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Coping and social cohesion mechanisms in addressing climate change and land degradation in Ghana

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The West Africa sub-region is faced with major interlinked challenges in ensuring sustainable livelihoods in the context of climate change and land degradation. To ensure sustainable food production and resource use, agriculture needs to be resilient through the application of responsive adaptation and coping strategies. While many studies have explored coping and adaptation strategies employed by farmers, little attention has been paid to the farmers' indigenous practices and the role of social cohesion mechanisms. Using the sustainable livelihood framework, this study addressed this gap by exploring coping strategies and social cohesion mechanisms used by smallholder farmers in northern Ghana. It made use of a mixed-method approach, including a household survey, focus group discussions, expert interviews, field observations, and key informant interviews. Data was collected from 60 households in 6 communities across 3 districts in the study region. The results showed that social assets such as membership of self-help groups were the most important source of coping, particularly for the most vulnerable households. Such membership enabled farmers to secure micro-loans and receive aid from fellow members during extreme climate events such as floods. Farmers' tacit knowledge emerged as pivotal in coping with climate change and enhancing soil fertility, encompassing traditional weather forecasting, the making of bio-pesticides, and sustainable land management (SLM) practices such as ridge and bund creation as well as intercropping. Key coping practices reported by the study participants included reduction of food consumption, off-farm jobs, selling livestock, charcoal making and reliance on remittances. The results further revealed that social cohesion mechanisms or collective action play a key role in helping farmers cope and adapt to climate change while improving soil fertility. Social cohesion is mainly reflected in two different structures depending on gender. While diverse challenges of innovation adoption exist, socio-cultural barriers differ by gender. The study recommends the integration of farmers throughout the innovation development process and proposes the need for a concerted effort to strengthen land tenure security policies, ensuring equitable access to farmlands for all genders.

KEYWORDS

coping strategies, adaptation strategies, sustainable intensification, climate change, social cohesion, collective actions, sustainable land management

1 Introduction

1.1 Background and objectives

The West Africa sub-region is faced with major interlinked development challenges in ensuring sustainable livelihoods in the context of resource degradation and climate change. The economies in the region are particularly vulnerable due to their reliance on rain-fed agriculture and limited adaptive capacity (Masson-Delmotte et al., 2018; Seipt et al., 2013; Tachie-Obeng et al., 2013). Building resilient agriculture and expanding production has become increasingly urgent, given the region's rapid population growth (United Nations, 2022).

The northern region of Ghana has been identified to be a climate change vulnerability hotspot (Riede et al., 2016), experiencing recurrent droughts, floods, rising temperatures and erratic rainfall patterns (Adu-Prah et al., 2019). These trends threaten agricultural productivity and impede efforts to achieve sustainable development goals, particularly goals 1 and 2 (Yiran and Stringer, 2016). Without boosting the uptake of responsive coping and adaptation measures to strengthen agricultural resilience, the region's production is forecasted to decline (Pinto et al., 2012). Yield of major crops in northern Ghana has become unstable over the years due to the impact of climate change and land degradation (File et al., 2023; Nakasone et al., 2021). Schlenker and Lobell (2010) reported that maize production could decline up to 18% by 2050, if adaptation measures are not put in place.

While research has recommended an array of coping and adaptation strategies, including agroforestry (Antwi-Agyei and Nyantakyi-Frimpong, 2021; Toth et al., 2017), drought/flood resistant varieties (Antwi-Agyei and Nyantakyi-Frimpong, 2021; Tachie-Obeng et al., 2013), and crop diversification and rotation (Asmare et al., 2019), uptake by farmers has been low, and scaling up from a few farmers in the context of projects to regional levels has been a challenge (Alidu et al., 2022; Asante et al., 2024; Zakaria et al., 2020). This limited uptake can be attributed to various factors, including weak institutional and policy support (Yang et al., 2021), variations in farming systems, household heterogeneity (Pinto et al., 2012), and the lack of locally specific solutions (Apraku et al., 2021).

This paper argues for the critical importance of farmers' perceptions of environmental stress and their local strategies for addressing these challenges. Recent studies highlight the importance of incorporating farmers' perceptions, traditional knowledge, and local strategies into climate adaptation and soil fertility management efforts (Apraku et al., 2021; Ebhuoma et al., 2023). However, the role of gendered experiences and social cohesion mechanisms in shaping these perceptions and responses is still underexplored, despite growing recognition that social networks and identity-based dynamics influence how communities cope with environmental stress (Akullo et al., 2007; Antwi-Agyei and Nyantakyi-Frimpong, 2021). Also, while several studies, notably Adimassu et al. (2014), Alam et al. (2017) and Fanadzo et al. (2021), have explored farmers' perceptions of climate change or land degradation, these studies have nevertheless fallen short of examining both phenomena simultaneously. With this study, we contribute to this conversation by examining how farmers in northern Ghana perceive climate change and land degradation, the strategies they use to cope, and the social cohesion mechanisms or collective actions that support or constrain their adaptation. In specific terms, the study aims to: (1) Assess farmers' perception of climate change and land degradation, (2) Analyse the coping strategies used by farmers in addressing the impacts of land degradation and climate change, (3) Examine the role of social cohesion mechanisms in supporting farmers cope and adapt to climate change and land degradation, and (4) Identify factors that hinder farmers from adapting to climate change.

1.2 Literature review

The impacts of climate change and land degradation are intensifying existing vulnerabilities in agrarian communities of northern Ghana (Adu-Prah et al., 2019; File et al., 2023). These impacts threaten food production and undermine rural livelihoods, particularly among smallholder farmers with limited adaptive capacity (Masson-Delmotte et al., 2018). Evidence shows that the impacts of climate change in Northern Ghana are not uniform across farming households but are shaped by socio-economic, gender, and livelihood typologies. For instance, studies by Alhassan et al. (2019), Antwi-Agyei et al. (2013) and Tambo (2016) show that resource-poor and female-headed households tend to experience greater vulnerability due to limited access to productive assets and extension services. Antwi-Agyei et al. (2013) further reported that youth-headed households and migrant returnees also experience differentiated risks, often due to weaker social networks and insecure land tenure.

Studies increasingly emphasize the importance of incorporating farmers' perceptions and indigenous knowledge into climate adaptation efforts (Ebhuoma et al., 2023; Mortimore, 2010). These perceptions shape both risk interpretation and the willingness to adopt new technologies or practices (Baars, 2011; Pinto et al., 2012). Yet, literature has largely focused on technical or behavioral solutions, while often neglecting broader sociocultural dynamics that influence adaptation decisions, particularly gender relations and social cohesion.

Social cohesion refers to the strength of social relationships, shared norms, and trust within and between communities, which facilitate collective action and mutual support during times of crisis (Aldrich, 2017; Aldrich and Meyer, 2015) and acts as a central component of effective adaptation (Adger, 2010). Communities with strong social ties are more able to mobilize (community) labour, share resources, and disseminate indigenous knowledge, thereby enhancing their resilience to environmental stressors (Fanadzo et al., 2021; Sanfo et al., 2014). However, the evidence on the role of social cohesion in adaptation is mixed. While some studies report strong communal bonds enhancing coping and adaptive capacity, others including Bahta et al. (2016) highlight fragmentation due to migration, land pressures, or elite capture. In Ghanaian contexts, traditional institutions such as communal labour groups and local savings associations play a crucial role in buffering shocks and supporting recovery (Antwi-Agyei and Nyantakyi-Frimpong, 2021; Assan et al., 2018).

Gender plays a crucial role in shaping how climate change is experienced and addressed at the household and community levels. Studies show that women and men have differential perception and vulnerabilities based on gendered roles in agricultural production, resource access, and decision-making (Adeola et al., 2024; Antwi-Agyei and Nyantakyi-Frimpong, 2021; Eastin, 2018). In northern Ghana, Adeola et al. (2024); Antwi-Agyei and Nyantakyi-Frimpong (2021) reported that female farmers perceived food insecurity and water scarcity as impacts of

climate change, while male farmers on the other hand perceived increase in crop pests and diseases and crop failure as the main impacts of climate change.

While the literature acknowledges the complex interplay between climate change, gender, and social cohesion, there remains a clear gap in integrative empirical research, particularly in West Africa. Most studies focus on one or two dimensions in isolation, rather than examining how these factors converge to shape vulnerability and adaptation (Akullo et al., 2007; Olsson et al., 2019). This study seeks to fill this gap by exploring how smallholder farmers in northern Ghana perceive climate change and land degradation, the coping strategies they employ, and the social cohesion mechanisms that support (or hinder) adaptation. In doing so, it builds on and extends prior research by providing a more holistic and context-sensitive analysis that recognises the relational nature of vulnerability and resilience.

1.3 Conceptual framework

The study is guided by the Sustainable Livelihoods Framework (SLF) presented in Figure 1. This conceptual framework focuses on how livelihood assets are used to achieve livelihood outcomes. SLF provides a comprehensive viewpoint for examining the livelihoods of poor individuals to determine optimal interventions, developmental priorities, and effective strategies for alleviating poverty (Krantz, 2001 cited in Serrat, 2017). The framework was developed by the Sustainable Rural Livelihoods Advisory Committee of the British Department for International Development Studies. According to them "A livelihood comprises the capabilities, assets and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base" (Department for International Development (DFID), 1999, p. 1).

1.3.1 Vulnerability context

The Vulnerability Context encompasses the external environment (e.g., Natural shocks, Economic shocks, Conflict, Crop/livestock health shocks, seasonality) that shapes people's lives (Department for International Development (DFID), 1999). Objective 1 is directed toward understanding the vulnerability context of the study area and it is based on the reasoning that vulnerability context of farmers is best understood and explained under the lens of local perceptions.

1.3.2 Livelihood assets

This provides an understanding of the strengths or resources available to individuals (referred to as assets or capital endowments) and how they are mobilised to achieve favourable livelihood outcomes (Department for International Development (DFID), 1999). These assets are grouped into five key categories: human, social, natural, physical, and financial capital. Objective 2 of the study is focused on these assets, with particular attention to their role in shaping farmers' coping strategies. Among the five assets, social capital, which includes networks, relationships of trust, norms of reciprocity, and collective action, is foundational to social cohesion. This part of the framework clarifies the interactions and interdependencies among the different assets and their influence on the choice of strategies. The guiding reason was that higher levels of access to livelihood assets among farmers are positively associated with an increased likelihood of adopting effective coping strategies.

1.3.3 Transforming structures and processes

Transforming structures and processes refers to the institutions, organizations, policies, and legislation that shape livelihoods (Department for International Development (DFID), 1999). The third

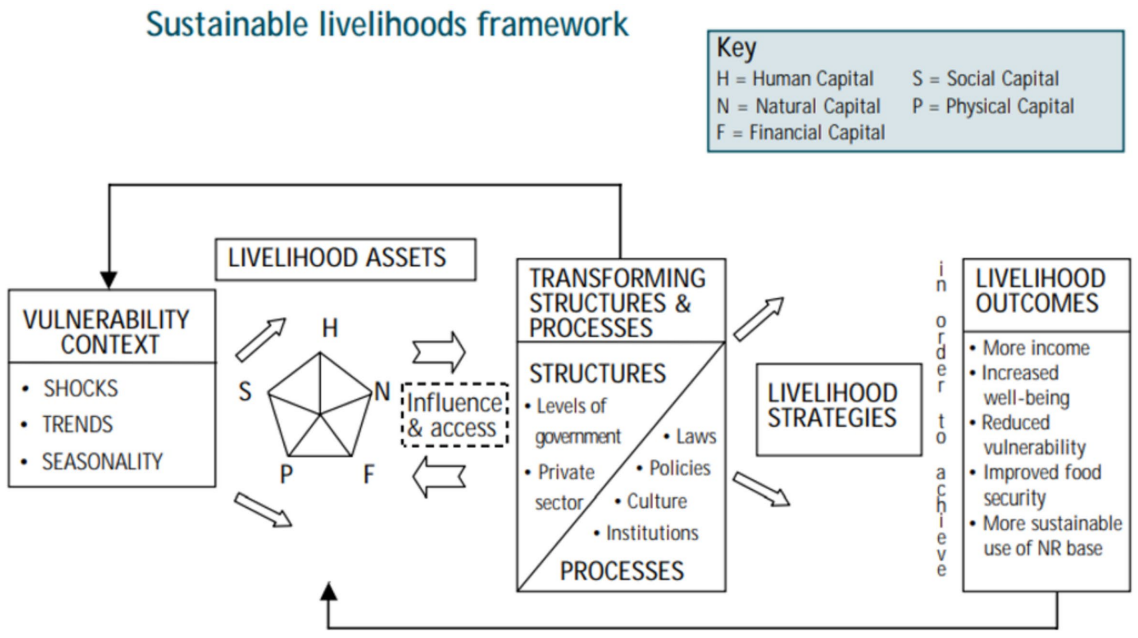

FIGURE 1
Conceptual framework; adapted from Department for International Development (DFID) (1999).

and fourth objectives of the study are focused on this aspect of the framework. Here we focused on the informal networks, local institutions, cultural values and norms, and community support mechanisms that influence social cohesion, collective action, and cooperation among farmers in adapting to climate change.

We chose the SLF for this study because it offers a holistic approach to understanding how farmers' access to and use of livelihood assets shape their perceptions of environmental stresses. The SLF highlights the interplay between resources, institutional structures, and vulnerability contexts. Its emphasis on social capital as well as social structures and processes aligns with our goal of exploring social cohesion mechanisms and indigenous practices as adaptive responses to environmental stressors.

2 Materials and methods

2.1 Study area

The research was conducted in Ghana's northern region, situated between longitude 0° and 1°W, and latitudes 1°00′N and 9°30′N. The region is the largest among the country's 16 administrative regions, spanning an extensive land area of 70,384 km^2 (Abdul-Razak and Kruse, 2017). Geographically, the region falls within the Guinea Savannah agro-ecological zone and is characterized by significant rainfall variability.

The Northern Region was chosen based on several criteria, including the region's high vulnerability to climate change, prevalence of poverty, food insecurity (Yiran and Stringer, 2016; Azupogo et al., 2023), and its critical role in agriculture (Abatania et al., 2012; Ndah, 2020). Among the 14 districts of this region, three were selected purposefully in consultation with local experts for the study. This was mainly based on accessibility and proximity while ensuring diversity in responses. Two districts closer to each other were not selected. The selected districts were Mion, Tolon, and Savelugu. The study site is represented in Figure 2. Two communities were selected from each of the three districts. Thus, the study was conducted in six rural agricultural communities.

2.2 Study approach, data collection and data analysis

The study employed a mixed-methods approach, combining a quantitative household survey with qualitative interviews and field observations. The integration of qualitative and quantitative methods enhances complementarity, triangulation, and facilitates a more comprehensive understanding of phenomena compared to mono-method approaches (Lall, 2021; Timans et al., 2019). The quantitative aspect comprised 60 interviews, 20 from each district. To address potential biases associated with self-reported data, multiple qualitative methods were employed for triangulation. These included 8 focus group discussions (FGDs) across the three districts, 2 key informant interviews, 2 expert interviews, and 3 field observations. Additionally, data collection was conducted during the farming season (October to November 2023), which minimized recall challenges and allowed respondents to report ongoing experiences more accurately. The data

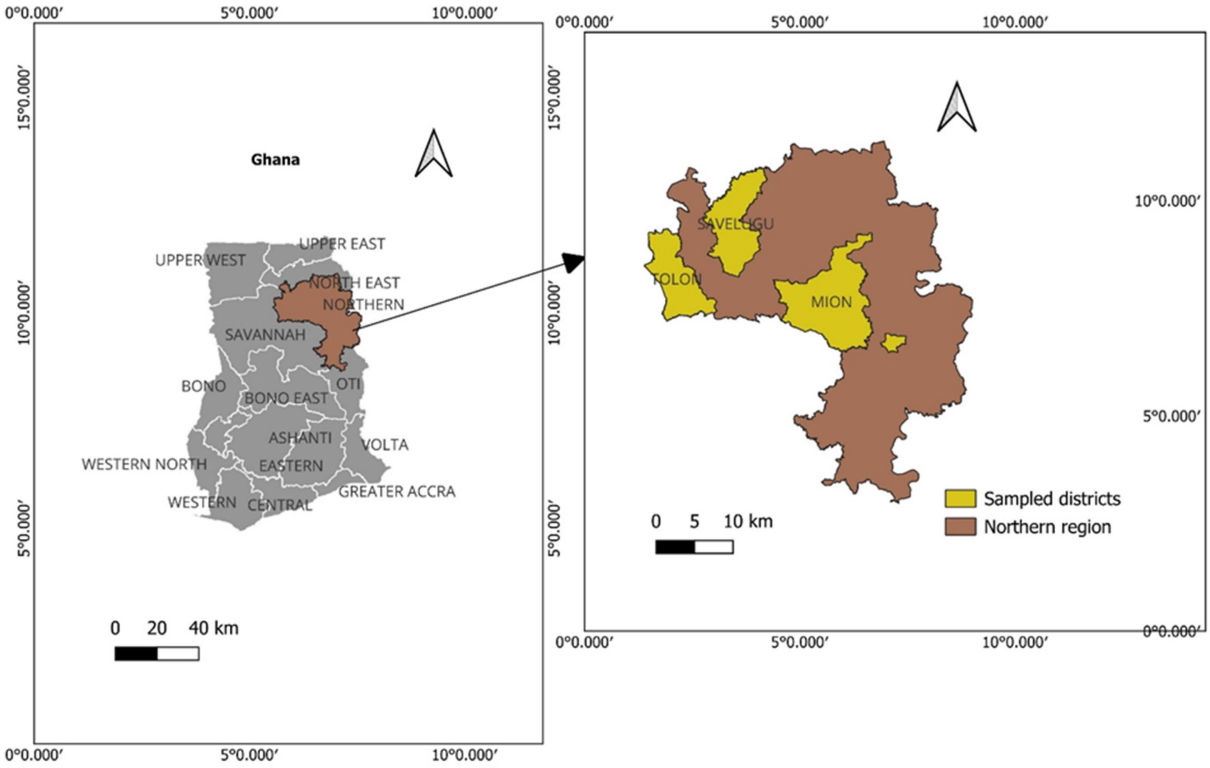

FIGURE 2
Study region. Source: Created using QGIS version 3.34.2 and downloaded shapefile from DIVA-GIS.

collection process was done in three phases. See Table 1 for the summary of the data collection process.

2.2.1 Phase I

This phase comprised 2 expert interviews, 2 key-informant interviews, and 3 field observations to gain an initial understanding of environmental stressors in the region and their impact on farmers' livelihoods. Respondents were purposively selected from the community leadership, a research institute, and the regional agricultural office, using purposive and snowball sampling techniques. Field visits were guided by local extension agents and farmers' willingness to participate.

2.2.2 Phase II

A survey of 60 farm households was conducted using systematic sampling, complemented by snowball technique to reach hard-to-identify subgroups. The process began with a randomly selected residential structure (i.e., house), with subsequent houses chosen at regular intervals. Since a single house may accommodate more than one household (e.g., in extended family settings), only one household actively involved in farming was selected per house to ensure sampling independence. Within each selected household, one respondent (defined as an active farmer who independently manages a farm and makes autonomous production decisions) was interviewed. Due to challenges in locating active female farmers, a snowball sampling strategy was employed to purposively identify women farmers for inclusion. These were from largely female-headed households (predominantly widows), identified through community informants. After each interview, respondents recommended the next eligible female farmer.

2.2.3 Phase III

This phase focused on Focus Group Discussions (FGDs) with 6–8 participants to foster natural discussions and improve facilitation (Webber and Hill, 2014). Stratified and simple random sampling were used to select participants. Farmers were stratified based on their demonstrated knowledge during the household survey, and participants were randomly drawn from the group with extensive knowledge of key issues.

2.2.4 Data analysis

Qualitative data were analysed thematically using MAXQDA 22. Audio recordings in Dabgani were transcribed and translated into English, systematically coded, and examined for themes and patterns. Quantitative data were analysed using Stata. Descriptive statistics included mean, standard deviation, frequencies, and percentages. Advanced analyses included the Mann–Whitney U test, Kendall's Tau correlation, and weighted average index. See Appendix 1 for the summary of how data was collected and analysed for each specific objective of the study.

3 Results and discussion

3.1 General socio-economic characteristics of the respondents

Responses to the socio-demographic characteristics of the respondents came from a total of 60 farm households across three districts of the study region. Out of the pooled sample, 55% were males and females comprised 45%. The summary of the socio-economic characteristics of the respondents is presented in Appendix 2. The average age of respondents was 40 years. The minimum and maximum ages were 18 years and 65 years, respectively. On average, respondents shared a household population size of 11 members. Regarding farming experience, 71.7% of the respondents have been engaged in farming for more than 10 years prior to the study. 80% of farmers had no formal education, 8.3% have a primary education, 10% have secondary school education (i.e., Junior and secondary education) and 1.7% have tertiary education. 62% of respondents were members of farmers' groups and 73% were in self-help groups. While only 19% of the farmers have a land size greater than 10 acres, the average land size was 9.2 acres.

TABLE 1 Summary of data collection methods.

Phase	Method	Respondents	Sampling strategy and sample size	Information collected
1	Key-informant & expert interviews.	- Key informant: community leader, lead farmer. - Expert: extensionists, researchers	Random sampling - 2 Key-informants - 2 Experts	- General climate change and land degradation issues in the region.
1	Field observations	1 field each in; • Tolon • Savelugu • Mion	Purposive sampling - Fields	- General climate change and land degradation issues in the region.
2	Household survey	Farm household heads. Target group • Male and female farmers • Old and young farmers	Systematic and Snowball sampling - 60 farmers	- Climate change and land degradation perceptions. - Coping strategies - Social cohesion mechanism - Challenges to adoption of coping strategies
3	Focus group discussions	- 4 male groups - 4 female groups	Stratified and Random sampling - 8 focus groups	- Climate change and land degradation perceptions. - Coping strategies - Social cohesion mechanism

3.2 Farmers' perception of climate change and land degradation

The thematic analysis revealed that farmers perceive climate change along with five extreme climatic events (see Table 2). These are irregular rainfall patterns, erratic rainfall, increased incidence of flooding, increased incidence of drought, and increased temperature. These findings align with observations by Antwi-Agyei and Nyantakyi-Frimpong (2021), who similarly reported erratic rainfall, increased windstorms, and heightened flooding incidents in farming communities in Northeast Ghana.

Apart from the indicative signs of climate change which were common to both male and female farmers we observed that perceived cause and impacts of climate are divided along gender lines (see Table 2 and Appendix 4). Regarding perceived cause, male farmers associated climate change and land degradation with social and environmental changes, population growth, urbanization, and poor farming practices. This is in line with Engdawork and Bork (2016) and Tesfahunegn et al. (2016) who reported that farmers attributed climate change to deforestation and other anthropocentric activities. This is, however, contrary to Fanadzo et al. (2021) and Sanfo et al. (2014) who reported that farmers perceived climate change to be triggered by supernatural powers. According to our result from the FGDs, some female farmers attributed climate change to the work of "god," perceiving it as a phenomenon beyond human influence. This finding is in line with what was reported by Fanadzo et al. (2021) and Sanfo et al. (2014), but contrary to Engdawork and Bork (2016) and Tesfahunegn et al. (2016).

The results further show that male farmers perceive total crop failure, increase in production cost, reduction of income, increase in crop pests and diseases, and reduction in working hours on farm as the major impacts of climate change. Female farmers reported high incidence of illness, food insecurity, total crop failure and water scarcity as main impacts of climate change. It can be inferred that while male farmers primarily associate perceived impacts of climate change with production, females revealed a broader range of concerns that extend beyond production and encompass the general welfare of life (see Table 2 for summary of extreme climate events reported and their respective impact by gender). These differences suggest that coping and adaptation strategies may also differ by gender, with men likely to prioritize on-farm adjustments, while women may adopt strategies focused on household welfare, food security, and health. This has implications for resilience planning, emphasizing the need for gender-responsive approaches that address the distinct risks and adaptive capacities of both men and women. Gender disparity on impact of climate change in Africa has been reported in literature including Adeola et al. (2024), Antwi-Agyei and Nyantakyi-Frimpong (2021) and Eastin (2018) whose studies focused on northern Ghana, reported that female farmers perceived food insecurity and water scarcity as impacts of climate change. Male farmers on the other hand perceived increase in crop pests and diseases and crop failure as the main impacts of climate change.

Regarding land degradation, the thematic analysis revealed no gender disparity in perception. Farmers used six main indicative signs including plant growth, soil colour, and erosion in describing soil degradation. This is in line with previous literature including Ebhuoma et al. (2023), Engdawork and Bork (2016) and Fanadzo et al. (2021). Engdawork and Bork (2016) reported that farmers in southern Ethiopia have good knowledge on land degradation and have developed a diverse array of traditional land management practices. Similarly, our study's findings confirm the report of Engdawork and Bork (2016), as the results show that farmers were using various SLM practices including composting, intercropping, planting leguminous crops, and mulching to improve soil fertility.

A Mann–Whitney U test (see Table 3) was conducted to compare the perceptions of land degradation and climate change between males and females. The assumptions of the test, including the independence of observations, ordinal measurement scale, and similar shapes of distributions, were checked and met. The result shows that there is no significant difference in perception of land degradation between the genders. However, for climate change, a significant difference is observed between the groups ($p < 0.01$), indicating that male farmers and female farmers differ in their perceptions or experiences of climate change. This result confirms the findings from the qualitative analysis.

Results on environmental stressors faced by farmers revealed that farmers ranked climate change, and land degradation as severe stressors, deforestation and pests and diseases as moderate stressors, and biodiversity loss and pollution were ranked as low stressors (Appendix 3). While it may appear obvious to rank climate change and land degradation as the top two stressors, the placement of deforestation in the third position ahead of pests and diseases might seem unexpected. However, insights from interviews with farmers shed light on their concerns about the rapid loss of trees. According to the farmers although pests and diseases pose significant environmental challenges, farmers indicated that they were able to get solutions to pest and disease in the immediate or short term, whiles restoring land cover is a process that cannot be promptly achieved. It can be inferred that the farmers are very concerned about environmental sustainability, and this could be an entry point for promoting and supporting environmentally friendly farming approaches like agroecology. Similar to this finding, Ebhuoma et al. (2023), reported that farmers perceive deforestation as the primary driver of land degradation and climate change.

TABLE 2 Perceived extreme climate events and their impact reported by gender.

Extreme climate events	Impacts reported by female farmers	Impacts reported by male farmers
Irregular rain pattern	Food insecurity	Increase cost of production
High temperature	High incidence of illness	Reduction in working hours
High incidence of drought	Water scarcity	High incidence of pests and diseases
High incidence of flood	Food insecurity	Total crop failure
Erratic rain	Total crop failure	Reduction/loss of income

Source: Field data (2023).

TABLE 3 Output of Mann–Whitney U test on the perception of farmers on land degradation and climate change.

Variable	Sex	Obs	Rank sum	Expected	Adjusted variance	z-value	*p*-value
Land Degradation	Fem	27	769.5	823.5	846.45	−1.856	0.1678
	Mal	33	1060.5	1006.5			
Climate Change	Fem	27	961	823.5	2595.60	2.699	0.0071***
	Mal	33	869	1006.5			

Female = Fem; Male = Mal. ***statistical significance at $P \leq 0.010$ level.
Source: Author's elaboration from analysis of field data (2023).

3.3 Coping strategies employed by farmers

The results show that farmers use a range of practices in coping and adapting to the impacts of climate change and land degradation. The analysis here was guided by the livelihood assets component of the framework, drawing primarily on qualitative data from FGDs with supplementary insights from survey data. Below, the strategies are categorized and discussed according to the five livelihood assets.

3.3.1 Natural capital

Farmers identified land, trees, and farm animals as the most important natural assets. The study categorized all coping and adaptation strategies that directly utilize these assets as natural strategies. Overall, strategies related to natural capital were mentioned 20 times across the 8 FGDs, with the majority coming from male farmers (See Appendix 7). In terms of usage, livestock was the most frequently cited natural asset used for coping. Farmers, particularly men, reported selling animals such as goats and poultry to meet urgent household needs during climatic shocks. Trees and other non-timber forest products (NTFPs), such as shea nuts and firewood, were also gathered and sold, primarily by women, to supplement household food and income. While land was regarded as a critical asset, farmers emphasized that it was not sold, due to cultural restrictions.

3.3.1.1 SLM practices

Farmers reported using eight SLM practices in coping with climate change while improving soil fertility (see Table 4). Some farmers reported positive impacts on yield as a result of applying SLM practices. This was evident during farm visits. Figure 3 illustrates a stark contrast between two neighbouring plots owned by different farmers.

3.3.1.2 Changing farming area

Farmers reported changing farmlands in line with climate projections. Farmers that anticipated drought reported switching to low land areas and those projecting floods indicated switching to high land areas. The farmers further added that this practice is fading out due to scarcity of land.

3.3.1.3 Crop diversification, crop-livestock integration

The results indicate that farmers use crop diversification and crop-livestock integration to cope with extreme climate variation and land degradation. Specifically, 57% of the participants in the survey practice intercropping, 67% use crop rotation, and 47% combine crop and livestock farming. Among those integrating livestock, 93% report beneficial synergies between crops and animals. These strategies serve as insurance, investment, and soil fertility management. Some farmers shared their perspective, as follows: "We sometimes plant more than one crop on the field so that if one fails, we can still get something from the others" (Female farmer, FGD, Gnoli-Mion District, 2023).

TABLE 4 Ranking of SLM practices based on farmer adoption.

Variable	Obs.	Mean	Std. dev.	Min	Max	Rank
Crop rotation	60	0.65	0.48	0	1	1
Intercropping	60	0.52	0.50	0	1	2
Planting fertilizer crop	60	0.45	0.50	0	1	3
Composting	60	0.37	0.48	0	1	4
Windbreaks	60	0.18	0.39	0	1	5
Burying rice straw	60	0.18	0.39	0	1	6
Fallow land	60	0.10	0.30	0	1	7
Mulching	60	0.08	0.28	0	1	8

Source: Author's elaboration from analysis of field data (2023).

Switching of cropping area in line with climate change projections, crop diversification, crop-livestock integration, and SLM practices are reported in literature. Guodaar et al. (2017) and Ndah (2020) reported that farmers change farm location as a strategy to cope with extreme climate variations. The use of crop diversification and crop-livestock integration have been reported by studies including Antwi-Agyei and Nyantakyi-Frimpong (2021), Ebhuoma et al. (2023), and Mapfumo et al. (2022). Livestock manure for enhancing soil fertility was one of the synergies reported by farmers under the crop-livestock integrated strategy. The results revealed that farmers prefer mineral fertilizers due to the labour-intensive and high labour requirement of livestock manure usage. "Using the animal droppings on the farm is very good. I have done it before and I can attest to that, but the problem is, it is too laborious, and this is why I rarely apply it" (Male, FGD, Yapalsi-Savelugu District, 2023). This finding is in line with Ebhuoma et al. (2023) and Mapfumo et al. (2022), but contrary to Wainaina et al. (2016). Wainaina et al. (2016) reported that farmers operating mixed crop-livestock systems consider organic manure and mineral fertilizer as substitutes and prefer using animal droppings to fertilize their crop farm.

3.3.2 Physical capital

Our focus on physical capital was centred on public infrastructures and services that could enhance people's ability to cope and have a sustainable livelihood. The main coping strategies reported by

FIGURE 3
Adopter and non-adopter of SLM practices; The left side of the image shows a farmer who practices crop rotation, while the right side depicts a non-adopter of SLM practices. Photo by H.T. Ndah.

respondents included increasing working hours on farms, migration, and planting improved crop varieties. These strategies stemmed from three physical assets: extension services, a dam, and accessible roads. In total, strategies related to physical capital were mentioned 11 times across the 8 FGDs, with majority coming from male farmers. Refer to Appendix 7 for the distribution of the strategies across assets and FGDs.

Farmers emphasized that through extension services, they gain access to valuable information and farm inputs like certified seeds of improved crop varieties. Most farmers reported receiving extension support at least once or twice during the farming season. This aligns with Antwi-Agyei and Nyantakyi-Frimpong (2021) and Tachie-Obeng et al. (2013) who reported that farmers in Ghana are using early maturing and drought tolerant varieties to cope and adapt to extreme climate conditions. Similarly, Maredia and her colleagues reported that farmers in Tanzania and Ghana were using certified seeds and were willing to pay more for seeds of higher quality and yield rate (Maredia et al., 2019). Findings on migration is confirmed by studies including Antwi-Agyei and Nyantakyi-Frimpong (2021) and Rademacher-Schulz et al. (2014), all conducted in northern Ghana. Rademacher-Schulz et al. (2014) found that for the purpose of stimulating household consumption during the dry-seasons, farmers migrate to more suitable farming areas in the south in search of non-farm jobs. This strategy, however, was reported by previous studies not to be applied by the poorest of the poor due to the cost involved in the travel (World Bank, 2008, cited in Shayamunda, 2021).

In the Tolon district, respondents (particularly females) reported that the presence of a dam in the community has reduced the burden of fetching water for household use. As a result, they are able to allocate more time to farm work, effectively extending working hours. This improved time availability may help explain the relatively higher adoption of crop rotation and intercropping observed in Tolon compared to the other districts (see Figure 4).

While these SLM practices are labour-intensive (Akinyi et al., 2021; Wainaina et al., 2016) and typically discussed under natural capital, their uptake here is facilitated by the physical capital investment in water infrastructure, which indirectly enhances the utility of natural resources and labour productivity.

3.3.3 Human capital

Our focus was on the skills, knowledge, experience, and abilities individuals possess that contribute to their sustainable livelihoods. The results of the study revealed six key strategies stemming from four assets: indigenous knowledge, experience, age, and household size. Farmers in the study area relied on diverse forms of indigenous knowledge systems including traditional weather forecasting, cultural and biological pest control, construction of stone bunds and ridges for water conservation and erosion control. While age and household size may not traditionally be classified as human capital, they were considered here due to their strong influence on it. For instance, older individuals tend to have greater knowledge, experience, and access to resources such as land compared to younger people. Similarly, larger households—especially those with more working-age members—may have greater labour capacity and adaptive abilities than smaller households. The six strategies are changing planting date, use of family labour, off-farm employment, and reduction of household food consumption. Overall, human capital-related strategies were mentioned 19 times across the 8 FGDs. The human strategies were much more mentioned in the male FGDs compared to the females. See Appendix 7 for the distribution of the strategies across assets and FGDs.

Shifting from agriculture to non-farm occupations during extreme climate events aligns with previous studies including Antwi-Agyei and Nyantakyi-Frimpong (2021); Guodaar et al. (2017); Ngenoh et al. (2018). Antwi-Agyei and Nyantakyi-Frimpong (2021), further reported that over 80% of farmers in North-Eastern Ghana cope with climate change by adjusting planting schedules. Shifting planting date has also been established in other studies including Bryan et al. (2013) and Tachie-Obeng et al. (2013).

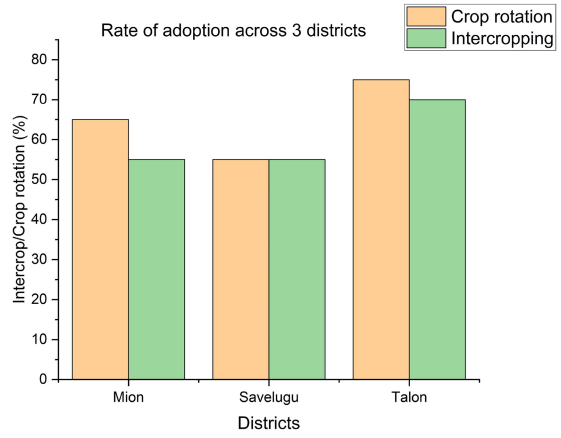

FIGURE 4
Rate of adoption across the three districts based on survey data.

Cutting back on food consumption as a coping strategy has been reported in literature including Goh (2012); Haggblade et al. (2017); Mehar et al. (2016) and Ngenoh et al. (2018). Mehar et al. (2016) found that this strategy is more commonly employed by women, whereas Goh (2012) noted that male decision-makers are more likely to reduce food intake. In contrast to these gender-specific findings, the results of this study show that the reduction in food consumption is implemented at the household level, affecting all members, including the elderly and children. Haggblade et al. (2017) highlighted that this strategy involves a reduction in both the quality and quantity of food which heightens the risk of stunting and contributes to the perpetuation of chronic poverty. These concerns hold particular relevance in the study region, given the evidence of the region's high levels of food insecurity and poverty (Azupogo et al., 2023; Dang et al., 2020).

3.3.4 Social capital

The results of this study show that social capital is the most crucial livelihood asset to farmers (see Figure 4). The strategies reported under social capital are collaborative disease surveillance, communal labour, sharing of food items/planting materials, peer-to-peer learning, access to microloans through self-help groups, prayer, and emotional support. In total, these strategies were mentioned 38 times across the 8 FGDs, with majority coming from the female FGDs. Refer to Appendix 7 for the distribution of the strategies across assets and FGDs. As one male farmer in Gnoli explained, "We keep an eye on each other's farms. Once a disease is detected, the owner is informed right away. If it's beyond one farmer's control, the information is quickly shared with neighbouring farmers, and then the lead farmer is alerted." Similarly, a female participant in Dimabi highlighted the importance of interdependence: "Whenever someone needs help—whether for harvesting or facing a loss—we go together to support them. If we do not, and they suffer post-harvest losses, they will not be able to contribute, and the whole group is affected." Some of the strategies reported have been documented in literature. For instance, Antwi-Agyei and Nyantakyi-Frimpong (2021) reported that farmers engage in sharing food within their social circles as a strategy for coping to floods. Assan et al. (2018) found that many farmers, particularly female farmers, cope with climate change through microloans from social networks.

Consolations of social networks and prayer were also important coping strategies revealed from the results. Farmers explained that when they experience extreme climate events like floods, sometimes, all they could do is to draw emotional strength from their close networks and pray that the flood does not extend to neighbouring farms. Emotional support helps the farmers to develop the courage to cultivate in the following farming season. This confirms what was reported by Aldrich (2017) and Aldrich and Meyer (2015), that social cohesion promotes individuals, groups, and community resilience during disaster. This finding also aligns with evidence from Fanadzo et al. (2021) and Sanfo et al. (2014), who reported that farmers that are severely impacted by extreme climate events often resort to prayer. However, this contradicts the perspective presented by Bahta et al. (2016) and Tesfahunegn et al. (2016). Tesfahunegn et al. (2016) reported that farmers do not perceive prayer as relevant in coping with climate variations. Bahta et al. (2016), reported that smallholder farmers in South Africa do not consider social networks as an important means of coping with drought.

3.3.5 Financial capital

Strategies related to financial capital were mentioned 7 times across the 8 FGDs. The results of the study show that financial assets were the most limited in supply. This finding is in line with several studies which have highlighted a lack of financial capital as one of the major constraints faced by small-scale farmers in the global south (Ekwere and Edem, 2014 cited in Shayamunda, 2021). The results show that the main strategies under this category are income diversification and remittances from family members. This is in line with Antwi-Agyei and Nyantakyi-Frimpong (2021); Assan et al. (2018); Shayamunda (2021). Antwi-Agyei and Nyantakyi-Frimpong (2021) reported that male farmers diversify their income primarily through selling livestock. Shayamunda (2021) highlighted that some rural households in Ethiopia rely on remittances from migrant family members. This conclusion was also reached by Antwi-Agyei and Nyantakyi-Frimpong (2021) in northeastern Ghana.

3.3.6 Assets in perspective

Overall, the findings on coping strategies reveal that livelihood assets are interconnected and interdependent. Recognizing these connections is essential for understanding how farmers cope and for guiding support efforts to enhance adaptation and sustainable livelihood. It can be inferred from the findings which reveal that farmers leverage on less scarce assets (e.g., Social capital, see Figure 5) to acquire scarcer ones (e.g., Financial assets, see Figure 5). This implies that strengthening one asset could positively impact others. For instance, while financial capital is the scarcest asset, social capital emerges as a vital resource, enabling farmers to access microloans and share resources. Natural capital, such as land and livestock, is bolstered by physical capital like extension services, which provide improved seeds and farming techniques. Human capital, encompassing indigenous knowledge and labour, further integrates with these assets to enhance overall resilience. This synergy highlights the necessity of a holistic approach in policy and intervention strategies to reinforce these interdependencies, ultimately enhancing the sustainability and adaptability.

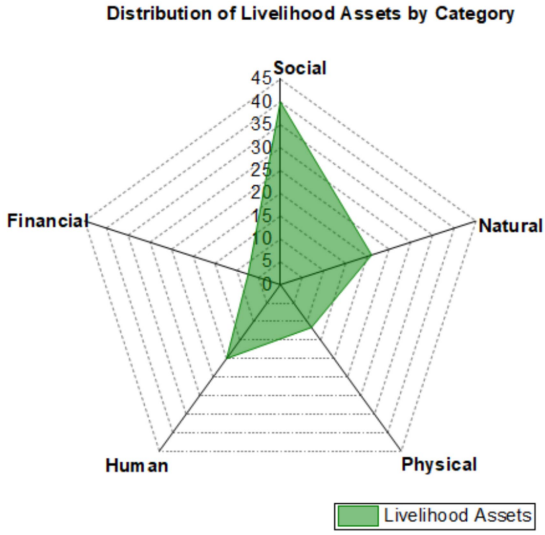

FIGURE 5
Distribution of livelihood assets across five categories, based on FGD analysis. The radar chart illustrates the relative prominence of each asset type.

3.4 The role of social cohesion mechanisms

This section provides insights beyond social assets (resources available through relationships) shedding light on the main social structures and processes (social systems) that exist and the role they play in helping farmers cope and adapt. Farmers reported receiving support from both formal social structures (e.g., farmer associations) and informal social structures (e.g., self-help groups, religious groups, extended family networks, and neighbourhood groups). Overall, farmers' associations and self-help groups were the main social structures reported. The data revealed that 73% of farmers participated in self-help groups, while 62% were involved in farmers' associations. A gender disparity was evident, male farmers were pronounced in farmers' groups whilst females were dominate in self-help groups. Out of the sampled male farmers, 73% of them were in farmers' groups. Female farmers on the other hand were more active in self-help groups, with 95% of them in self-help groups. This is in line with Shayamunda (2021) who reported for a study in Ethiopia 82% female membership in savings and lending groups against 18% of male.

The groups play distinct roles with few commonalities. The farmers' groups were mainly into supporting members in their farming operations. Members were farmers who cultivate the same or similar crops. Each group is led by a farmer. The lead farmers play a critical role in disseminating information and transferring knowledge to their group members. The farmer groups primarily provide agricultural training, peer-to-peer learning, information sharing, and communal labour to its members. Members could also access humanitarian assistance like food items and planting materials when they experience extreme climate events. Appendix 6 presents a summary of illustrative quotes from the interviews.

Self-help groups on the other hand were concerned mainly with provision of micro financial services (micro savings and loans), and non-financial services like humanitarian support, communal labour, training, and peer-to-peer learning (see Appendix 6 for the summary of illustrative quotes from the interviews). The group collects savings from members based on individual financial strength. This is then used to extend loans to group members at an interest rate of 10% per annum. The loans were given based on one's savings, and membership as collateral. The groups operate on a non-profit basis, utilizing interest accrued from loan activities to provide humanitarian and emergency assistance (such as giving planting materials, food items, cash) to members who have experienced total crop failure due to extreme climate events. FGDs reveal that the groups were not having collective action problems as members expressed strong transparency, trust, and commitment among members.

The role of micro loans in helping smallholder farmers cope with the impacts of climate change has been reported in literature. Assan et al. (2018) found that provision of micro-loans by self-help groups to members plays a crucial role in helping farmers, particularly female farmer to cope with climate change. Antwi-Agyei and Nyantakyi-Frimpong (2021) reported that relying on social networks is one of the most important coping strategies by farmers in the Upper East of Ghana. Abdul-Rahaman and Abdulai (2018) reported that farmers in groups are more likely to enhance their profits through increased yield and technical efficiency compared to those operating individually. Shayamunda (2021) observed that farmers that are part of social groups are more likely diversify their income and improve household food and nutrition security.

The results of the study further show that most of the members of both groups have adopted SLM practices. The Kendall's Tau correlation analysis (presented in Table 5, see Appendix 5 for the complete table), show a positive (moderate) correlation between crop rotation and farmers' group at 1% significance level. Likewise, intercropping had a positive (weak) association with self-help group ($p \leq 0.10$). This aligns with findings from Tanti et al. (2022), who reported that farmers in self-help groups are 10% more likely to adopt crop rotation, and members of farmer cooperative societies are 17% more likely to engage in crop diversification. It can be inferred from the study results that social cohesion plays a key role in enhancing the resilience of farmers, enabling income diversification, strengthening livelihoods, and promoting sustainable agro-ecological practices.

3.5 Barriers to adoption

The results revealed that despite farmers' efforts to adopt different adaptation and coping strategies, they nonetheless face diverse hindrances. These hindrances border across economic, socio-cultural, and technical domains, with most of the socio-cultural challenges disproportionately affecting female farmers compared to their male counterparts.

Lack of access to credit emerged as the primary economic barrier, limiting farmers' ability to invest in agricultural innovations. In one of the FGD, a farmer remarked that: "One of our biggest hindrances is money and the lack of access to credit. So, if the price of the innovation is higher than what we can afford, then that will hinder us from adoption." This is in line with several studies including Antwi-Agyei et al. (2021); Antwi-Agyei and Nyantakyi-Frimpong (2021); Ayisi et al. (2022), which highlight financial

TABLE 5 Kendall's Tau correlation coefficients and significance levels for agricultural practices and demographic factors (n = 60).

Variable	Male	Female	Farm size	Livestock integration	Farmer group	Self-help group	Freq. of extension	Intercropping	Crop rotation
Male	1.00								
Female	−1.00 (0.000) ***	1.00							
Farm size	0.71 (0.000) ***	−0.71 (0.000) ***	1.00						
Livestock integration	0.57 (0.000) ***	−0.57 (0.000) ***	0.35 (0.002) ***	1.00					
Farmer group	0.49 (0.000) ***	−0.49 (0.000) ***	0.41 (0.000) ***	0.42 (0.002) ***	1.00				
Self-help group	−0.39 (0.003) **	0.39 (0.003) **	−0.21 (0.049)	−0.15 (0.251)	−0.07 (0.609)	1.00			
Freq. of extension	0.43 (0.000) ***	−0.43 (0.000) ***	0.41 (0.000) ***	0.40 (0.001) ***	0.27 (0.019)	−0.15 (0.192)	1.00		
Intercropping	−0.32 (0.015) **	0.32 (0.015) **	−0.23 (0.039) **	−0.13 (0.306)	0.03 (0.809)	0.23 (0.075) *	0.23 (0.046) **	1.00	
Crop rotation	0.57 (0.000) ***	−0.57 (0.000) ***	0.49 (0.000) ***	0.42 (0.001) ***	0.64 (0.000) ***	−0.03 (0.846)	0.45 (0.000) ***	−0.11 (0.366)	1.00

***Statistical significance at $p \leq 0.010$ level, ** statistical significance at $p \leq 0.050$ level, * statistical significance at $p \leq 0.10$ level.

exclusion as a persistent structural constraint for smallholder farmers in Ghana.

In terms of labour and operational costs, innovations with high labour demands and operational costs were considered as unattractive. One of the farmers elaborated this point in a FGD as follows: "We also consider the innovation's relevance to labour requirement. If we think that technology is going to lift much of our farm burden, then it might influence our decision to adopt it" (Male farmer, FGD, Yipalsi-Savelugu District, 2023). This is in line with evidence reported by Antwi-Agyei and Nyantakyi-Frimpong (2021) and Ndah (2020).

Farmers expressed a desire to verify the yield impact of an innovation through demonstrations or field visits before adoption. Similar findings were reported by Ndah (2020) and Maredia et al. (2019). According to Ndah (2020), farmers seek assurance of an innovation's impact on crop yield before deciding to adopt it. Maredia et al. (2019) found that farmers are willing to pay for improved seeds once they have verified their higher yield returns. However, this study deviates slightly from Maredia et al. (2019) as it found that farmers, despite recognizing the benefits, cannot adopt innovations that are financially out of reach. One farmer commented: "A few years ago, some individuals do bring us improved seeds at a low price but now the prices have increased, so we are unable to buy" (Male farmer, FGD, Nakpanzoo-Savelugu district, 2023).

The results from the FGDs also show that the region has a complex land tenure system that is of disadvantage to women. This is documented in previous literature including Antwi-Agyei and Nyantakyi-Frimpong (2021). The results revealed that women do not own land but were only given a piece of land (usually less productive lands) to cultivate under an undefined period. The prevailing notion, gathered from interviews was that women were good at transforming unproductive lands into fertile ones. This is in line with Tourtelier et al. (2023) and Unay-Gailhard and Bojnec (2021). However, there was a concern that once the lands were rejuvenated, they could be reclaimed by men. Despite the prevailing notion suggesting that female farmers exhibit high sensitivity to the environment and engage in sustainable agricultural practices more than their male counterparts, our data reveals a contrasting perspective (see Table 5).

Kendall's Tau correlation coefficient test was computed to examine the relationships between various agricultural practices and demographic factors among farmers (presented in Table 5, see Appendix 5 for the complete table). The result shows that most of the sustainable agricultural practices, notably crop rotation, livestock integration, planting of fertilizer crops, and composting, were negatively associated with the female gender. This paradox may signify a strategy by female farmers to avoid making long-term investments in land they may later lose, highlighting how tenure insecurity undermines both innovation and sustainability. Moreover, even in cases where land is held by families, land titles are often registered solely in the names of male heads of households. This reinforces the fact that women typically occupy secondary decision-making positions regarding sustainability-oriented decisions on farms in Northern Ghana as highlighted by Doss and Meinzen-Dick (2020).

The results further show that female farmers have a limited access to essential inputs such as land, tractors, fertilizers, and agrochemicals. This finding is in line with Antwi-Agyei et al. (2021). A female farmer expressed her worry in a FGD as follows. "(…) for instance, if a tractor is here for ploughing. Unless all the men finish with their land before the women can get access to the tractors. And sometimes when the men are certain that, oh, I do not need a particular land anymore, then they give it out to the women to farm" (Female farmer, FGD, Nakpanzoo, Savelugu district, 2023). This illustrates how gender hierarchies in access to key production resources like land, tractors, and fertilizers, persist through both cultural norms and institutional practices. The Kendall's Tau analysis reinforces this, showing negative

correlations between female gender farm size, livestock ownership, extension services, and female gender ($p \leq 0.010$). These findings highlight systemic gender disparities that restrict women's capacity to adopt and benefit from innovations and suggest a pressing need for gender-targeted interventions.

Social norms and perceptions also appeared to be a major hindrance to innovation adoption. The analysis of key-informant and expert interviews revealed community-held beliefs, such as equating large farms to industriousness and small farms to laziness. Also, the presence of weeds on one's farm was perceived as a sign of laziness. These perceptions are contrary to the principles of sustainable intensification, minimum tillage, and other SLM practices, and could deter innovation uptake. The farmers reported unwillingness to adopt a technology that is not endorsed by their peers or social circles. This aligns with findings from Asare-Nuamah et al. (2022), who highlighted that social perception and acceptance plays a vital role in innovation adoption.

Lastly, low literacy and limited technical capacity further inhibited adoption. Many farmers, especially older ones and those with no formal education, reported that they found certain technologies too complex to understand or operate. One key reason given for non-adoption was the perceived difficulty in applying innovations correctly. While this supports the findings of Popoola et al. (2020), it contrasts with Ayisi et al. (2022), who found no significant relationship between education and adoption. Our findings suggest that it is not formal education per se, but rather how technologies are introduced, demonstrated, and explained, that matters most.

4 Conclusion

West Africa is at a crossroad in ensuring sustainable livelihoods in the context of climate change and land degradation. This study explored the coping strategies and social cohesion mechanisms used by smallholder farmers to address the impacts of climate change and land degradation in Northern Ghana. The study also explored farmers' perception on the subject and identified the key barriers impeding the adoption of SLM innovations.

Farmers demonstrated high awareness and knowledge of both climate change and land degradation. They described climate change in terms of irregular rainfall patterns, frequent flooding, rising temperatures, and droughts. Land degradation was identified through indicators such as poor plant growth, soil erosion, and changes in soil colour. While both male and female farmers recognized similar signs of climate change, their perceptions of its causes and impacts differed: male farmers attributed it to human activities, whereas female farmers associated it with the actions of a supreme being.

Farmers reported using different coping and adaptation practices to manage climate risks and improve soil fertility. Coping strategies reported include reliance on social networks, engaging in non-farm jobs, reduction of food intake, and selling livestock. Some of the practices which are of long-term response to climate change and land degradation include SLM practices (e.g., crop rotation, intercropping, composting, among others), crop-livestock integration, planting of drought-tolerant crop varieties, adjusting the planting calendar, and the use of indigenous knowledge in weather forecasting and making of bio-pesticide. Examined under the lens of livelihood assets (Human Capital, Natural Capital, Financial Capital, Social Capital, and Physical Capital), Social Capital (such membership in self-help groups) emerged as most important means of coping, especially for female farmers.

Farmers reported facing economic and socio-cultural challenges in adopting SLM innovations. These include poor access to credit, land tenure insecurity, cultural barriers, and poor access to key inputs. Most of the barriers identified under the socio-cultural segment differed by gender and disproportionately affect female farmers.

The study recommends integrating farmers' indigenous knowledge into the development of SLM innovations, with a focus on tackling land degradation. Policy makers should integrate indigenous farming practices—such as composting, intercropping, and ridge construction—into SLM programs by training lead farmers to disseminate this knowledge through local demonstrations. Gender-sensitive reforms are needed to enforce joint land titling and prioritize input support for female-headed households lacking secure land. Support for farmers' associations and self-help groups should include formal registration, seed grants, and linkage to microfinance institutions to enhance their role in resilience building. Climate education should be embedded in adult literacy programs, with gender-tailored content on soil conservation and adaptive farming. Finally, extension services must be strengthened through mobile units and tied to gender quotas in FBO leadership, supported by annual gender-disaggregated monitoring of SLM adoption.

This study is primarily exploratory in nature, and certain limitations merit consideration. First, the choice of statistical methods (Mann–Whitney U test and Kendall's Tau Correlation) was well-suited to the small sample size and ordinal data structure. While these methods provided robust insights for the study's objectives, they may not fully capture complex interactions among variables. Future research could extend this analysis using multivariate or inferential techniques to explore potential causal relationships and structural dynamics. Second, while the study identified gendered patterns in perceptions and strategies, it did not conduct a fully disaggregated analysis of gender-specific responses. Future work could build on these findings by employing more detailed gender-focused frameworks to unpack the differentiated experiences and adaptive capacities of male and female farmers.

Data availability statement

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

Author contributions

HA: Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing. HN: Conceptualization, Funding acquisition, Methodology, Project administration, Resources, Supervision, Writing – review & editing. JS: Funding acquisition, Project administration, Resources, Supervision, Writing – review & editing. AA: Investigation, Validation, Writing – review & editing. AK: Conceptualization, Resources, Supervision, Validation, Writing – review & editing.

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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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