$). For men, access to credit significantly influences the use of this strategy ($p < 0.01$). Men's years of education and training are significantly associated with the use of improved seeds ($p < 0.05$ and $p < 0.01$, respectively), while women's climate change planning has a significant effect ($p < 0.1$).

The results in Table 6 provides valuable insights into the determinants of the use of different climate change adaptation strategies among farmers and highlights the importance of considering gender differences in the design of climate change policies and programs. For instance, access to extension services is generally more influential for women, while men's decisions are more influenced by their marital status, access to credit, and education. Perceptions of the impacts of different climate changes (dry spell, delayed onset of rains, short rain duration) do not seem to significantly affect the choice of strategies, except in a few cases for men.

4. Conclusion

This study provides critical insights into the gender differences in the adoption of climate change adaptation strategies among farmers of common beans and cowpeas. Socioeconomic factors, institutional support, and climate change perceptions significantly influence the choice of adaptation strategies, with notable differences between men and women farmers. Men farmers, with higher levels of education and farming experience, were found to be influenced more by their marital status, access to credit, and education in their choice of adaptation strategies. On the other hand, women farmers, despite having lower levels of formal education, showed a higher utilization of extension

TABLE 6 Probit regression results of determinants of use of climate change adaptation strategies—reduced models.

Variable	Rotation		Mixed cropping		Cropping pattern		Improved seed	
	Women	Men	Women	Men	Women	Men	Women	Men
Age	−0.040	−0.023	−0.007	−0.008	−0.055*	0.002	−0.006	−0.016
Education in years	0.003	−0.006	0.045	−0.016	0.015	0.016	−0.023	0.011**
Household size	−0.018	−0.049	−0.038	−0.042	−0.091	−0.028	0.023	0.078
Farming experience	0.059*	0.019	0.009	0.009	0.077**	−0.007	0.017	−0.005
Marital status	−0.413	−0.727	−0.234	−1.367**	−0.299	−0.546	−0.681	0.187
Farm size	−0.004	0.052	0.005	0.044	0.072	0.037	−0.037	−0.038
Access to extension	1.320**	0.143	1.727**	0.739*	1.607	−0.197	−0.248	0.107
Training	1.003	0.568	−0.142	0.263	1.248*	0.650	−0.123	1.159**
Access to credit	−0.098	0.964**	−0.368	1.618***	−0.012	1.045***		0.706
Climate change planning	1.433***	1.488***	1.114	1.727***	1.68***	1.507***	0.977*	1.375***
Impact of dry spell	6.038	1.465	6.093	1.022	6.236	1.408	1.793	0.314
Impact of delayed onset of rains	−5.966	−2.924**	−5.913	−2.336*	−6.033	−2.665	3.980	−0.566
Impact of short rain duration	−0.427	1.460	−0.518	1.713	−0.486	1.092	−5.845	0.560
Constant	−0.569	0.285	−1.591	−1.021	−0.452	−0.551	−0.438	−2.251**
R-squared	0.364	0.283	0.314	0.354	0.434	0.259	0.2233	0.243

*, **, and *** denote significance at $p < 0.1$, $p < 0.05$, and $p < 0.01$, respectively.

services, possibly due to targeted efforts to reach out to more women farmers. This suggests that institutional support, particularly extension services, plays a crucial role in empowering women farmers to adopt effective climate change adaptation strategies. The study also revealed a variety of adaptation strategies employed by farmers, including changing planting dates, crop rotation, mixed cropping, and the use of improved seed varieties. However, the choice of these strategies is influenced by various factors, including household size, marital status, access to credit, and climate change planning, with distinct differences between men and women.

Therefore, understanding these gender differences in the adoption of climate change adaptation strategies is crucial for designing effective climate change policies and programs. Policymakers should consider these gender differences when designing and implementing climate change adaptation strategies. This could involve providing more targeted support to women farmers, such as improving access to credit and providing more gender-sensitive training and extension services. Additionally, efforts should be made to reduce the barriers that prevent men farmers from accessing these services, such as cultural norms and expectations. By doing so, we can ensure that both men and women farmers are adequately supported in their efforts to adapt to climate change, ultimately enhancing the resilience of our agricultural systems.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by CSIR-Crops Research Institute, Kumasi, Ghana. Verbal consent was obtained from the respondents for the publication.

Author contributions

PA, JA, and EN: conceptualization. PA and RA: data curation. PA, VN, and CL: formal analysis. JA and EN: funding acquisition. SY, RA, and MO: investigation. PA: writing—original draft. VN, CL, SY, JA, EN, and MO: writing—review and editing. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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