

Full Length Research Paper

Barriers of smallholder farmers to climate change adaptation decisions: Evidence from semi-arid region of Ghana

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Climate change poses significant threats to global agricultural output, affecting the livelihoods of millions of farmers, particularly in Ghana's semi-arid Upper East region. Here, millet and sorghum producers face increasing challenges due to changing climatic patterns. Smallholder farmers frequently employ adaptation strategies in response to these conditions. However, despite their efforts, these adaptations often yield unsatisfactory results due to various challenges. Identifying and understanding these difficulties is crucial for developing successful strategies to improve smallholder farmers' resilience and sustainability. To investigate further, a cross-sectional survey design with multi-stage sampling was employed to select 150 farmers for structured interviews. Data were analyzed using descriptive statistics and Principal Component Analysis. Respondents perceived climate change trends highly (3.64), while the extent of adaptation decisions employed by farmers was moderate (2.89). Barriers such as personal production resources, infrastructure, support mechanisms, and institutional challenges significantly hindered sorghum and millet farmers' adaptation efforts. Notably, the personal productive resources barrier emerged as the most significant impediment to farmers' ability to adapt to climate change. To ensure successful adaptation, improvements in financial and labor resources, as well as better accessibility to extension services, are essential.

Key words: Sorghum and millet farmers, adaptation barriers, financial barriers, irregularity of extension service.

INTRODUCTION

Climate change and its consequences have sparked the interest and concern of development organizations on local, regional, and global scales (Santos et al., 2022). It gravely impacts food production, affecting soils in terms of groundwater discharge, soil moisture, frequency of droughts and floods, and soil fertility (Furtak and Wolińska, 2023). High temperatures and insufficient

rainfall also damage crop growth (Mahendra-Dev, 2012; Mendelsohn, 2014). The proliferation of insect pests and diseases due to changes in precipitation and temperature has serious implications for food security, prompting the use of pesticides that cause devastating harm to ecosystems (Nasir et al., 2018). Adaptation is seen as a panacea for poor farmers who often lack resources to

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mitigate climate change. In sub-Saharan Africa, adaptation is often reactive, with strategies implemented only after the initial impacts have occurred (Ford et al., 2015).

Studies by Ruiz et al. (2020) and Van der Linden (2015) indicate that perception is often influenced by individuals' past experiences, available information, and geographical location. Farmers in Africa and Asia have perceived increases in temperature, irregular rainfall and distribution patterns, as well as reductions in rainfall quantity (Amir et al., 2020; Balasha et al., 2023; Nyang'au et al., 2021). Research by Fosu-Mensah et al. (2012) reported that a significant majority of farmers, 92% and 87% respectively, observed an increase in temperature and a decrease in rainfall. However, they faced significant obstacles in implementing adaptation measures, primarily stemming from poverty, limited knowledge about adaptation strategies, and a lack of accessible climate information. The majority of farmers in the Upper East region perceived an increase in temperature and a decrease in rainfall (Limantol et al., 2016).

The study by Zakaria and Matsui (2020) confirmed that farmers often employ climate-smart crop varieties, adjust planting dates, optimize the use of inorganic and organic fertilizers, diversify livelihood sources, practice crop diversification and rotation, utilize dugouts, and implement soil conservation (mulching) as mitigation strategies against climate change. Farmers frequently adopt water and soil conservation practices, agronomic techniques such as intercropping, altering planting dates, crop rotation, crop diversification, improved crop varieties, inorganic fertilizer use, manure application, and irrigation practices as adaptation measures (Asravor, 2023; Fadina and Barjolle, 2018).

Researchers have identified several barriers that hinder farmers from effectively using adaptation strategies to address the impacts of climate change, including lack of financial resources, institutional barriers (Pasquini et al., 2013), information gaps (Boyd et al., 2013), technological constraints (Kithiia, 2011), and socio-cultural factors (Adger et al., 2013). A study by Muench et al. (2021) indicated that limited access to information, agricultural extension services, availability of irrigation infrastructure, and low participation in training negatively impact adaptation efforts. Additionally, insecure land tenure was identified as another barrier to adaptation (Nkuba et al., 2020).

Smallholder sorghum and millet farmers in the Bolgatanga Municipality of Ghana are particularly vulnerable to the adverse effects of climate change due to their heavy reliance on rain-fed agriculture and limited access to technological advancements (Kumasi et al., 2019). Despite the increasing volume of information on climate change adaptation, farmers face significant obstacles that hinder their ability to implement effective adaptive strategies. Moreover, empirical data on barriers

to climate change adaptation in the Municipality remains limited. Understanding and addressing these constraints is crucial for enhancing the resilience of smallholder farmers and ensuring sustainable agricultural productivity in the Municipality.

METHODOLOGY

The Bolgatanga Municipality is located in savannah woodland, characterized by short, scattered drought-tolerant trees and grasses that are susceptible to bushfires and scorched by the sun during the long dry season. The soils in the municipality support the cultivation of millet and sorghum and are situated at longitude 0° 50' 59.99" E and latitude 10° 46' 59.99" N. It experiences an average annual rainfall of 950 mm from May/June to September/October, with hot and dry temperatures averaging 12°C in December to February and exceeding 45°C in March to April (MoFA, 2021). The selection of the Bolgatanga Municipality was based on its rural-urban dichotomy characteristics and the significance of agriculture to the majority of the population.

A cross-sectional survey design was employed to gather primary data for the study, using a multistage sampling technique to ensure representation of the population. The Bolgatanga municipality was randomly chosen from other districts in the Upper East Region known for millet and sorghum production. Subsequently, eight communities were randomly selected from fourteen millet and sorghum-growing communities within the Municipality. The required sample size from each community was determined using the Krejcie and Morgan table for sample size determination, and farmers were selected via simple random sampling using the lottery technique (Krejcie and Morgan, 1970), shown in Table 1.

Primary data was collected using interview schedules. Principal Component Analysis (PCA) conducted using SPSS was employed as the statistical method to analyse barriers to climate change adaptation. This involved validating the data adequacy (Kaiser-Meyer-Olkin technique), assessing data orthogonality and suitability using the Bartlett test of sphericity, and interpreting Eigenvalues greater than one for appropriate results interpretation (Tabachnick et al., 2013). Mean values and standard deviations were used to assess farmers' perceptions of climate change trends and the extent of adaptation strategies employed. Table 2 presents the interpretation scales for these perceptions and adaptation decisions made by the farmers.

Ethical approval and participants consent

The permission to conduct the study was approved by the Directorate of Research Innovation Consultancy in the University of Cape Coast, Ghana.

RESULTS AND DISCUSSION

Socio-economic characteristics of the cereal farmers

Sex influences the type of crop a person grows, with men more likely to engage in labor-intensive production. Therefore, it is unsurprising that there are more male cereal growers than females in the study area. This finding is consistent with research conducted by Ahmad-Yahaya et al. (2022) in Nigeria, which indicated that the majority of millet and sorghum farmers were men.

Table 1. Population and sample size of farmers in communities.

Community	Population	Sample size
Dachio	20	19
Asonge	40	36
Benkute	30	28
Kumbosigo	20	19
Zono Zore	15	14
Gambibgo	10	10
Katanga	15	14
Kantia	10	10
Total	-	150

Source: Field data.

Table 2. Interpretation of scales used for categorization of perception on changes in climatic and adaptation decisions of farmers.

Perception of farmers on climate change trend	Extent of adaptation decisions used by farmers	Numerical value of responses	Numerical value range
Very high perception	Very large extent	5	4.20 - 5.00
High perception	Large extent	4	3.40 - 4.19
Moderate perception	Moderate extent	3	2.60 - 3.39
Low perception	Small extent	2	1.80 - 2.59
Very low perception	Very small extent	1	1.0 - 1.79

Source: Field data.

Table 3. Cereal farmers' perception of climate change trends.

Climate change variable	$\bar{X}$	SD
Early beginning of rainfall	4.12	0.95
High temperature	4.27	1.01
Frequent rainfall	3.12	1.41
Incessant flood	3.02	1.30
Erratic rainfall	3.31	1.31
Decrease in rainfall	3.11	1.25
Early end of rainfall	3.82	1.18
Change in intensity of dry season	4.35	0.64
Weighted mean ($\bar{X}_w$)	3.64	1.13

Hint: $\bar{X}$ =Mean, SD=Standard deviation.

Source: Field data.

Age plays a role in a farmer's acceptance of new agricultural technology. Younger farmers are typically more willing to adopt new technologies because they are more open to taking risks. Another factor influencing farmers' adoption of agricultural technologies is their level of education. Farmers with higher levels of education are more likely to seek out information about new technologies and assess their benefits compared to older technologies. If the benefits outweigh those of the older technology, educated farmers are more inclined to adopt the new technology. The socio-economic characteristics

of cereal farmers are detailed in the Appendix.

Cereal farmers' perception of climate change trends

The results presented in Table 3 indicate that cereal farmers in the Bolgatanga municipality have a very high perception index regarding climate change, particularly concerning changes in the intensity of the dry season (4.35) and changes in temperatures (4.27). These high perception indices regarding changes in harmattan

Table 4. Extent of adaptation decisions used by farmers.

Adaptation decision	F	No	Yes	$\bar{X}$	SD
Food storage	143	2.7	95.8	3.83	1.10
Livelihood diversification	141	20.6	79.4	3.46	1.92
Creation of bunds	145	82.1	17.9	2.75	1.35
Planting improved varieties	143	31.5	68.5	3.42	1.10
Planting at the onset of rains	147	32.7	67.3	3.06	0.84
Increased pesticide use	148	43.9	56.1	3.81	5.98
Crop diversification	148	40.5	59.5	3.40	1.09
Planting trees	147	63.9	36.1	1.30	1.08
Application of inorganic fertilizer	146	48.6	51.4	2.79	1.20
Reduced tillage	146	68.5	31.5	1.40	1.37
Irrigation	145	85.5	14.5	2.63	1.24
Weighted mean ($\bar{X}_w$)				2.89	1.66

Hint: $\bar{X}$ =Mean, SD=Standard deviation, F=Frequency.
Source: Field data.

intensity may stem from the fact that weather conditions were significantly colder in the past compared to current conditions in the municipality.

Additionally, the study revealed that farmers also perceive early onset of rainfall (4.12) and early cessation of rainfall (3.82) with a high degree of awareness.

Farmers also moderately perceive erratic rainfall (3.31), frequent rainfall (3.12), decreased rainfall (3.11), and incessant floods (3.02) as climate change trends. These findings suggest that while farmers in the municipality are aware of climate change trends, they do not frequently experience significant shifts such as changes in rainfall frequency, decreased rainfall, or incessant floods. Therefore, farmers' perceptions of these climatic variables tend to be moderate.

These findings are consistent with previous studies by Amir et al. (2020), Fosu-Mensah et al. (2012), Limantol et al. (2016) and Nyang'au et al. (2021), which also found that farmers significantly perceived increases in temperature irregular rainfall patterns, and decreases in rainfall.

Extent of adaptation decisions used by farmers

Food storage (3.83), increased pesticide use (3.81), and livelihood diversification (3.46) were extensively employed by farmers. Stored food is often rationed during the lean season until it runs out or the next growing season begins (Table 4). The increase in temperature creates a favorable environment for pests, hence the need for increased pesticide use to control pest populations, which raises environmental sustainability concerns. Therefore, it would be appropriate to provide extension training and education to farmers on the optimal and efficient use of pesticides. Livelihood diversification typically involves planting different crops with varying water requirements

and harvesting periods, as well as raising animals alongside millet and sorghum farming or engaging in non-farming activities such as hunting and basket weaving.

Furthermore, improved varieties (3.42), crop diversification (3.40), early planting (3.06), bund creation (2.75), application of inorganic fertilizer (2.79), and irrigation (2.63) were moderately utilized. However, reduced tillage and tree planting were implemented to a lesser extent as adaptation strategies. The study findings support that improved crop varieties, crop diversification, fertilizer use, irrigation, and early planting were adaptation strategies employed by farmers in response to climate change (Asravor, 2023; Fadina and Barjolle, 2018; Muench et al., 2021; Paulos and Belay, 2018; Zakaria and Matsui, 2020).

Principal component analysis results on adaptation barriers

The PCA technique identified three main barriers to climate change adaptation. Personal productive resources explained 28.09% of the dataset, followed by infrastructure and support mechanisms accounting for 23.64% of the variance, and institutional barriers contributing 18.74%. Together, these factors explain approximately 71% of the total variations in barriers to climate change adaptation by cereal farmers in the semi-arid regions of northern Ghana (Table 5).

Inadequate personal financial resources (0.899), inadequate labor (0.892), and a poor land tenure system (0.766) were highly significant, indicating a strong impact on personal productive barriers. Similarly, the absence of irrigation facilities (0.847) and the ineffectiveness of indigenous strategies (0.814) had high positive loadings, underscoring their significant roles in affecting infrastructure and support mechanisms. Although the lack

Table 5. Principal component analysis results on adaptation barriers.

Barrier	Factor loadings			Communality
	1	2	3	
Inadequate personal financial resource	0.899			0.81
Inadequate labour	0.892			0.82
Poor land tenure system	0.766			0.77
Absence of irrigation facilities		0.847		0.74
Ineffectiveness of indigenous strategies		0.814		0.69
Lack of credit facilities		0.518		0.31
Irregularity of extension services			0.884	0.79
Late supply of subsidized fertilizer			0.802	0.71
Eigenvalues	2.25	1.89	1.49	
% of variance	28.09	23.64	18.74	

Loadings <.40 are omitted; N = 95.

Source: Field data.

of credit facilities (0.518) was also notable, its impact was slightly less compared to the absence of irrigation and ineffective indigenous strategies. Furthermore, the irregularity of extension services (0.884) and the late supply of subsidized fertilizer (0.802) had high positive loadings, highlighting their substantial contributions to institutional barriers.

Inadequate personal financial resources (0.899) emerged as the foremost constraint within personal productive resources and proved to be the most severe among the eight barriers hindering cereal producers' efforts to adapt to climate change. This barrier prevents farmers from acquiring labor, land, and other critical adaptation techniques necessary for greater productivity. Inadequate labor (0.892), ranked second among all barriers, affects farmers' ability to clear land of weeds and applies inputs such as fertilizer and agrochemicals in a timely manner, thereby reducing crop resilience against pests. The results also indicated that the irregularity of extension services (0.884) ranked first among institutional barriers to climate change adaptation. This irregularity often resulted in farmers lacking up-to-date information on adaptation strategies. Consequently, farmers faced challenges in maintaining vibrant Farmer-Based Organizations (FBOs), which are crucial for sourcing personal funds to purchase production inputs. Moreover, the irregularity of extension services hindered timely access to information on the distribution of subsidized fertilizer, thereby affecting crop yields. These findings align with Asravor (2023) identification of a lack of extension services as a significant barrier to adaptation.

The absence of irrigation facilities (0.847) ranked first among infrastructure and support mechanism barriers and fourth overall. This deficiency is critical for successful adaptation, especially given variable and low rainfall patterns crucial for agricultural growth and development. This finding supports Muench et al. (2021) conclusion

that inadequate irrigation infrastructure hampers effective adaptation.

Poor land tenure systems (0.766), which ranked seventh overall and third among personal productive resource barriers, exacerbated difficulties in responding to climate change, particularly in areas where land ownership was insecure and adaptation solutions required permanent changes. This finding is consistent with Nkuba et al. (2020), who argued that insecure land tenure poses a significant barrier to climate change adaptation.

Conclusion

Farmers demonstrate a high awareness of climate change trends, showing a clear understanding of the environmental challenges affecting agriculture. However, despite this awareness, their adaptation measures remain moderate, indicating that farmers are only partially implementing necessary modifications. The primary reason for this perception-action gap is the presence of significant barriers. Personal productive factors, such as insufficient financial resources, labor shortages, and land tenure issues, severely limit farmers' ability to adapt. Additionally, infrastructural and support mechanism challenges, including a lack of irrigation facilities and ineffective indigenous practices, further hinder adaptation efforts. Institutional constraints, such as irregular extension services, limited involvement of Farmer-Based Organizations, and delays in the delivery of subsidized fertilizers, also play a crucial role in limiting effective adaptation among farmers.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

- Adger WN, Barnett J, Brown K, Marshall N, O'brien K (2013). Cultural dimensions of climate change impacts and adaptation. *Nature Climate Change* 3(2):112-117.
- Ahmad-Yahaya M, Shimelis H, Nebie B, Ojiewo CO, Danso-Abbeam G (2022). Sorghum production in Nigeria: Opportunities, constraints, and recommendations. *Acta Agriculturae Scandinavica, Section B- Soil and Plant Science* 72(1):660-672.
- Amir S, Saqib Z, Khan MI, Khan MA, Bokhari SA, Zaman-ul-Haq M, Majid A (2020). Farmers' Perceptions and Adaptation Practices to Climate Change in Rain-Fed Area: A Case Study from District Chakwal, Pakistan. *Pakistan Journal of Agricultural Sciences* 57(2). <http://www.pakjas.com.pk/papers/3136.pdf>
- Asravor RK (2023). Factors Influencing Farm-Level Climate Adaptation Strategies of Smallholder Farmers in Rural Ghana. *Journal of Land and Rural Studies* 11(1):52-68.
- Balasha AM, Munyahali W, Kulumbu JT, Okwe AN, Fyama JNM, Lenge EK, Tambwe AN (2023). Understanding farmers' perception of climate change and adaptation practices in the marshlands of South Kivu, Democratic Republic of Congo. *Climate Risk Management* 39:100469.
- Boyd E, Cornforth RJ, Lamb PJ, Tarhule A, Lélé MI, Brouder A (2013). Building resilience to face recurring environmental crisis in African Sahel. *Nature Climate Change* 3(7):631-637.
- Fadina AMR, Barjolle D (2018). Farmers' adaptation strategies to climate change and their implications in the Zou Department of South Benin. *Environments* 5(1):15.
- Ford JD, Berrang-Ford L, Bunce A, McKay C, Irwin M, Pearce T (2015). The status of climate change adaptation in Africa and Asia. *Regional Environmental Change* 15(5):801-814.
- Fosu-Mensah BY, Vlek PLG, MacCarthy DS (2012). Farmers' perception and adaptation to climate change: A case study of Sekyedumase district in Ghana. *Environment, Development and Sustainability* 14(4):495-505.
- Furtak K, Wolińska A (2023). The impact of extreme weather events as a consequence of climate change on the soil moisture and on the quality of the soil environment and agriculture - A review. *Catena* 231:107378.
- Kithiia J (2011). Climate change risk responses in East African cities: Need, barriers and opportunities. *Current Opinion in Environmental Sustainability* 3(3):176-180.
- Krejcie RV, Morgan DW (1970). Determining Sample Size for Research Activities. *Educational and Psychological Measurement* 30(3):607-610.
- Kumasi TC, Antwi-Agyei P, Obiri-Danso K (2019). Small-holder farmers' climate change adaptation practices in the Upper East Region of Ghana. *Environment, Development and Sustainability* 21:745-762.
- Limantol AM, Keith BE, Azabre BA, Lennartz B (2016). Farmers' perception and adaptation practice to climate variability and change: A case study of the Veia catchment in Ghana. *SpringerPlus* 5:1-38.
- Mahendra-Dev S (2012). Climate change, rural livelihoods and agriculture (focus on food security) in Asia-Pacific region.
- Mendelsohn R (2014). The impact of climate change on agriculture in Asia. *Journal of Integrative Agriculture* 13(4):660-665.
- MoFA (2021). Bolgatanga Municipality. Accessed 22nd March, 2024 from <https://mofa.gov.gh/site/sports/district-directorates/upper-east-region/257-bolgatanga-municipal>
- Muench S, Bavorova M, Pradhan P (2021). Climate change adaptation by smallholder tea farmers: A case study of Nepal. *Environmental Science and Policy* 116:136-146.
- Nasir MJ, Khan AS, Said-Alam SA (2018). Climate change and agriculture: An overview of farmers perception and adaptations in Balambat Tehsil, District Dir Lower, Pakistan. *Sarhad Journal of Agriculture* 34:85-92.
- Nkuba MR, Chanda R, Mmopelwa G, Adedoyin A, Mangheni MN, Lesolle D, Kato E (2020). Barriers to Climate Change Adaptation Among Pastoralists: Rwenzori Region, Western Uganda. In: W. Leal Filho, N. Oguce, D. Ayal, L. Adeleke, and I. Da Silva (Eds.), *African Handbook of Climate Change Adaptation*. Springer International Publishing pp. 1-18.
- Nyang'au JO, Mohamed JH, Mango N, Makate C, Wangeci AN (2021). Smallholder farmers' perception of climate change and adoption of climate smart agriculture practices in Masaba South Sub-county, Kisii, Kenya. *Heliyon* 7(4). [https://www.cell.com/heliyon/pdf/S2405-8440\(21\)00892-6.pdf](https://www.cell.com/heliyon/pdf/S2405-8440(21)00892-6.pdf)
- Pasquini L, Cowling RM, Ziervogel G (2013). Facing the heat: Barriers to mainstreaming climate change adaptation in local government in the Western Cape Province, South Africa. *Habitat International* 40:225-232.
- Paulos A, Belay S (2018). Farmers' perception of climate change and adaptation strategies in the Dabus watershed, North-West Ethiopia. *Ecological Processes* 7(1). <https://search.proquest.com/openview/ff1c1d88d95659bb655a7ef3706b3a50/1?pq-origsite=gscholarandcbl=2034775>
- Ruiz I, Faria SH, Neumann MB (2020). Climate change perception: Driving forces and their interactions. *Environmental Science and Policy* 108:112-120.
- Santos FD, Ferreira PL, Pedersen JST (2022). The climate change challenge: A review of the barriers and solutions to deliver a Paris solution. *Climate* 10(5):75.
- Tabachnick BG, Fidell LS, Ullman JB (2013). Using multivariate statistics, 6th edn Boston. Ma: Pearson.
- Van der Linden S (2015). The social-psychological determinants of climate change risk perceptions: Towards a comprehensive model. *Journal of Environmental Psychology* 41:112-124.
- Zakaria AR, Matsui K (2020). Smallholder rice farmers' adaptation capacity to climate change in the Bawku zone of Ghana. *About the Journal. International Journal of Environmental Science and Development* 11(5):258-262.

Appendix.

Variable	Categories	F	%		SD
Sex	Male	104	69.8	41.8	11.0
	Female	45	30.2		
Age	Youth (18-35)	52	35.1		
	Adult (36-60)	87	58.8		
	Elderly (+60)	9	6.1		
Farming experience	>10 (less experienced)	33	22.9		
	+10 years (more experienced)	111	77.1		
Educational level	No formal education	71	47.7		
	Formal education	78	52.3		
Marital status	Married	118	78.7		
	Single	32	21.3		
Household size	1-6	108	72.0		
	+6	42	28.0		
Farm size (ha)	1-3	109	75.17		
	+3	36	24.83		
Types of crops	Millet	87	58.0		
	Sorghum	63	42.0		
Type of farming system	Continuous cropping	147	98.0		
	Fallowing	3	2.0		
FBO association	Yes	29	19.7		
	No	118	80.3		
Main source of income	Farming	88	58.7		
	Non-farm activity	62	41.3		