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Smallholder Farmers' Livelihood Vulnerability in Northwestern Ghana: Do Climate Adaptation Strategies and Socioeconomic Characteristics Matter in the Sissala East Municipality?

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Abstract
Scientific research has demonstrated that climate change adaptation holds the potential to enhance crop yields and diminish the susceptibility of smallholder farmers in Sub-Saharan Africa to poor agricultural productivity. Nevertheless, there exists a limited comprehension of the interplay between these adaptation strategies and the socioeconomic characteristics of smallholder farmers in relation to their livelihood vulnerability. Consequently, the present study endeavoured to assess the climate change adaptation strategies and the livelihood vulnerabilities of smallholder farmers within the Sissala East Municipality. Data was meticulously collected from 120 farmers employing a concurrent embedded research design. A fractional Probit regression model analysis has been employed to elucidate the findings. The analysis revealed that farmers who adopt charcoal production, crop rotation, cover cropping, and temporal migration exhibit heightened vulnerability to climate change. Conversely, those who adopt drought-tolerant and early-maturing varieties demonstrate reduced vulnerability to climate change. These findings underscore the imperative for governmental interventions, facilitated by the Ministry of Food and Agriculture and non-governmental organisations, to mitigate the adverse effects of climate change in rural areas and address the vulnerability of farmers. Prioritising such interventions is paramount to prevent farmers' vulnerability from exceeding their tolerance threshold.

Keywords
climate adaptation, Livelihoods, Vulnerability, smallholder farmers, socioeconomic characteristics, Ghana.

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1. Introduction

Globally, climate change has emerged as a significant threat to farmers' livelihoods, particularly in developing nations where rain-fed agriculture is the backbone of the economy (Mondal, 2019). The impact of climate change is real, with the most acute stressors on food security, biodiversity, and livelihoods (Sargani, Jiang, Chandio, et al., 2023; Sargani, Jiang, Joyo, et al., 2023). Scientific evidence overwhelmingly supports the detrimental effects of climate change on agricultural production, impacting food security and the well-being of millions who depend on farming (Chausson et al., 2020; Cobbinah & Anane, 2016; Pörtner et al., 2021; Sargani, Jiang, Joyo, et al., 2023). Based on this, the Intergovernmental Panel on Climate Change (IPCC) was set up to deal with climate change. The IPCC specializes in climate change and its adaptation, as vulnerability and adaptation are keys in the cycle of disaster coping and disaster risk reduction for residents now and in the future (Cutter & Finch, 2008; Kendra & Wachtendorf, 2003). Research suggests that the vulnerability of farmers' livelihoods to climate change is shaped by adaptation strategies and socioeconomic factors (Azumah et al., 2022; Harvey et al., 2014; Poudel et al., 2020; Sargani, Jiang, Joyo, et al., 2023). Also, more studies have focused on the livelihood vulnerability of farmers and their livelihood adaptation strategies under climate change (Cutter & Finch, 2008). Moreover, farmers' perceptions of climate change significantly influence the adoption of various livelihood strategies and adaptation measures (Harvey et al., 2014; Jha & Gupta, 2021; Mamun et al., 2021), which play a crucial role in mitigating negative impacts on agricultural production (Singh et al., 2021).

Smallholder farmers, particularly those in tropical regions, face multiple risks to agricultural production, and this is expected to worsen with climate change (Ariom et al., 2022; Aryal et al., 2020; Harvey et al., 2014). Additionally, the adoption of climate change adaptation strategies by smallholder farmers has been significantly hindered by constrained resources and limited capacity (Ariom et al., 2022; Harvey et al., 2014). Consequently, climate change poses a substantial impediment to the realisation of food security and the fulfilment of pivotal developmental objectives within numerous global economies, from which Ghana cannot be excluded (Adu et al., 2018). In Northern Ghana, households employ various adaptation strategies, including the use of improved seeds, adjustments to planting dates, and cultivation of drought-resistant crops, in response to climate change effects (Aniah et al., 2019; Antwi-Agyei et al., 2018; Azumah et al., 2017; Williams et al., 2018). Adzawla et al. (2020) also highlight the influence of social and economic factors such as age, loan availability, households without non-farm economic activity, household per capita consumption, and the frequency of recent floods on climate change impacts on farmers' livelihoods. The 21st century has seen a shortage in the per capita global food production by 7% and the shortage is believed to be caused by climate change and variability, and low soil productivity (Adu et al., 2018; Rosenzweig & Parry, 1994). In Ghana, agriculture contributed 22% to the nation's Gross Domestic Product (Quartey, 2018), and smallholder farmers dominate the agricultural sector in the Ghanaian economy, with about 90 percent being resource-poor(Ghana Statistical Service, 2013, 2021). Smallholder farmers primarily depend on family labor and operate under rain-fed conditions (Chamberlin, 2008). This has contributed to the inability of Ghana to produce more to feed its population. Also, climate change has adversely affected agricultural productivity by reducing the area suitable for cultivation (Denkyirah et al., 2017; Okoffo et al., 2016) and modifying the development of crop pests and diseases (Hutchins et al., 2015; Oyekale & Idjesa, 2009; Raza et al., 2019). To cope with these challenges, farmers have traditionally relied on indigenous knowledge (Naab et al., 2019). However, such knowledge may not be sufficient to prepare smallholder farmers for the unpredictable nature of the changing climate and may sometimes worsen their vulnerability.

To assess the vulnerability of smallholder farmers' livelihoods to climate change in the Sissala East Municipal, the Livelihood Vulnerability Index (LVI) was used. The LVI approach involves several variables that capture the level of smallholder farmers' exposure to climate change, their adaptation capacities, and their sensitivity to climate change impacts (Adu et al., 2018; Hahn et al., 2009). Livelihood strategies are the most effective protection against external shocks. Also, smallholder farmers' livelihood strategies are constantly adjusted with changes in policies and systems, the external environment, and their capital. Theoretically, farmers in different natural-disaster-threatened areas will adopt different livelihood strategies according to their social and economic differences. Natural disasters will not only lead to a decline in the income and welfare level of the affected families but also lead to the widening of the income gap between resident families (Hu et al., 2020). Studies, (eg. Antwi-Agyei et al. 2012), discovered that families and communities had varying degrees of climate sensitivity, which was mostly influenced by socioeconomic factors, including access to money and productive assets. Shah et al. (2013) also note that the LVI varied within communities, particularly because of variations in sociodemographic traits, like health, and access to water.

Similarly, Dendir and Simane (2019) suggested that LVI varies depending on the farmer's agroecological location and is higher for those who live in lowland agroecological zones. One benefit of assessing LVI is that it enables the evaluation of the influence of socioeconomic and other elements within the human system, in addition to climatic influences, on vulnerability (Sujakhu et al., 2019). Overall, the vulnerability of farmers' livelihoods to climate change is influenced by various factors, including assets, livelihood diversification, innovation, infrastructure, sociodemographic factors, social capital, agriculture, food security, natural disasters, and climate variability (Amare & Simane, 2017). Addressing these factors through targeted adaptation strategies and support systems can help enhance the resilience of farmers' livelihoods in the face of climate change. This study investigates whether climate adaptation strategies and other socioeconomic characteristics of smallholder farmers affect their livelihood vulnerability in Sissala East Municipality of Ghana to help identify robust adaptation strategies that can enhance the resilience of farmers in the face of climate change.

The rest of the paper is structured into four sections. First, we present a brief overview of the literature, the second section covers a brief profile of the study area and methodology, and the third section captures the results and discussion, while conclusions are presented in the last section.

1.1 Climate Adaptation Strategies and Vulnerabilities

Most studies have investigated some of the on-farm and off-farm techniques farmers have used to adjust to climate shocks (Adzawla et al., 2020; Azumah et al., 2021).

Some farmers in sub-Saharan Africa use off-farm strategies like the sale of family properties, timber lumbering, charcoal production, and temporal migration to offset climate shocks (Lawson et al., 2019). Some of these adaptation strategies rather worsen environmental conditions. According to Branch et al. (2022), charcoal production, for instance, poses considerable threats to ecosystems and communities. The extensive deforestation for charcoal production precipitates a sequence of habitat disruption and destruction, contributing to biodiversity losses and environmental equilibrium disruption. Soil degradation, erosion, and diminished water retention, exacerbated by wood harvesting for charcoal production, heighten the ecosystems' susceptibility (Kyere-Boateng & Marek, 2021; Kyere-Boateng et al., 2021; Richard & MV, 2021). While the socioeconomic ramifications of charcoal production for communities are profound (Ali, 2023), the exhaustion of forests for this purpose can lead to critical resource depletion, loss of economic opportunities, and a reduction in the yield of farmers. This scarcity can inevitably deepen poverty and curtail livelihood choices for these communities (Ablo et al., 2022; Byaro et al., 2023; Maja & Ayano, 2021).

In contrast, on-farm adaptation techniques, such as altering planting dates, utilizing drought-tolerant crop varieties, and implementing practices like crop rotation, mixed cropping, and cover cropping, have shown promise in enhancing resilience to climate change impacts (Aniah et al., 2019; Azumah et al., 2017). Drought-tolerant seed varieties hold paramount importance in the realm of climate change adaptation within the field of crop production (Adzawla & Baumüller, 2021). These varieties possess specific genetic traits or are deliberately bred to endure drought conditions, thus enhancing their resilience against water stress (Ahmad et al., 2021). Key traits present in these varieties include an extensive root system, amplified water-use efficiency, and the capacity to sustain productivity, even in water-deprived situations (Agyapong et al., 2022; Rosero et al., 2020). By employing these drought-tolerant seed varieties, farmers may mitigate yield losses during water-scarce periods and elevate their productivity within drought-prone zones (Adzawla et al., 2020; Adzawla & Baumüller, 2021). Other on-farm adaptation strategies include the use of weedicides, planting in rows, crop rotation, mixed cropping, and cover cropping (Azumah et al., 2017). Crop rotation, for example, not only promotes soil health and productivity, but it also helps manage pest and disease cycles, and soil erosion, improves biodiversity, reduces nutrient depletion, and fortifies agricultural systems (Antwi-Agyei & Nyantakyi-Frimpong, 2021; Yu et al., 2022). Similarly, cover cropping contributes to soil vitality, erosion control, water retention, and carbon sequestration, thus bolstering resilience to climate variability (Jacobs et al., 2022). Research has proven that temporal migration as an off-farm adaptive strategy has both positive and negative feedback. Positive feedback loops come into effect when migration patterns increase susceptibility in both the departure and arrival locations (Benveniste et al., 2020). Contrastingly, negative feedback mechanisms can occur when migration trends lessen vulnerability. For instance, if resettlement leads to a prosperous economic climate and resource accessibility, it can boost adaptive capabilities and minimize vulnerability (Parrish et al., 2020). Furthermore, remittances can provide capital for an alternative source of livelihood and boost adaptive capacities in comprehending these cyclic patterns aids in the creation of efficient policies and interventions to accommodate climate vulnerability, considering temporal migration (Entwisle et al., 2020; Šedová, 2021). Various factors contribute to the disparity in the livelihood vulnerability index among smallholder farmers. Socioeconomic indicators such as sex, marital status, education, access to credit facilities, and land size play significant roles (Adzawla & Baumüller, 2021; Antwi-Agyei & Nyantakyi-Frimpong, 2021). Dumenu and Takam Tiamgne (2020) argue that comparing the livelihood vulnerability index between sexes reveals gender-based discrepancies, highlighting socio-cultural elements limiting women's access to resources, economic prospects, and decision-making authority. The heavy reliance of male farmers on traditional farming methods hinders their adaptability to climate change (Derbile et al., 2022) , potentially exposing them to heightened risks (Nyantakyi-Frimpong, 2021). Addressing these underlying causes is crucial for encouraging gender equality and mitigating vulnerability (Kuran et al., 2020). Marital status also significantly impacts livelihood vulnerability, with studies indicating lower vulnerability among the married population due to benefits like resource pooling and emotional support (Azumah et al., 2021). However, the influence of marital status is diverse and affected by factors such as gender, socioeconomic status, and cultural norms (Kaczan & Orgill-Meyer, 2020). Understanding these implications can inform policies aimed at reducing vulnerability across different marital statuses in local communities (Mekonen & Berlie, 2021). Education is also said to play a vital role in reducing livelihood vulnerability, as individuals with higher levels of education are less likely to experience vulnerability (Antwi-Agyei et al., 2012; Paudel et al., 2020) . Education equips individuals with knowledge and skills to adapt to changes and make informed decisions, thereby enhancing resilience (Yin et al., 2021). Illiteracy hampers the dissemination of information among smallholder farmers, affecting their adaptation needs (Kosoe & Ahmed, 2022). Farm size is another determinant of livelihood vulnerability, with larger farms exhibiting greater financial stability and access to credit, enabling them to adopt resilient approaches (Azumah et al., 2021). Additionally, market proximity significantly influences livelihood vulnerability, as distant markets limit revenue potential and increase dependence on subsistence farming (Ayana et al., 2021; Ningrum et al., 2020). Agricultural extension services play a crucial role in modulating livelihood vulnerability by providing access to agricultural practices, technologies, and information (Fabregas et al., 2022; Sujakhu et al., 2019). These services also facilitate the adoption of sustainable farming methods and empower farmers to confront issues collectively (Steinke et al., 2021). In conclusion, understanding the various factors influencing livelihood vulnerability among smallholder farmers is essential for developing effective policies and strategies to reduce vulnerability and foster resilience.

2. Materials and Methods

2.1 Location of Study Area

The study was conducted in the Sissala East Municipality, one of the Resilience Against Climate Change - Social Transformation Research (REACH-STR)[1] districts in the Upper West Region of Ghana. The Sissala East District was created in 2004 by LI.1766, with Tumu serving as the district capital as part of the government's decentralization strategy (Ghana Statistical Service, 2021). Geographically, the district is situated in Ghana's Upper West Region in the North-East.

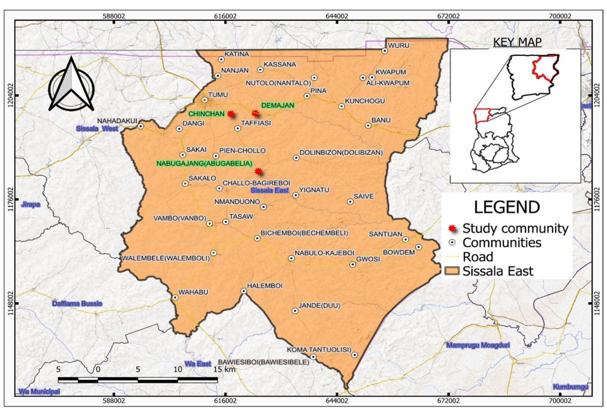

Figure 1. Sissala East Municipality Map. Source: Author's construct

Figure 1 is a Map indicating the location of the study area. It lies between Latitudes 10.000N and 11.000 N and Longitude 1.300 W in the country. The total land mass is estimated to be 4,990 square kilometers, representing about 26% of the total landmass in the region. Burkina Faso is its neighbour to the North, Kasena Nankana and Builsa Districts to the east, West Mamprusi District to the south-east, Wa East and Nadowli Districts to the south-west, and Sissala West District to the west (Ghana Statistical Service, 2021). The Sissala East Municipality is a business and socioeconomic activities hub as it is located close to the border. The municipality is ideally situated for improved socio-economic, cultural, and political interaction with the adjacent districts as well as Burkina Faso due to its geographic location (Ghana Statistical Service, 2021).

2.2 Research Methodology

The study employed the concurrent embedded design, which is a type of mixed methods design where both qualitative and quantitative procedures are employed at any point in time in the research process (Creswell & Garrett, 2008; Creswell et al., 2011; Tashakkori & Creswell, 2007) . The sample size for the study was determined using Taro Yamane's formula (Yamane, 1967) for sample size determination. The study employed a multi-stage sampling procedure to select the study area and farmers for the study. Because the study is part of the Resilience Against Climate Change - Social Transformation Research (REACH-STR), a simple random sampling was first used to select Sissala East Municipality, one of the project districts in the Upper West Region of Ghana. Again, the simple random sampling technique was adopted to select three communities (Chinchang, Navirawie, and Dimajan) from three zonal councils, namely Bujan, Sakai & Nabulo zonal councils in the Sissala East Municipality. This technique was used to avoid the selection of communities from the same zone and to ensure full representation. In the third stage, the convenience sampling technique was used to select 120 respondents in the three communities, thus 40 respondents from each community. By using the convenience sampling technique, any farmer who was free and willing to participate in the study was interviewed in these communities. The study acknowledges that convenient sampling increases the range of limitations, including the risk of bias; limits the generalizability of the findings across and within different contexts, and hampers our ability, in some cases, to effectively eliminate measurement errors. We found it practical, given the urgency of the research. Future studies of this nature may rely on randomization, which would better ensure accurate representation of the targeted population and appropriate distribution of the results. A structured questionnaire was administered to smallholder farmers. The questionnaire contained background information on farmers, such as age, sex, marital status, education, family size, source of income, and asset ownership. This allowed the researchers to collect data that partially responded to the study questions about the variables that affected

[1]REACH STR Project (2018- 2024, Agreement # 4500000909) is funded by the European Union and conducted by a partnership of four Institutions led by the International Water Management Institute (IMWI), with partners including The University of Ghana-Center for Migration Studies; Science and Technology Policy Research Institute (STEPRI); and the Simon Diedong University of Business and Integrated Development Studies (SDD-UBIDS). This project is part of a larger EUGAP (EU Ghana Agriculture Programme) and it complements the action of a larger REACH project. REACH intends to increase the resilience of rural communities in districts of the Northern Development Authority.

farmers' adaptation techniques in the Sissala East Municipality. To gather crucial viewpoints and perspectives from farmers on their susceptibility to climate change, their adaptation strategies, and the effects of their adaptation on their livelihoods, Focus Group Discussions (FGDs) were conducted using a focus group guide. The FDGs provided an opportunity for the farmers to express and discuss important concerns, which resulted in the fusion of ideas. One FGD was held in each community in the study area. That is, three FGDs were conducted to supplement the structured questionnaire data. Each community had one group each with six men and six women. Because the researcher wants to encourage women to openly discuss with males, the groups' makeup was intended to be mixed gender.

2.3 Data Analytical Strategy

The data was analyzed using the fractional probit regression model. The response variable is the livelihood vulnerability Index (LVI), whose values range between zero and one. The LVI is determined by three major components: adaptive capacity, sensitivity, and exposure of farmers to climate change, each of which has subcomponents (indicators) to determine the overall LVI for farmers as obtained from the literature (Adu et al., 2018; Gerlitz et al., 2016; Hahn et al., 2009; Tuyet Hanh et al., 2020).

The measurements of the sub-components (indicators) were normalized using the normalization index given by $Z_n = (S_d - S_{min.})/(S_{Max.} - S_{min.})$, where Z_n denote the normalized value for each sub-indicator, the S_d denotes observed value of the sub-indicator, S_{max} denotes the maximum value of the observed indicator, and the S_{min} denotes the minimum value of the observed indicator.

The index for each major indicator was then computed based on the normalized values of the subcomponents as follows: $MI = (\sum Z_n)/W$, the MI denotes a major indicator, and the W is the number of components under each MI.

The LVI for each farmer was then computed as $LVI = (\sum Z_n * W)/(\sum W)$, which yields values bounded between zero and one. An LVI of zero depicts that the farmer is less vulnerable, and one depicts that the farmer is very vulnerable.

The fractional probit regression model is employed when an outcome variable of interest is measured as a fraction. That is, it has been designed to handle response variables like LVI, whose value is greater than or equal to zero (0) and less than or equal to 1. The outcome variable of interest is often observed when proportions are generated from aggregated binary outcomes (Papke & Wooldridge, 1996, 2008).

The fractional probit model is a quasi-likelihood estimator like a generalized linear regression model. The model of the mean dependent variable, in this case, LVI, is conditioned on covariates (X). The model assumes that a researcher does not need to know the true distribution of the entire model to estimate consistent parameters (Gray & Alava, 2018). The fractional model can be expressed as $E(Y_i|X_i) = G(X_i\beta)$......(3.1)

The G(.) is a function satisfying the condition, 0<G(LVI)<1 This ensures that predicted values of LVI lie between 0 and 1. Following the work of Schwiebert (2018), the fractional probit regression model can be specified as: $LVI_i = \phi(X_i^{'}\beta + \varepsilon_i)$......3.2)

Where X denotes climate adaptation strategies and socioeconomic factors, β is the parameters to be estimated, and ε is for error term capturing the aggregated effects of unobserved variables, which are assumed to be normally distributed.

2.4 Major and subcomponents of vulnerability indicators

There were three major components of the vulnerability index: adaptive capacity, sensitivity, and exposure of farmers to climate change. The adaptive capacity index illustrates how well the sample communities can adapt to and prosper in the face of climate change. The subcomponents of adaptive capacity are: participation in off-farm income generation activity, land tenure, source of energy for cooking, membership in Farmer-Based Organisations (FBO), participation in capacity-building training, and access to agricultural extension. Sensitivity analysis is another Monte Carlo (MC) for measuring farmers' vulnerability to climate change with the following subcomponents: source of drinking water, number of months experienced drought, access to production credit, fertilizer application, months of food shortage in a year, and participation in agricultural insurance. Exposure index is determined by the following subcomponents: access to climate change information, received warning information on any climate shock before its occurrence, field experiences pest infestation, number of times a farmer experience windstorm in the past 5 years, number of times a farmer experience bushfire in the past 5 years, number of times a farmer experienced floods in the past 5 years, and number of times a farmer experience drought in the past 5 years

3. Results and Discussion

In all, there were one hundred and twenty (120) respondents, the majority (60%) of whom were males. Over half of them (60%) had attained educational levels below secondary education. Thus, they either had primary or junior high school education (23%) or no formal education at all (37%). Interestingly, the majority (55%) of the respondents without formal education were females. The rest (40%) had either a secondary cycle education or a tertiary education. An overwhelming majority (87%) of the respondents were married, with all the female respondents being married (Table 1). Household sizes varied from 0 to 16. A little above half (53%) of the respondents interviewed had households consisting of 5 to 8 members. The rest had household sizes in the ranges of 1-4 and 9-12. Most (97) of the respondents were primarily farmers, whilst few of them (40%) had access to credit.

A chi-squared test (Table 1) of association to check if there is an association between the sex of a respondent and his/her educational level, marital status, household size, primary occupation, and access to credit revealed an association with marital status, household size, and access to credit. The study sought to explore the other sources of income of the farmers besides farming. Very few of them (14%) indicated they had no other source of income either than farming, with male respondents dominating this number. The rest were either engaged in one- or two-income-generating ventures. The majority (58%) of the respondents, with more than half (51%) of the number being female, indicated engaging in charcoal production or selling firewood for extra income; others engaged in trading (16%) by either operating convenience or electrical shops or just petty trading (Table 2). Very few of these respondents, mainly males, engaged in ventures like manual labor at construction sites (2%), hunting (2%), irrigational (vegetable) farming (2%), and livestock farming (2%). A few of them (8%) also engage in artisanal works such as dressmaking, masonry, and wood and joinery for extra income. The respondents who did not have farming as their primary occupation (3%) had it as their other source of income-generating activity.

Generally, the farmers interviewed were aged between 19 and 55 years. The average age of these farmers was 34 years. The distribution of their ages was positively skewed and platykurtic, indicating that most of them were below the average age, and the tail of the distribution is thinner than the normal distribution, an indication of fewer extreme values. The farm size of farmers ranged between 1 and 30 acres, with the average farm size being pegged at 7.48 acres. This value is highly positively skewed with an excess skewness of 1.469, implying that there are many farms that are of smaller sizes (below the average) and very few of the large farm sizes. The distribution of the farm sizes is leptokurtic (with excess kurtosis of 1.937), implying the presence of extreme values in the data (Table 3).

Table 1. Frequency distribution of sex versus other demographic characteristics

Variable	Category	Sex					
		Female		Male		Total(%)	Pearson Chi-Square value (p-value)
		Freq.	%	Freq	%		
Educational Level	None	24	**55**	20	45	44(37)	9.03(0.06)
	Basic	8	28	20	71	28(23)	
	Secondary	12	42	16	57	28(23)	
	Tertiary	4	20	16	80	20(17)	
Marital Status	Married	48	46	56	53	104(87)	12.308(0.00)
	Otherwise	0	0	16	100	16(13)	
Household Size	0	0	0	2	100	2(2)	22.851(0.043)
	1 - 4	14	41	20	58	34(28)	
	5 - 8	26	40	38	59	64(53)	
	9 - 12	8	44	10	55	18(15)	
	13 - 16	0	0	2	100	2(2)	
Primary Occupation	Otherwise	0	0	4	100	4(3)	2.759(0.097)
	Farming	48	41	68	58	116(97)	
Access to credit	No	28	38	44	61	72(60)	58.51(0.00)
	Yes	20	41	28	58	48(40)	
Total		**48**	**40**	**72**	**60**	**120(100)**	

Source: Field survey, 2023

Table 2. Frequency distribution of sex versus other sources of income of respondents

Other sources of income	Sex				Total
	Female	%	Male	%	
Farming	0	0	4	50	4(3)
Charcoal/ Firewood business	36	51	34	49	70(58)
Trading	10	50	10	50	20(16)
vegetable farming	0	0	2	100	2(2)
Hunting	0	0	2	100	2(2)
Artisan	2	25	6	75	8(6)
Labourer	0	0	2	100	2(2)
livestock farming	0	0	2	100	2(2)
None	4	22	14	78	18(14)

Source: Field survey, 2023

Table 3. Descriptive statistics of age and farm size of respondents

variable	N	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
Age	120	19	55	34.38	8.179	0.3	-0.496
farm size	120	1	30	7.48	6.486	1.469	1.937

Source: Field survey, 2023

3.1 Effects of Climate Adaptation Strategies on Livelihood Vulnerability Index

The Fractional probit model assessed the effects of climate adaptation strategies and other socioeconomic factors on LVI. The results are presented in Table 4. The Wald Chi-square value was 316.55, which was statistically significant at a 1% level. This implies that the fractional probit regression model was fit for the analysis. Charcoal production was found to have a positive coefficient and was significant at a 1% level. This implies that farmers who participate in charcoal production as climate change adaptation strategies are more vulnerable to climate change and variability compared to non-participants. Charcoal production not only contributes to the vulnerability of farmers but also poses some threat to the ecosystem and communities since it involves cutting down trees and burning them (Branch et al., 2022). The burning increases carbon emissions to the environment, causing climate change. Also, as confirmed by Kyere-Boateng et al. (2021); Richard & MV, (2021) cutting trees for charcoal production not only affects the fertility of the soil by exposing it to excessive soil erosion but also contributes to the drying up of small water bodies in the area. This goes a long way to affect the production level of farmers and makes it difficult for farmers to water their crops during the dry season and leading to loss of opportunities and livelihood choices due to resource depletion (Byaro et al., 2023; Maja & Ayano, 2021). Charcoal production as an adaptation strategy in response to climate change should be discouraged among smallholder farmers since its impact on the environment and the farmers is severe and affects the sustainability of their livelihoods (Ablo et al., 2022). Acknowledging the effects of charcoal burning, a farmer had this to say:

"*. . . Even though we know felling trees for charcoal production is not good for our land because we are gradually losing our little forest here, we do not have any option since the money we get from our farming activities alone cannot cater to our family needs hence, we have to rely on charcoal production to complement what we get from the farm (Male farmer, Chinchang).*"

Drought-tolerant seed and early maturing seed varieties were found to have a significant negative effect on farmers' LVI at 5% and 1% levels, respectively. This implies that adopters of drought-resistant/early-maturing varieties are less vulnerable to climate change and variability. This result corroborates the findings of Azumah et al. (2021) that the adoption of improved varieties like early maturing and drought-tolerant varieties has a positive and significant effect on the LVI of smallholder farmers in Northern Ghana. Research has shown that sixty-three percent (63%) of crops farmed in the Upper West Region of Ghana are vulnerable to drought and other climatic conditions (Derbile E. K et al., 2022). From a focus group interview, respondents agreed on the importance of early maturing yields in the communities:

"*For some time now, most people in this community have planted the "Kunjor-Wari" and "Suhudoo" maize seed varieties since that one matures within 3 months and can even do well if the rains are not sufficient (Dimajan, Focus Group Discussant)*"

The finding aligns with an earlier study by Adzawla and Baumüller (2021) that farmers can mitigate yield losses by adopting early-maturing and drought-tolerant seed varieties, which lessen their susceptibility to climate change. Also, as confirmed by Rosero et al. (2020) drought-tolerant crop varieties reduce complete crop failure among farmers than other varieties and completely reduce food insecurity and vulnerability of farmers to climate change; hence, the adoption of these varieties should be encouraged and promoted among farmers through price subsidies, technical training, and demonstration fields to enhance effective climate change adaptation in agriculture.

Furthermore, crop rotation was found to have a positive effect on LVI, and it was statistically significant at a 1% level. The implication is that adopters of crop rotation are more vulnerable to climate change than non-adopters. This finding contradicts studies that note that crop rotation is a sustainable land management practice, reduces greenhouse gas emissions, and pest and disease cycles, improves soil nutrients, promotes biodiversity, and negates the necessity for artificial fertilizer application (Antwi-Agyei & Nyantakyi-Frimpong, 2021; Francis & Clegg, 2020). The possible explanation for this finding could be that farmers in the study area do not apply the appropriate methods of adoption of crop rotation at the farmgate level. For instance, farmers could be rotating cereals with cereals instead of legume-cereal rotation. Practice cereal-cereal crop rotation weakens soil structure, reduces soil biomass and soil productivity, and provides an opportunity for certain weed species to flourish (El Sabagh et al., 2020; MacLaren et al., 2020; Singh et al., 2021). This will consequently lead to a reduction in yield and household income. These cumulative impacts make farmers more vulnerable to climate change and variability.

Contrary to the expectation, the adoption of cover cropping has a positive effect on LVI at a 1% significance level. This indicates that farmers who adopt cover cropping are more vulnerable than non-adopters. Cover cropping is an adaptation technique that helps in the preservation of soil moisture and fertility. This finding contradicts the findings of Adzawla et al. (2020); (Jacobs et al., 2022; Yu et al., 2022); who noted that cover cropping reduces the vulnerability of farmers to climate change since it helps in fortifying soil vitality, reduces soil erosion, and enhances water retention and carbon trapping. The reason for such a finding could be that the adoption of cover cropping was very low among farmers in the study area. This could be a result of some factors, such as financial constraints and a lack of knowledge and awareness. Autio et al. (2021) noted that some farmers remain unaware of the potential benefits associated with cover crops, leading to a reluctance to embrace these techniques. Also, the initial costs associated with implementing cover cropping practices, such as procuring seeds and machinery, can be daunting, especially for farmers with limited financial resources (Mortensen & Smith, 2020; Simon et al., 2022). Once the adoption of cover cropping is low, it is expected that farmers will be more vulnerable to climate change and its related shocks. This was alluded to by a male farmer in the FGD:

"*Initially, I used to plant beans in my millet and guinea corn farm during the rainy season. I was not getting enough yield from it, so I stopped. I now plant it separately on a different plot and that seems better to me than what I was doing before (Male farmer, Dimajan).*"

Temporal migration was found to have a positive effect on LVI, which was significant at a 1% level in the study area (Table 4). That is, farmers who engage in temporal migration as a climate adaptation strategy are more likely to be vulnerable than farmers who do not engage in temporal migration as a mitigation strategy. This finding is not surprising because research has proven that migration has both positive and negative feedback on migrants (Entwisle et al., 2020). The positive impact comes into play when migration patterns reduce susceptibility in both the departure and arrival locations and vice versa (Benveniste et al., 2020). Usually, farmers who migrate to a new environment may face challenges to adapt to the way of life and financially to adapt to climate change adaptation strategies to cope with the new environment, making them more vulnerable. However, this finding contradicts (Antwi-Agyei & Nyantakyi-Frimpong, 2021; Baffour-Ata et al., 2021) who noted that temporal migration offers a remarkable degree of adaptability and responsiveness, granting individuals the freedom to pursue favourable conditions and access vital resources during different seasons.

"*Most of the young people in this community travel to the south during the dry season to do menial jobs for money. Only a few of them come home with some tangible some of them still can't afford fertilizers for their farms after coming back when the rains set in (Focus Group Discussants, Navirawie).*"

Table 4. Effects of climate adaptation strategies and other socioeconomic factors on LVI: Fractional probit model

Variable	Coefficient	Std. Errs.	Z	P>Z
Charcoal production	0.166	0.052	3.17	0.002
Rearing production	0.007	0.035	0.2	0.839
Changing planting time	0.138	0.091	1.52	0.128
Planting drought-resistant variety	-0.188	0.091	-2.06	0.04
Early maturity varieties	-0.123	0.045	-2.7	0.007
Crop rotation	0.123	0.041	2.97	0.003
Cover cropping	0.179	0.049	3.67	0
Mixed cropping	-0.019	0.042	-0.45	0.649
Application weedicides	-0.064	0.046	-1.37	0.17
Temporal migration	0.3	0.085	3.52	0
Manure application	0.047	0.047	0.99	0.32
Sex	0.15	0.048	3.13	0.002
Age	-0.004	0.003	-1.05	0.294
Marital status	0.129	0.07	1.84	0.066
Household size	-0.015	0.01	-1.53	0.125
Primary	-0.01	0.059	-0.17	0.865
JHS/Middle School	-0.006	0.072	-0.09	0.929
SHS/O Level/A level/Vocational	-0.222	0.075	-2.97	0.003
Tertiary	-0.203	0.078	-2.6	0.009
Farm size	0.073	0.039	1.88	0.06
Extension service	0.428	0.062	6.91	0
Community-distance market	0.065	0.04	1.63	0.103
Navirawie	0.002	0.059	0.04	0.972
Dimajan	0.022	0.049	0.45	0.651
_cons	-0.464	0.137	-3.39	0.001
Model summary				
Number of obs.=	120			
Wald chi2(24) =	316.55			
Prob > chi2 =	0			
Pseudo R2 =	0.0246			
Log pseudolikelihood =	-80.445			

Source: Field Data, 2023

3.2 Effect of Socioeconomic Factors on LVI

Turning to the effect of socioeconomic factors on LVI, sex was found to have a positive effect on LVI, which was highly statistically significant at a 1% level. The positive effect implies that male farmers are more likely to be vulnerable to climate change than female farmers. This is plausible within contexts, since in recent times it was observed that most non-governmental organizations and donor agencies' activities are geared towards women's empowerment through agriculture (Antwi-Agyei & Nyantakyi-Frimpong, 2021). Women were found to participate more in climate change and nutrition capacity-building workshops than men. This is a disadvantage to male farmers, making them more vulnerable than women. Also, Derbile E. K et al. (2022) & Nyantakyi-Frimpong

(2020) concluded that the vulnerability of male farmers to climate change is a result of their heavy dependence on traditional farming practices. This finding contradicts other researchers who argue that women are more vulnerable to climate change than men (Azumah et al., 2021; Ncube, 2017). Also, Appiah et al. (2021) opined that some sociocultural factors limit women's access to economic resources, land rights, and decision-making authority, which makes women more vulnerable to climate change than men. To enhance farmers' livelihood activities to reduce their vulnerability to climate change, equal opportunities need to be given to both male and female farmers. Since empowering one more than another makes them more vulnerable to climate change. The study demonstrated that marital status has a significant positive effect on LVI at a 10% level. This implies that married farmers are more likely to be climate-vulnerable than singles/never-married. This finding corroborates Azong and Kelso (2021)'s conclusion that the lack of credit from married farmers is a result of household responsibilities such as paying children's school fees, feeding the family, and attending social meetings at the community level, making married farmers more vulnerable to climate change since some adaptation strategies are capital intensive. Similarly, when there is a long drought that affects farm production, married farmers find it difficult to engage in temporal migration to find alternative livelihoods compared to those who are either single or never married (Baffour-Ata et al., 2021). As a female farmer narrates:

"*Purchasing fertilizer during the rainy season has become difficult for me nowadays because of the huge sums of money I pay for my two children who are in tertiary institutions. I now rely on the small organic manure I get from my animal droppings (Female Farmer, Navirawie).*"

However, this finding contradicts Appiah et al. (2021), who posit that in Ghana, married farmers are less vulnerable to climate change due to some socioeconomic benefits such as the pooling of resources and the distribution of household chores.

Access to formal education is one way of building human capital as it empowers farmers to be more resilient and less vulnerable to climate change. The study revealed that access to senior high and tertiary education has a positive effect on LVI, both at a 1% significance level. The intuition is that farmers who attended senior high and tertiary education are less vulnerable to climate change and variability. This is not surprising since education empowers farmers to access farming knowledge, climate change information, price information, access extension services, and participate in social intervention programs (Antwi-Agyei et al., 2012; Poudel et al., 2020). This enhances farmers' ability to make informed decisions when it comes to climate change adaptation. A high level of illiteracy among smallholder farmers makes climate adaptation information dissemination incompatible with their adaptation needs (Kosoe & Ahmed, 2022). Azumah et al. (2021) also found that education reduces farmers' vulnerability to climate change in Zabzugu and South Tongo in Ghana. It is important to highlight that because they have a wide range of information, educated farmers may also investigate several possibilities to enhance their adaptation skills and reduce vulnerability to climate change (Nyantakyi-Frimpong & Bezner-Kerr, 2015). This is testified by a male farmer:

"*I completed Wa Polytechnic two years ago and decided to venture into farming while looking for a white-collar job. I always make a lot of inquiries on which seed variety to plant and what fertilizer to use for that crop because I know some fertilizers are meant for some specific crops (Male farmer, Chinchang).*"

Farm size was found to have a positive effect on farmers' LVI at a marginal 10% significance level. This indicates that increasing farm size by farmers does not lead to a reduction in farmer climate vulnerability. This could also be interpreted as larger farm holders are more likely to be climate-vulnerable than their counterparts. In line with the findings of Amfo and Ali (2020) and Asante et al. (2021), production cost and pest and disease control are the main factors that make large farm owners vulnerable to climate. To an extent, it is difficult for such farmers to apply appropriate chemical fertilizers and improved seed varieties to enhance production because of the high cost of farm inputs. Relatively larger farm-holders might be unable to adopt climate adaptation strategies to mitigate climate change's impact on farm productivity, making them vulnerable to climate change and variability. On the contrary, the studies (Balaganesh et al., 2020; Swami & Parthasarathy, 2021) noted that large farm owners are financially stable since they have access to credit and strong links to markets, which allows them to explore different avenues for financing to mitigate climate-related risk, which makes them less vulnerable to climate change. Access to agricultural extension services could not meet the study's prior expectations. That is, the study revealed that extension service has a positive effect on LVI at a 1% significance level, meaning that farmers with access to extension service are more vulnerable to climate change than their counterparts. Some researchers believe that, due to farmers' expansive demography and resource constraints, farmers are not provided with individual-specific aid when it comes to extension services (Mohammed & Abdulai, 2022; Teye & Quarshie, 2022). Anyarayor et al. (2020) also argued that extension services are not effectively delivered because of the language barrier. This affects the productivity level of farmers due to their unique challenges and circumstances, hence contributing to their climate vulnerability. The results of the study contradict Tiyumtaba (2016), which discovered that a farmer's contacts with an extension officer relate to a lessened vulnerability. Agricultural extension services enhance the productivity of farmers through technology dissemination and refined knowledge and practices, and stimulate the adoption of sustainable farming methods (Fabregas et al., 2022; Steinke et al., 2021). In addition, the community-market distance was found to have a positive effect on LVI, which was marginally significant at 10% level. This implies that communities far from market centers are more likely to be vulnerable than communities close to market centers. Market centers provide communities with some necessities, as well as opportunities to generate income (Ayana et al., 2021). However, the accessibility of such opportunities can be influenced by proximity to the market (Ningrum et al., 2020). Any hindrance to these necessities could expose them to risks and hazards, rendering them vulnerable. Therefore, market accessibility is key to reducing the livelihood vulnerability of smallholder farmers (Reddick et al., 2020). Improving market access and integration to boost income opportunities is therefore critical to alleviating the livelihood vulnerability of smallholder farmers.

4. Conclusion

The study examines the impact of climate adaptation strategies and socioeconomic factors on the livelihood vulnerability index (LVI) of smallholder farmers in the Sissala East Municipality. The findings indicate that certain adaptation measures, such as temporal migration, charcoal production, crop rotation, and cover cropping, are positively associated with increased vulnerability to climate change among smallholder farmers. Conversely, the use of improved seed varieties, particularly drought-tolerant and early-maturity varieties, is negatively correlated with LVI, suggesting that they mitigate vulnerability to climate change. The study identifies demographic factors such as gender, marital status, and farm size as influencing vulnerability to climate change, with male, married, and larger-scale farmers being more susceptible. Educated farmers, on the other hand, exhibit lower vulnerability, likely due to their increased access to farming knowledge and climate change information. Based on these findings, the study recommends interventions to reduce farmers' vulnerability to climate change. It suggests discouraging charcoal production as an adaptation strategy due to its contribution to carbon emissions and climate change. Instead, policymakers are urged to promote the availability of improved seed varieties, including early maturing and drought-tolerant varieties, through subsidies and education campaigns. Furthermore, initiatives to promote crop rotation and cover cropping should be intensified to enhance food production and resilience to climate variability. Overall, the study underscores the importance of targeted interventions and education programs to empower smallholder farmers and enhance their resilience to climate change, thereby safeguarding livelihoods, food security, and socioeconomic well-being in the Sissala East Municipality.

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