Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

From Awareness to Action: What Drives Climate Change Adaptation among Smallholder Farmers in Ghana's Nkoranza South Municipality

Elijah Mamoa

mamoaelijah@gmail.com

Kwame Nkrumah University of Science and Technology

Simon Kwabena Dankyi

Kwame Nkrumah University of Science and Technology

Michael Osei Asibey

Kwame Nkrumah University of Science and Technology

Owusu Amponsah

Kwame Nkrumah University of Science and Technology

Research Article

Keywords: climate change, adaptation strategies, smallholder farmers, adaptive capacity, Social Cognitive Theory, Nkoranza South Municipality

Posted Date: November 10th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11145504/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

Climate change continues to threaten smallholder agriculture in sub-Saharan Africa, where rain-fed systems are highly sensitive to rainfall variability. This study examines the factors that shape the adoption of climate change adaptation strategies among smallholder farmers in the Nkoranza South Municipality of Ghana, a transitional agro-ecological zone that has received little farmer-level attention. Using a convergent mixed-methods design, the study combined a survey of 368 crop farming households with focus group discussions and key informant interviews, and it analysed the evidence through an integrated framework that joins Social Cognitive Theory with the concept of adaptive capacity. Adoption was widespread, reported by about four in five farmers, but concentrated in low-cost and labour-based practices such as organic manure application and adjusted planting dates, while capital-intensive options such as irrigation and agroforestry recorded low uptake. Awareness of specific adaptation strategies was more strongly associated with adoption than general awareness of climate change. Access to agricultural loans and to government or NGO support showed the strongest bivariate associations among the institutional factors, but in a multivariable logistic regression only loan access retained an independent effect, and awareness of specific strategies remained the strongest predictor of adoption. Male farmers and younger, less experienced farmers adopted at higher rates in bivariate tests, and the qualitative evidence traced these differences to unequal access to information, labour, and decision making rather than to willingness. The results indicate that adaptation in the study area depends jointly on practical knowledge of adaptation options and on the credit that helps farmers act on that knowledge.

1. Introduction

Agriculture remains one of the most important sectors in the global economy, accounting for about 4% of global gross domestic product and more than a quarter of gross domestic product in most developing countries (Baffour-Ata et al., 2023). It underpins incomes, poverty reduction, and food security for the large share of the world's poor who live in rural areas and depend on farming for their livelihoods (Baffour-Ata et al., 2023). This role is increasingly threatened by conflict, the spread of crop pests and diseases, and rising climate variability, which weighs most heavily on sub-Saharan Africa, where production systems are highly sensitive to climatic change and least able to absorb it (Nhemachena et al., 2020; Calzadilla et al., 2013).

In Ghana, agriculture employs more than half of the workforce and is the main source of survival for rural households, with smallholder farmers making up about 80% of the agricultural labour force (Baffour-Ata et al., 2023). Most of these farmers practise rain-fed agriculture, which ties their livelihoods closely to rainfall patterns that are becoming less predictable (Abubakari & Abubakari, 2015). Traditional planting and harvesting calendars are losing their reliability, raising the risk of crop loss from floods and droughts, and many smallholders still lack the climate information services that would guide decisions on land preparation, planting, input use, and harvesting (Antwi & Antwi-Agyei, 2023; Etwire, 2020). The resulting

exposure threatens both national development and the Sustainable Development Goals tied to poverty reduction and food security (Dapilah, 2023).

The consequences of climate change for agriculture are already visible. Changing weather patterns disrupt farming systems and reduce productivity, and smallholder farmers in developing countries are the most exposed because they depend on climate-sensitive resources and have limited capacity to respond (Grigorieva et al., 2023). Beyond direct effects on output, climate change alters the distribution of pests and diseases and depresses farm incomes and household well-being (Adzawla & Alhassan, 2021; Etwire, 2020). These pressures fall on food crops that are central to the national diet, including maize, which accounts for more than half of Ghana's cereal production and is highly sensitive to rainfall and temperature stress (Barimah, 2014).

Adaptation is widely recognised as the central policy response to this exposure, since it reduces vulnerability and cushions livelihoods against changes that are already under way (Gebremedhin et al., 2025). In Ghana's agricultural sector, the available options range from improved farming practices and technologies such as drought-tolerant varieties, irrigation, and crop diversification, to institutional and off-farm measures, alongside indigenous practices such as organic manure use, agroforestry, mulching, and crop rotation (Naazie et al., 2024; Zakaria et al., 2020). Whether these options are taken up, however, depends less on their technical merit than on how farmers perceive climatic risk and, on the resources, they can bring to bear (Grigorieva et al., 2023).

Despite a growing body of work on adaptation in Ghana (Awuni et al., 2023; Acheampong et al., 2023; Opoku Mensah et al., 2025), most studies report the strategies farmers use without isolating the local-level factors that decide whether a given farmer adopts, and the evidence is concentrated in the northern savannah. There is little farmer-level analysis of how socio-economic attributes, institutional access, and perceptions jointly shape adoption in climatically sensitive areas, and almost none for the Nkoranza South Municipality, where smallholder systems in the transitional zone are highly exposed to rainfall variability. This study addresses that gap by examining the factors that shape the adoption of climate change adaptation strategies among smallholder farmers in the municipality, with the aim of generating evidence that can support more specific and better targeted policy than adaptation in general.

2. Literature Review and Conceptual Framework

2.1 Theoretical Framework

This study is grounded in Social Cognitive Theory (SCT) developed by Bandura (1986), which explains behaviour through reciprocal interaction among personal or cognitive, behavioural, and environmental factors. This process, termed reciprocal determinism, means that each factor both influences and is influenced by the others. Building on Social Learning Theory (Bandura, 1977), SCT has been applied to technology adoption, health behaviour, and agricultural innovation (Schunk & DiBenedetto, 2020). Its

relevance here is that adaptation is understood as a decision shaped by farmers' knowledge, experience, capabilities, and surrounding conditions rather than by climate exposure alone.

Three cognitive constructs are particularly relevant. Self-efficacy refers to beliefs about one's ability to perform a specific action (Bandura, 1997), outcome expectations concern the anticipated consequences of a practice, and observational learning involves acquiring behaviour by observing others and their outcomes (Bandura, 1986; van Valkengoed et al., 2021). Together, these constructs suggest that climate-change awareness alone may not lead to adaptation. Farmers must also recognise viable responses, expect useful outcomes, and perceive themselves as capable of implementing them.

SCT also directs attention to the environmental conditions that enable or constrain behaviour. For smallholders, these include both biophysical conditions and institutional factors such as extension, credit, farmer organisations, and external support. Access to these resources is uneven and shaped by structural conditions including gender, wealth, and institutional reach (Bryan et al., 2009; Below et al., 2012). Because SCT gives less attention to material and structural constraints, this study complements it with the adaptive capacity literature. Smit and Wandel (2006) define adaptive capacity in terms of a household's ability to adjust to climate stress through available assets and institutional access, while Adger (2006) links this capacity to the distribution of resources and entitlements. Together, these perspectives suggest that adoption depends on both farmers' cognitive readiness and their access to the resources needed to act.

The integrated framework guides four expectations. First, awareness of specific adaptation options should be more closely associated with adoption than general climate-change awareness. Second, direct experience of climate-related losses should strengthen adoption by increasing perceived risk and shaping outcome expectations. Third, access to credit, extension, and institutional support should be associated with adoption by reducing resource constraints. Fourth, socio-demographic differences such as gender and farming experience should partly reflect differences in access to assets and information rather than operate as fixed determinants of behaviour. The following review examines the conceptual and empirical literature relevant to these expectations.

2.2 Coping and Adaptation as Distinct Responses

A distinction that runs through the analysis is the difference between coping and adaptation. Eriksen et al. (2005) define coping as the short term and often reactive adjustments that households make to survive a shock, and separate these from adaptation, which involves durable changes that reduce vulnerability over the longer term. The distinction matters for measurement, because a household that reduces the number of meals it eats during a poor season is coping rather than adapting, even when such a response is reported alongside genuine adaptation (Antwi-Agyei & Stringer, 2021). Treating the two as equivalent inflates the apparent level of adaptation and hides the extent to which households remain exposed.

A second distinction, between incremental and transformational adaptation, clarifies the composition of the practices farmers use. Kates et al. (2012) describe incremental adaptation as adjustments that extend existing practices, such as changing planting dates or applying manure, and transformational adaptation as more fundamental shifts, such as taking up irrigation or moving into new activities that require larger investment and institutional support. Reading an adoption profile through these two distinctions shows that a high headline adoption rate can coexist with limited progress toward durable resilience.

2.3 Farmers' Perceptions of Climate Change

Perception is central to adaptation because behavioural responses depend on how people observe and interpret climatic change. Van Valkengoed et al. (2021) describe climate change perception as a multifaceted construct that combines awareness, beliefs, attitudes, and concern about the causes and consequences of change, and Jellason et al. (2019) show that it is shaped by individual characteristics, past experience, access to information, and the social and cultural setting in which farmers work. Because perception is socially situated, farmers exposed to the same conditions may read a given signal differently according to their knowledge, values, and tolerance of risk (Grigorieva et al., 2023).

A consistent finding in the literature, however, is that perception does not translate directly into action. Deressa et al. (2009) and Bryan et al. (2009) show for Ethiopia and South Africa that many farmers who perceive climate change do not adapt, because perception must be joined by the knowledge and the means to respond, and Mertz et al. (2009) report the same disjunction in the Sahel, where farmers weigh climatic and non-climatic pressures together. Nielsen and Reenberg (2010) add that cultural and social factors can block adaptation even where risk is clearly perceived. These studies point to a two-step structure in which farmers must first perceive a risk and then hold an actionable understanding of how to respond to it, a structure that the present study examines directly through separate measures of climate change awareness and adaptation strategy awareness.

2.4 Effects of Climate Change on Smallholder Agriculture

Climate change and variability reduce agricultural productivity and undermine the livelihoods of smallholder farmers, both directly through extreme weather and indirectly through shifts in the distribution of pests and diseases (Etwire, 2020; Adzawla & Alhassan, 2021). Ghana is particularly sensitive to these effects because of its dependence on rain-fed subsistence systems, and the problem is compounded across Africa by weak climate information and limited support, which leaves the continent more exposed than most other regions (Odame Appiah et al., 2018). Within Ghana, vulnerability is often described as greatest in the northern savannah, yet the transitional zone in which this study is located is also exposed, because it depends on a bimodal rainfall regime whose timing has become less reliable. Baffour-Ata et al. (2023) document irregular precipitation and rising temperatures in the Bono East Region between 2011 and 2021, and Nyantakyi-Frimpong and Bezner Kerr (2015) caution that climate is only one of several stresses acting on smallholder systems, so that the effects seen at farm level reflect the interaction of climatic change with soil degradation, input costs, and market

access. The transitional zone therefore warrants attention in its own right rather than as a milder version of the north.

2.5 Adaptation Strategies and the Determinants of Adoption

Adaptation refers to the adjustments that reduce the vulnerability of people or systems to the actual or expected effects of climatic change, spanning behavioural, technological, and institutional responses (Bartlett & Dedekorkut-Howes, 2023; Sadiq et al., 2019). Effective adaptation depends first on awareness, since farmers must recognise a changing climate before they can respond, but awareness alone is a weak predictor of action, and the more decisive question is what determines whether a farmer who is aware actually adopts (Bartlett & Dedekorkut-Howes, 2023). Because the aim of this study is to explain adoption rather than to catalogue practices, the determinants of adoption require closer attention than the strategies themselves. The empirical literature groups these determinants into cognitive factors such as risk perception and knowledge, socio-demographic factors such as age, gender, education, and experience, and institutional or resource factors such as access to credit, extension, and farmer organisations (Deressa et al., 2009; Below et al., 2012; Gebru et al., 2020). Below et al. (2012) find that household-level socio-economic variables explain only part of the variation in adaptation and that institutional access often matters more, a result echoed by Bryan et al. (2009), who identify credit and information as the binding constraints in Ethiopia and South Africa. For Ghana, Zakaria et al. (2020) and Gebru et al. (2020) show that training and extension contact raise adoption while the cost of improved inputs suppresses it. This body of work frames adoption as the outcome of an interaction between what farmers know, who they are, and what they can access, which is the interaction the present study sets out to examine in the transitional zone. Figure 1 summarises the climate adaptation practices most commonly reported for smallholder farmers in the literature, several of which recur among the strategies examined in Section 4.

Source: Quarshie et al. (2023)

3. Study Setting and Research Methods

3.1 Study Setting

The study was conducted in Nkoranza South Municipality of the Bono East Region of Ghana. The municipality was selected because agriculture is a major livelihood and is dominated by smallholder farming, making it suitable for examining climate-change adaptation among farmers (Nkoranza South Municipal Assembly, 2023). It covers approximately 923 km², lies between longitudes 1°10'W and 1°55'W and latitudes 7°20'N and 7°55'N, and shares boundaries with Nkoranza North, Techiman, Offinso North, and Ejura Sekyedumase (GSS, 2010; Nkoranza South Municipal Assembly, 2023). Its population increased substantially from 21,715 in 2000 to more than 100,000 in 2010, increasing pressure on land and other natural resources.

The municipality lies within Ghana's transitional zone between the forest and savanna woodland belts and is underlain by the Voltaian sandstone formation. Its forest- and savanna-derived soils support the cultivation of maize, yam, cassava, plantain, cocoyam, groundnut, cowpea, and vegetables, with cotton and tobacco produced in some areas. However, continuous cultivation without adequate nutrient restoration, bushfires, and slash-and-burn practices have contributed to soil degradation, erosion, and declining fertility, with implications for agricultural productivity and farm incomes (Nkoranza South Municipal Assembly, 2023). These pressures are particularly relevant in a municipality dominated by smallholders, many of whom cultivate less than one hectare and depend heavily on rain-fed agriculture. The interaction of smallholder dependence, environmental degradation, and climatic variability provides a relevant setting for examining climate-change adaptation and its implications for livelihood sustainability. Figure 2 shows the location of Nkoranza South Municipality within Ghana and the ten communities included in the study.

Source: Author's construct (2025)

3.2 Research Approach

The study used a mixed-methods approach with a convergent parallel design, combining quantitative and qualitative evidence to examine determinants of climate-change adaptation among smallholder farming households. Quantitative data were collected through a household survey in ten communities selected by multistage sampling to capture diverse environmental and socio-economic settings. Household heads or main farming decision-makers were interviewed, with one household randomly selected where compounds contained multiple households. A sample of 383 households was drawn from an estimated 9,077 using Slovin's formula at a 5% margin of error, with proportional allocation across communities and largest-remainder rounding (Table 1). Of these, 368 were successfully interviewed, giving a 96.1% response rate.

Three focus group discussions were conducted using purposive and snowball sampling, with attention to age, gender, and environmental setting. Each group had eight participants with at least ten years of farming experience and involvement in maize, cassava, yam, or pepper production (Manoranjitham et al., 2007). Key informant interviews were conducted with the Municipal Agricultural Extension Officer and representatives of farmer-based organisations. Interviews and discussions were recorded with consent, transcribed, and thematically analysed.

The survey covered demographic, awareness, institutional, financial, and informational factors. Demographic variables included age, education, sex, farming experience, and income. Awareness measures captured recognition of climatic changes involving temperature, rainfall, drought, and pests and diseases. Institutional and financial measures covered extension support, credit and farming loans, farmer-organisation membership, and government or NGO support, while informational measures captured extension access, visit frequency, and training. Quantitative data were analysed using SPSS 27, R 4.3.3, Python 3 with statsmodels, and Excel, while qualitative data were analysed thematically in NVivo.

Analysis proceeded in two stages. Pearson's chi-square tests examined associations between adoption status and categorical variables, with Phi reported for two-by-two tables and Cramér's V for larger tables. Independent-samples t-tests compared continuous variables between adopters and non-adopters. Binary logistic regression was then used to assess whether these associations persisted after adjustment. Adoption was coded 1 for farmers who had adopted at least one strategy and 0 for those who had adopted none. Predictors were entered in three blocks: socio-demographic and farm resources (sex, age, farming experience, education, cultivated land, and irrigation); cognitive factors (climate-change awareness and strategy awareness); and institutional and informational factors (farming loan access, government or NGO support, training received, and information and training frequency).

Credit facility access was excluded because of its overlap with farming loan access (Spearman ρ = .60). Extension access was available for only 305 respondents and was therefore represented through information and training frequency. Household income was excluded from the main model because 12 reported values above GH₵1 million could not be verified. A sensitivity analysis using log income with these observations excluded produced the same pattern, and income was not significant (AOR = 1.36, p = .063). Changes in model chi-square and loss of fit after removing each block were used to assess the contribution of each determinant group.

Model fit was assessed using likelihood-ratio chi-square, Nagelkerke R^2, the Hosmer-Lemeshow test, classification accuracy, and the area under the ROC curve (Hosmer et al., 2013). Variance inflation factors were all below 3.0, indicating no serious multicollinearity. Listwise deletion left 296 farmers, including 56 non-adopters, giving approximately 4.7 non-adoption events per coefficient. Because this falls below the five-to-nine events per variable identified by Vittinghoff and McCulloch (2007), the model was re-estimated using Firth's penalised likelihood (Firth, 1993). The direction and significance of all coefficients were unchanged, so the maximum-likelihood estimates are reported.

Internal consistency was assessed using Cronbach's alpha for all multi-item Likert scales. The information and training scale had acceptable reliability (α = .78), while perceived temperature and rainfall change showed high reliability (α = .93). Cultural factors (α = .92), environmental barriers (α = .86), technological barriers (α = .90), market-access barriers (α = .92), supply-chain barriers (α = .92), and perceived effectiveness of adaptation strategies (α = .80) all exceeded the .70 threshold recommended by Nunnally and Bernstein (1994). Single-item dichotomous measures of awareness, institutional access, and adoption were not subjected to alpha testing. The reliability results indicate that the multi-item measures were internally consistent and could be treated as coherent constructs in the analysis.

Table 1
Sampled communities and allocation of the household sample.

Community	Population	No. of households	Allocated sample
Nkwabeng	10,521	2,630	111
Bonsu	5,301	1,325	56
Dotobaa	4,660	1,165	49
Asonkwa	3,140	785	33
Nsugum	1,304	326	14
John Krom	1,752	438	18
Asempanaye	715	179	8
Mpem	910	228	10
Kontonso	3,404	851	36
Prusu	4,601	1,150	48
Total	**36,308**	**9,077**	**383**

Note. The sample is allocated in proportion to the number of households and rounded by the largest-remainder method. Of the 383 allocated households, 368 were interviewed.

Source: GSS (2021)

4. Results

4.1 Demographic Characteristics of Respondents

Most respondents were male (57.9%). Formal education was limited, with 30.7% having no formal schooling, 44.6% basic education, 22.0% secondary education, and 2.7% tertiary education. Farming experience was fairly evenly distributed, with 30.7% reporting ten years or less, 22.8% between eleven and twenty years, 24.2% between twenty-one and thirty years, and 22.3% more than thirty years. Most respondents were married (79.3%).

4.2 Adoption Status and Adaptation Strategies

The adaptation strategies reported by farmers are classified here as either indigenous or conventional, and this distinction is applied consistently in the analysis. Indigenous strategies are locally developed, low-cost practices rooted in farmers' own knowledge, transmitted socially within the community, and reliant on locally available resources rather than external inputs. Examples include mixed cropping and intercropping, organic manure, changing planting dates in response to observed rainfall, and traditional soil and water conservation. Conventional strategies are externally introduced, science-based or market-based practices that depend on formal inputs, technologies, or institutional support, and typically require

purchased inputs, credit, or extension advice. Examples include improved or drought-tolerant seed, inorganic fertiliser, agrochemicals, and small-scale irrigation. The distinction matters because the two categories differ in cost, in the resources they require, and in who is able to adopt them, so the analysis examines not only how many farmers adapt but which type of strategy they use.

Table 2
Climate change adaptation adoption status.

Adaptation adopted	Frequency	Percentage (%)
Yes	294	79.9
No	74	20.1
Source: Field Survey (2025)		

As Table 2 shows, 79.9% of smallholder crop farmers in the municipality had adopted at least one adaptation strategy, while 20.1% had not. Among the 294 adopters, a clear stratification of strategies is evident in Fig. 3. Organic manure and compost (77.6%) and changing planting dates (74.1%) were by far the most widely used. Both require no special external inputs and draw on resources already available on the farm and on traditional knowledge. Crop diversification (31.0%) and intercropping (24.8%) fell in the middle tier, followed by drought or flood resistant varieties (23.5%), shifting cultivation (22.1%), and crop rotation (18.7%). Improved seeds (10.5%) and rainwater harvesting (8.8%) were used by about one in ten farmers, and agroforestry (6.1%) was the least adopted. Adoption declines systematically from low-cost indigenous practices, through conventional agronomic practices, to capital-intensive or infrastructure-dependent options, a gradient examined further in the discussion.

Source: Field Survey (2025)

The qualitative evidence is consistent with this profile. Focus group participants highlighted fertiliser application, organic manure, and calendar adjustment as first-resort strategies, and one participant foregrounded fertiliser while noting its dependence on the rains.

“Fertilizer application is widely accepted as a mechanism to cope with the shocks of climate change. Unfortunately, the fertilizer application can sometimes fail due to extreme climate events such as drought, storms etc.” (FGD participant, Nkoranza South Municipality, 2025)

4.3 Climate Change Awareness and Observed Climate Risks

Awareness of climate change was high. Of 366 valid responses, 348 farmers (95.1%) reported awareness of climate change, 314 of 361 (87.0%) were aware of adaptation strategies, and 304 of 362 (84.0%) acknowledged that awareness influences adoption. Concerning local experience, 342 farmers (94.0%) had noticed changes in climatic conditions. The changes most often observed were higher

temperatures (71.9%), irregular rainfall (70.8%), drought (62.2%), and pests and diseases (53.6%), while floods were less commonly reported (15.6%), as shown in Table 3.

Table 3
Climate change awareness and observed climate risks among smallholder farmers.

Variable	Valid N	Response	Frequency	Valid %
Climate change awareness	366	Yes	348	95.1
Adaptation awareness	361	Aware	314	87.0
Awareness affects adoption	362	Yes	304	84.0
Noticed climate change	364	Yes	342	94.0
Irregular rainfall	360	Yes	255	70.8
Droughts	360	Yes	224	62.2
Floods	360	Yes	56	15.6
Rising temperatures	360	Yes	259	71.9
Pests and diseases	360	Yes	193	53.6
Other observed effects	360	Yes	18	5.0

Source: Author's Construct (2025)

Tests of association in Table 4 show a strong link between awareness and adoption. Climate change awareness was significantly associated with adoption, $\chi^2(1) = 19.174$, $p < .001$, Phi = .230, but awareness of adaptation strategies was much the stronger correlate, $\chi^2(1) = 120.968$, $p < .001$, Phi = .583, which indicates that knowing the strategies is more closely tied to adoption than general awareness of climate change. The belief that awareness affects adoption was also significant, $\chi^2(1) = 24.477$, $p < .001$, Phi = .262, as was having noticed climatic change, $\chi^2(1) = 32.408$, $p < .001$, Phi = .300. Among specific indicators, rising temperatures and pests and diseases were significantly associated with adoption, whereas irregular rainfall, drought, and floods were not.

Table 4
Association between climate awareness, perceived climate risks, and adoption.

Variable	Test result	Effect size	Interpretation
Climate change awareness	$\chi^2(1) = 19.174$, $p < .001$	Phi = .230	Significant
Adaptation awareness	$\chi^2(1) = 120.968$, $p < .001$	Phi = .583	Strongest association
Awareness affects adoption	$\chi^2(1) = 24.477$, $p < .001$	Phi = .262	Significant
Noticed climate change	$\chi^2(1) = 32.408$, $p < .001$	Phi = .300	Significant
Irregular rainfall	$\chi^2(1) = 0.067$, $p = .795$	Phi = .014	Not significant
Droughts	$\chi^2(1) = 2.775$, $p = .096$	Phi = .088	Not significant
Floods	$\chi^2(1) = 2.221$, $p = .136$	Phi = .079	Not significant
Rising temperatures	$\chi^2(1) = 18.689$, $p < .001$	Phi = .229	Significant
Pests and diseases	$\chi^2(1) = 20.333$, $p < .001$	Phi = .239	Significant
Other observed effects	$\chi^2(1) = 8.659$, $p = .003$	Phi = .156	Significant
Source: Author's Construct (2025)			

The qualitative evidence gives this awareness an experiential grounding. Across the extension officer interview, the focus groups, and the interviews with farmer-based organisation leaders, participants expressed a detailed, observational understanding of change built on decades of farming. One focus group participant described the severity of heat.

“The way the sunshine is scorchy, it is so severe that anything that you plant can be dried and indeed burnt by the severe sunshine. We are largely maize farmers and this year, there are a lot of maize farms that have been dried and burnt completely beyond recovery due to the severity of the scorchy sunshine. This destruction is very disturbing to the farming community, not a joke.” (FGD participant, Nkoranza South Municipality, 2025)

Others emphasised the breakdown of the traditional bimodal calendar that had long structured planting.

“There is a drastic shift in rainfall particularly in terms of timing (start/stop). For instance, we are in June and we ought to have received rains 5 times or more but no rain. Sometime it takes 3 weeks with no rain.” (FGD participant, Nkoranza South Municipality, 2025)

The extension officer confirmed the institutional dimension of this shift, and a farmer-based organisation leader linked it directly to falling yields.

“Currently, you see by now we should have been preparing for minor season. The major season normally start around March and so there is now a shift in rainfall pattern. For instance, this year the rains started last month, May but previously by April the rain would have been there and farmers would have been

planting their fields. For here, the rainfall pattern has totally changed." (Agricultural Extension Officer, Nkoranza South Municipality, 2025)

4.4 Socio-Demographic and Economic Factors Associated with Adoption

Bivariate tests in Table 5 identify sex and irrigation access as significant correlates, while education and land ownership were not. More male farmers adopted (84.0%, 178 of 212) than female farmers (73.5%, 111 of 151), $\chi^2(1) = 5.936$, $p = .015$, Phi = .128. Farmers with irrigation access adopted at a higher rate (85.2%) than those without (72.8%), $\chi^2(1) = 8.353$, $p = .004$, Phi = .153. The t-tests show that adopters were significantly younger than non-adopters (45.40 against 49.77 years, $t(361) = 2.439$, $p = .015$) and less experienced (20.63 against 25.67 years, $t(345) = 2.720$, $p = .007$), and reported higher annual incomes (GH₵57,800 against GH₵44,200, $t(361) = -2.683$, $p = .008$). Land size did not differ significantly between the two groups. Of the variables entered in the multivariable model in Section 4.6, only farming experience retained a significant effect once the cognitive and institutional variables were held constant.

Table 5
Socio-demographic and farm-resource characteristics associated with adoption.

Variable	Key comparison	Test result	Effect size
Sex	Female 73.5%; Male 84.0%	$\chi^2(1) = 5.936$, $p = .015$	Phi = .128
Education	Association not significant	$\chi^2(3) = 6.666$, $p = .083$	V = .135
Own farmland	No 80.9%; Yes 78.4%	$\chi^2(1) = 0.283$, $p = .595$	Phi = .028
Irrigation access	No 72.8%; Yes 85.2%	$\chi^2(1) = 8.353$, $p = .004$	Phi = .153
Age	Non-adopters 49.77; adopters 45.40	$t(361) = 2.439$, $p = .015$	d = .318
Farming experience	Non-adopters 25.67; adopters 20.63	$t(345) = 2.720$, $p = .007$	d = .366
Land size	Non-adopters 7.41; adopters 8.66	$t(340) = -1.383$, $p = .167$	d = − .185
Income (annual, GH₵)	Non-adopters 44,200; adopters 57,800	$t(361) = -2.683$, $p = .008$	d = − .353

Note. Chi-square tests exclude respondents with a missing value on either variable. Effect sizes are Phi for two-by-two tables, Cramér's V for education, and Cohen's d for t-tests. One expected count in the education table was below five, and a Monte Carlo exact test gave the same result (p = .083).

Source: Author's Construct (2025)

The qualitative evidence explains the gender gap through the institutional mechanisms that reproduce it. The extension officer set out the dominant mechanism.

“Gender plays a role in adoption of adaptation or otherwise. In our traditional set up, women are usually not encouraged to attend meeting, men do on their behalf. So, if a meeting is to train farmers on adaptation techniques, she will not benefit from that training and subsequently adapt unlike the man. Also, it is the man who heads the patriarchal family leadership; head of the household and head of the family farm. Therefore, any adaptation innovations are introduced to the head of the farm and he is most likely to understand, appreciate and adopt adaptation than the woman.” (AEO, Nkoranza South Municipality, 2025)

Farmer-based organisation leaders confirmed this at the household level, framing the gap in terms of both information exclusion and physical capacity.

“A man can adopt adaptation because they do the adaptation themselves compared to females who would have to depend on labor or a second-hand person to ensure successful adaptation. For instance, if you have to raise mounts as an adaptive strategy, men can do it themselves but women cannot. Also, raising yam stakes can be done by men but women cannot.” (Farmer Based Organization Representative Interview, Nkoranza South Municipality, 2025)

On age and experience, one leader offered an experience-based view of adoption competence that runs against the survey result.

“Someone who have had experience in farming for long, can easily accept adaptation than a beginner because the beginner has no idea about the past history of crop yields, rainfall calendar.” (FBO representative Interview, Nkoranza South Municipality, 2025)

4.5 Institutional, Information, and Financial Factors Associated with Adoption

Among the institutional and financial conditions, farming loan access and government or NGO support showed the strongest bivariate associations with adoption. As Table 6 shows, access to a farming loan was associated with adoption for 93.9% of farmers who had it against 68.2% of those who did not, $\chi^2(1) = 36.993$, $p < .001$, Phi = .321, and government or NGO support with 93.3% against 69.7%, $\chi^2(1) = 31.192$, $p < .001$, Phi = .295. Credit access, extension access, and training received were each significantly associated with adoption, while technical support before adoption was not.

Table 6
Institutional and financial factors associated with adoption.

Variable	Key comparison	Test result	Effect size
Training received	No 75.1%; Yes 86.1%	$\chi^2(1) = 6.888$, $p = .009$	Phi = .139
Extension access	No 63.0%; Yes 80.8%	$\chi^2(1) = 10.339$, $p = .001$	Phi = .186
Technical support before adoption	No 94.5%; Yes 98.3%	$\chi^2(1) = 1.480$, $p = .224$	Phi = .073
Government/NGO support	No 69.7%; Yes 93.3%	$\chi^2(1) = 31.192$, $p < .001$	Phi = .295
Credit access	No 71.1%; Yes 86.5%	$\chi^2(1) = 12.536$, $p < .001$	Phi = .189
Farming loan access	No 68.2%; Yes 93.9%	$\chi^2(1) = 36.993$, $p < .001$	Phi = .321
Source: Author's Construct (2025)			

The analysis also compared adopters and non-adopters on three composite scores capturing the frequency and depth of their engagement with information, training, and advisory services, reported in Table 7. On every measure adopters scored significantly higher. They recorded a higher information and training frequency score (M = 2.20, SD = 0.738) than non-adopters (M = 1.53, SD = 0.667), $t(361) = -7.175$, $p < .001$, a higher extension frequency score (M = 2.11 against M = 1.32), $t(358) = -4.797$, $p < .001$, and a higher information and advisory access score (M = 2.94 against M = 2.18), Welch $t(131.029) = -6.795$, $p < .001$, with Mann-Whitney U tests confirming all three differences. These results indicate that the regularity and intensity of exposure to information and advisory services, and not merely whether farmers can reach them, distinguishes adopters from non-adopters.

Table 7
Information, training, and advisory access scores by adoption status.

Variable	Non-adopters (M ± SD)	Adopters (M ± SD)	Test result
Information/training frequency	1.53 ± 0.667	2.20 ± 0.738	$t(361) = -7.175$, $p < .001$
Extension frequency	1.32 ± 1.165	2.11 ± 1.291	$t(358) = -4.797$, $p < .001$
Information/advisory access	2.18 ± 0.822	2.94 ± 0.995	Welch $t(131.03) = -6.795$, $p < .001$
Source: Author's Construct (2025)			

Farmers' own accounts of motivation and finance reinforce this picture. Adaptation was prompted mainly by previous losses (64.6%) and by peer influence (59.1%), with extension advice cited less often (26.8%). Finance came overwhelmingly from personal savings (92.6%) and family support (53.4%), and radio and television were the leading source of information (81.8%), ahead of extension officers (45.3%) and fellow farmers (38.2%). The interviews located the limits of adaptation in the cost of the most effective options, as one farmer explained.

“The adaptation strategy that I have not practiced is irrigation but I want it. Why have you not adopted? I do not have the capital to buy the irrigation equipment and do not also have any land near the water sources.” (FBO representative Interview, Nkoranza South Municipality, 2025)

4.6 Multivariable Analysis of Adoption

Table 8 reports the binary logistic regression of adoption on socio-demographic, cognitive, and institutional variables entered together. The full model was significant, $\chi^2(12) = 119.21$, $p < .001$, explained substantial variation in adoption (Nagelkerke $R^2 = .534$), fitted the data adequately (Hosmer-Lemeshow $\chi^2(8) = 3.68$, $p = .884$), correctly classified 89.2% of farmers, and showed good discrimination (AUC = .884). The model therefore provides a basis for assessing whether the bivariate associations in Tables 4 to 7 persist after adjustment.

Awareness of specific adaptation strategies was the strongest predictor. Farmers with such awareness had about 38 times higher odds of adoption than those without it (AOR = 37.95, 95% CI [11.39, 126.46], $p < .001$), while general climate-change awareness was not significant (AOR = 0.93, $p = .947$). Among institutional variables, only farming loan access remained significant (AOR = 6.56, 95% CI [1.53, 28.04], $p = .011$). Government or NGO support was no longer significant after adjustment (AOR = 1.59, $p = .506$), consistent with its strong overlap with loan access (Spearman $\rho = .70$). Information and training frequency remained positive but did not reach significance (AOR = 1.81, $p = .081$).

Training received showed a negative adjusted association (AOR = 0.17, 95% CI [0.06, 0.49], $p = .001$), despite a positive crude association (OR = 1.43). Given its correlation with loan access, government or NGO support, information frequency, and irrigation ($\rho = .52–.62$), this estimate likely reflects the profile of trained farmers after controlling for related forms of access and may also indicate that training was targeted towards farmers who had not yet adopted. It should therefore not be interpreted as evidence that training discourages adoption. Among socio-demographic variables, only farming experience remained significant, with each additional year associated with about 5% lower odds of adoption (AOR = 0.95, $p = .024$). Sex, age, education, land size, and irrigation access were not significant after adjustment, suggesting that their bivariate associations may operate through awareness and institutional access.

The block-wise results reinforce the relative contribution of the determinant groups. Socio-demographic and farm-resource variables alone explained little variation (Nagelkerke $R^2 = .151$). Adding the cognitive variables increased this to .425, $\chi^2(2) = 61.72$, $p < .001$, while adding institutional and informational variables increased it further to .534, $\chi^2(4) = 28.43$, $p < .001$. Removing the cognitive block produced a larger loss in fit ($\chi^2(2) = 53.53$, $p < .001$) than removing the institutional block ($\chi^2(4) = 28.43$, $p < .001$), while the socio-demographic block was not jointly significant in the full model ($\chi^2(6) = 7.79$, $p = .254$). Overall, specific strategy awareness contributed more to explaining adoption than institutional access, although loan access retained an independent association..

Table 8
Binary logistic regression of the adoption of climate change adaptation strategies.

Predictor	B	SE	AOR	95% CI for AOR	p	Crude OR
Socio-demographic and farm resources						
Sex (1 = male)	0.648	0.460	1.91	0.78, 4.71	.159	1.50
Age (years)	0.032	0.026	1.03	0.98, 1.09	.215	0.98
Farming experience (years)	-0.056	0.025	0.95	0.90, 0.99	.024	0.97**
Education level (0 = none to 3 = tertiary)	-0.211	0.293	0.81	0.46, 1.44	.473	0.81
Land under cultivation (acres)	-0.025	0.040	0.98	0.90, 1.06	.536	1.04
Irrigation access (1 = yes)	0.165	0.541	1.18	0.41, 3.40	.761	2.04*
Cognitive						
Climate change awareness (1 = aware)	-0.076	1.141	0.93	0.10, 8.67	.947	4.61*
Adaptation-strategy awareness (1 = aware)	3.636	0.614	37.95	11.39, 126.46	< .001	39.00***
Institutional and informational						
Farming loan access (1 = yes)	1.880	0.741	6.56	1.53, 28.04	.011	5.17***
Government/NGO support (1 = yes)	0.466	0.701	1.59	0.40, 6.29	.506	5.40***
Training received (1 = yes)	-1.750	0.534	0.17	0.06, 0.49	.001	1.43
Information/training frequency (1–3)	0.591	0.339	1.81	0.93, 3.51	.081	3.32***
Constant	-2.779	1.327	0.06		.036	

Note. N = 296 (240 adopters, 56 non-adopters). B = coefficient, SE = standard error, AOR = adjusted odds ratio, CI = confidence interval. Crude odds ratios come from single-predictor models on the same 296 farmers (* $p < .05$, ** $p < .01$, *** $p < .001$). Model $\chi^2(12) = 119.21$, $p < .001$; -2 log likelihood = 167.93; Nagelkerke $R^2 = .534$; Hosmer-Lemeshow $\chi^2(8) = 3.68$, $p = .884$; correctly classified = 89.2%; area under the curve = .884; all variance inflation factors < 3.0.

Source: Author's Construct (2025)

5. Discussion

The findings are read here through the framework set out in Section 2, which treats adoption as the joint product of cognition, behaviour, and an environment that enables or constrains action. Organising the discussion around the three determinants shows where the results confirm existing scholarship, where they extend it, and where they run against it.

5.1 Awareness, risk perception, and the awareness to action gap

Awareness of climate change was almost universal at 95.1%, yet awareness of adaptation strategies was the stronger correlate of adoption and carried a much larger effect size. This confirms the argument of Harvey et al. (2018) and Rodríguez-Cruz and Niles (2021) that awareness by itself does not produce action, and it sharpens that argument by separating two kinds of awareness and showing that procedural knowledge, not general recognition, is what tracks adoption. The multivariable model shows that this pattern is not an artefact of confounding, since adaptation-strategy awareness remained the strongest predictor after socio-demographic and institutional factors were held constant, while general climate change awareness had no independent effect (Table 8). In the terms of Social Cognitive Theory, general awareness establishes that a risk exists, whereas awareness of specific strategies carries the outcome expectations and self-efficacy that Bandura (1986) places closest to behaviour. The finding that rising temperature and pests were associated with adoption while irregular rainfall, drought, and floods were not extending this reading, since farmers appear to act on hazards for which a feasible on-farm response exists and to hold back where the main response, irrigation, lies beyond their means. Perception therefore predicts adoption only when it is matched by an option that is both actionable and affordable, which qualifies the emphasis on risk perception found in much of the perception literature (Deressa et al., 2009; Mertz et al., 2009).

5.2 The adoption hierarchy and the distinction between coping and adaptation

Adoption was widespread but concentrated in low-cost and labour-based practices such as organic manure and adjusted planting dates, while capital-intensive options such as irrigation, agroforestry, and rainwater harvesting recorded low uptake. This gradient supports the finding of Antwi-Agyei and Stringer (2021) that input cost and weak extension are among the main barriers to climate-smart practice in Ghana, and it fits the wider preference for affordable options under resource scarcity (Grigorieva et al., 2023). The account of households reducing the number of daily meals shows why the coping and adaptation distinction of Eriksen et al. (2005) matters in practice, because a response that only protects short term survival was reported within the same narrative as genuine adaptation. Read through Kates et al. (2012), the profile is overwhelmingly incremental, so that the high headline rate overstates progress toward the transformational change that would reduce dependence on rainfall. The study extends the Ghanaian evidence by showing that the composition of adoption, and not only its level, is governed by the resource base.

5.3 Gender, experience, and access to adaptation resources

Male farmers adopted at a higher rate than female farmers, and the qualitative evidence located this gap in unequal access to training, information, and labour rather than in any difference in willingness to adapt. This confirms Acheampong et al. (2023) and Antwi and Antwi-Agyei (2023), who attribute gendered adaptation in Ghana to socio-economic and institutional differences, and it fits the broader argument of Jost et al. (2016) that gender shapes adaptation through access to resources and decision-making authority. The multivariable results are consistent with this reading, because the sex difference was no longer significant once awareness and institutional access were held constant (Table 8). The negative association between farming experience and adoption, which persisted in the multivariable model, confirms Gebru et al. (2020) for Ethiopia and aligns with Dessart et al. (2019), who show that established routines and risk aversion can hold back adoption even where knowledge is high. The claim by experienced farmers that they are more competent, set against their lower measured adoption, illustrates the gap between self-efficacy and enactment that the framework anticipates. Gender therefore acts on adoption through the environmental pole of access rather than as a personal attribute, which guards the analysis against treating a structural inequality as a fixed characteristic of women. The experience effect, by contrast, persisted after access was controlled, which places it closer to the behavioural pole of established routines that Dessart et al. (2019) describe than to unequal access.

5.4 Institutional and financial access as an enabling condition

Among the institutional variables, agricultural loans and government or NGO support showed the strongest bivariate associations with adoption, followed by information, training, and extension contact. This is consistent with Bryan et al. (2009) and Below et al. (2012), who identify credit and institutional access as important determinants of adaptation, and with Zakaria et al. (2020) and Ferdousi et al. (2024), who link training and extension to adoption. The multivariable results qualify this pattern. Specific strategy awareness, rather than institutional access, was the strongest net predictor, and the cognitive block explained more variation in adoption than the institutional block. Among institutional variables, only loan access retained an independent effect, suggesting that government or NGO support, training, and information exposure overlap substantially with other forms of access. The third expectation in Section 2.1 is therefore only partly supported. Practical knowledge appears to be the proximate determinant of adoption, while credit functions as an enabling condition.

Credit was not a necessary condition for adoption. Among farmers aware of specific strategies, 81.8% without a loan adopted compared with 95.4% of those with one. Among those unaware of any strategy, adoption was only 13.2% among farmers without a loan. This pattern reflects the dominance of relatively low-cost practices such as organic manure and adjusted planting dates, which can be implemented with limited external finance, while credit increases the scope for action. Through the lens of reciprocal determinism, the findings suggest that cognitive and environmental factors operate together rather than

hierarchically. Knowledge creates the basis for action, while access to financial and institutional resources increases the likelihood that knowledge can be translated into adoption (Bandura, 1986; Smit & Wandel, 2006; Adger, 2006).

Two limitations qualify this interpretation. Strategy awareness and adoption were measured simultaneously, so their association may partly reflect farmers learning about strategies through adoption. The negative adjusted coefficient for training may likewise reflect training being targeted at farmers who had not yet adopted. Finally, the heavy reliance on personal savings indicates that adaptation remains largely financed within households, which may constrain the scale and range of strategies that farmers can implement.

5.5 Contribution of the study

Read together across the three determinants, the findings position adaptation in the study area as a rational response to constrained opportunity rather than a matter of farmer willingness. The study contributes to the Ghanaian literature in three ways. It shows that procedural awareness rather than general awareness drives adoption, it demonstrates that the composition of adoption is set by the resource base and that reported rates conflate coping with adaptation, and it finds that practical knowledge of adaptation options and access to credit each shape adoption independently, with knowledge carrying the greater weight, in a transitional zone that has received little farmer-level attention. These contributions follow from applying an integrated cognitive and adaptive capacity framework to primary data, and they imply that policy should pair strategy-specific extension, which builds the knowledge most closely tied to adoption, with wider access to credit, since each has an effect on adoption that the other does not capture.

6. Conclusion

This study examined the factors shaping climate-change adaptation among smallholder farmers in Nkoranza South Municipality using survey, focus group, and key informant evidence interpreted through Social Cognitive Theory and adaptive capacity. Adaptation was widespread but uneven. Although climate-change awareness was almost universal, knowledge of specific strategies, rather than general awareness, was more closely associated with adoption. Farmers were more likely to adopt responses to hazards for which affordable on-farm options existed. Adoption was concentrated in low-cost indigenous practices, while capital-intensive options were less common, and some reported responses reflected coping rather than sustained adaptation. Gender differences were linked to unequal access to information, labour, and decision-making rather than willingness to adapt, while greater farming experience was associated with lower adoption after adjustment for other factors. In the multivariable model, specific strategy knowledge remained the strongest predictor, while agricultural credit was the only institutional factor with an independent effect.

The findings suggest that adaptation depends on both practical knowledge of available responses and the financial capacity to implement them. Near-universal awareness of climate change therefore does

not translate into uniform adoption where knowledge of specific options and access to finance remain uneven. This has implications for adaptation policy and extension. Climate-awareness campaigns alone are unlikely to be sufficient. Extension should emphasise practical knowledge of specific strategies and be complemented by improved access to agricultural credit, more consistent extension and training, gender-inclusive information platforms, and investment in irrigation and other infrastructure that can support higher-cost adaptation. The study is limited by its focus on one municipality and its cross-sectional design, which restricts inference about changes over time and the direction of the relationship between strategy knowledge and adoption. Future studies could examine these relationships across agro-ecological zones and follow farmers across successive seasons to assess whether improved knowledge and resource access translate into sustained adaptation.

Declarations

Author Contribution

Author contributions: EM and OA contributed to the study conception and design. Data collection was performed by EM. Data analysis was performed by EM, OA and SKD. MOA contributed to the interpretation of results and to the framing of the discussion. The first draft of the manuscript was written by EM, and all authors commented on previous versions. All authors read and approved the final manuscript.

Acknowledgement

Acknowledgements: The authors are grateful to the smallholder farmers of Nkoranza South Municipality who gave their time to the survey and focus group discussions, to the Municipal Agricultural Extension Officer and staff of the Department of Agriculture, Nkoranza South Municipal Assembly, and to the leadership of the farmer-based organisations in the study communities for their cooperation during fieldwork.

Data Availability

Data availability: Datasets will be made available upon request.

References

1. Abubakari F, Abubakari F (2015) Determinants of household food security and climate change impacts on agriculture in Ghana. Academic Research Journal of Agricultural Science and Research
2. Acheampong PP, Yeboah S, Adabah R, Asibuo JY, Nchanji EB, Opoku M, Toywa J, Lutomia CK (2023) Gendered perceptions and adaptations to climate change in Ghana: What factors influence the

choice of an adaptation strategy? Front Sustainable Food Syst 7:1091812. https://doi.org/10.3389/fsufs.2023.1091812

3. Adger WN (2006) Vulnerability Global Environ Change 16(3):268–281. https://doi.org/10.1016/j.gloenvcha.2006.02.006
4. Adzawla W, Alhassan H (2021) Effects of climate adaptation on technical efficiency of maize production in Northern Ghana. Agricultural Food Econ 9:14. https://doi.org/10.1186/s40100-021-00183-7
5. Antwi K, Antwi-Agyei P (2023) Intra-gendered perceptions and adoption of climate-smart agriculture: Evidence from smallholder farmers in the Upper East Region of Ghana. Environ Challenges 12:100736. https://doi.org/10.1016/j.envc.2023.100736
6. Antwi-Agyei P, Stringer LC (2021) Improving the effectiveness of agricultural extension services in supporting farmers to adapt to climate change: Insights from northeastern Ghana. Clim Risk Manage 32:100304. https://doi.org/10.1016/j.crm.2021.100304
7. Awuni S, Adarkwah F, Ofori BD, Purwestri RC, Bernal H, D. C., Hajek M (2023) Managing the challenges of climate change mitigation and adaptation strategies in Ghana. Heliyon 9(5):e15491. https://doi.org/10.1016/j.heliyon.2023.e15491
8. Baffour-Ata F, Atta-Aidoo J, Said RO, Nkrumah V, Atuyigi S, Analima SM (2023) Building the resilience of smallholder farmers to climate variability: Using climate-smart agriculture in Bono East Region. Ghana Heliyon 9(11):e21815. https://doi.org/10.1016/j.heliyon.2023.e21815
9. Bandura A (1977) Social learning theory. Prentice Hall
10. Bandura A (1986) Social foundations of thought and action: A social cognitive theory. Prentice Hall
11. Bandura A (1997) Self-efficacy: The exercise of control. W. H. Freeman
12. Barimah PT (2014) Impact of climate change on maize production in Ghana: A review. J Agricultural Sci Appl 3(2):89–93. https://doi.org/10.14511/jasa.2014.030402
13. Bartlett JA, Dedekorkut-Howes A (2023) Adaptation strategies for climate change impacts on water quality: A systematic review of the literature. J Water Clim Change 14(3):651–675. https://doi.org/10.2166/wcc.2022.279
14. Below TB, Mutabazi KD, Kirschke D, Franke C, Sieber S, Siebert R, Tscherning K (2012) Can farmers' adaptation to climate change be explained by socio-economic household-level variables? Glob Environ Change 22(1):223–235. https://doi.org/10.1016/j.gloenvcha.2011.11.012
15. Bryan E, Deressa TT, Gbetibouo GA, Ringler C (2009) Adaptation to climate change in Ethiopia and South Africa: Options and constraints. Environ Sci Policy 12(4):413–426. https://doi.org/10.1016/j.envsci.2008.11.002
16. Calzadilla A, Zhu T, Rehdanz K, Tol RSJ, Ringler C (2013) Economywide impacts of climate change on agriculture in Sub-Saharan Africa. Ecol Econ 93:150–165. https://doi.org/10.1016/j.ecolecon.2013.05.006

17. Cronbach LJ (1951) Coefficient alpha and the internal structure of tests. Psychometrika 16(3):297–334. https://doi.org/10.1007/BF02310555
18. Dapilah F (2023) Contract farming and smallholder farmers' resilience to climate change and variability in northern Ghana. Reg Envriron Chang 23:118. https://doi.org/10.1007/s10113-023-02151-x
19. Deressa TT, Hassan RM, Ringler C, Alemu T, Yesuf M (2009) Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Glob Environ Change 19(2):248–255. https://doi.org/10.1016/j.gloenvcha.2009.01.002
20. Dessart FJ, Barreiro-Hurlé J, van Bavel R (2019) Behavioural factors affecting the adoption of sustainable farming practices: A policy-oriented review. Eur Rev Agric Econ 46(3):417–471. https://doi.org/10.1093/erae/jbz019
21. Eriksen SH, Brown K, Kelly PM (2005) The dynamics of vulnerability: Locating coping strategies in Kenya and Tanzania. Geographical J 171(4):287–305. https://doi.org/10.1111/j.1475-4959.2005.00174.x
22. Etwire PM (2020) The impact of climate change on farming system selection in Ghana. Agric Syst 179:102773. https://doi.org/10.1016/j.agsy.2019.102773
23. Ferdousi R, Islam MA, Mamun M (2024) Role of extension service for climate change adaptation in agriculture: A systematic review for developing countries. Journal of the Bangladesh Agricultural University, 22(4), 490–496. https://doi.org/10.3329/jbau.v22i4.78863
24. Firth D (1993) Bias reduction of maximum likelihood estimates. Biometrika 80(1):27–38. https://doi.org/10.1093/biomet/80.1.27
25. Gebremedhin GG, Gebrekidan TK, Weldemariam AK, Weldemariam NG, Berhe DH (2025) Unveiling the challenges and opportunities of climate change mitigation through climate-smart agriculture in East Africa: A systematic review. Int J Clim Change Strateg Manag. https://doi.org/10.1108/IJCCSM-09-2024-0159
26. Gebru GW, Ichoku HE, Phil-Eze PO (2020) Determinants of smallholder farmers' adoption of adaptation strategies to climate change in Eastern Tigray National Regional State of Ethiopia. Heliyon 6(7):e04356. https://doi.org/10.1016/j.heliyon.2020.e04356
27. Ghana Statistical Service (GSS) (2010) Nkoranza South Municipality. Ghana Statistical Service
28. Ghana Statistical Service (GSS) (2021) [INSERT exact title, e.g., 2021 Population and Housing Census: Nkoranza South Municipality]. Ghana Statistical Service
29. Grigorieva E, Livenets A, Stelmakh E (2023) Adaptation of agriculture to climate change: A scoping review. Climate 11(10):202. https://doi.org/10.3390/cli11100202
30. Harvey CA, Saborio-Rodríguez M, Martinez-Rodríguez MR, Viguera B, Chain-Guadarrama A, Vignola R, Alpizar F (2018) Climate change impacts and adaptation among smallholder farmers in Central America. Agric Food Secur 7:57. https://doi.org/10.1186/s40066-018-0209-x
31. Hosmer DW, Lemeshow S, Sturdivant RX (2013) Applied logistic regression (3rd ed.). Wiley. https://doi.org/10.1002/9781118548387

32. Jellason NP, Baines RN, Conway JS, Ogbaga CC (2019) Climate change perceptions and attitudes to smallholder adaptation in northwestern Nigerian drylands. Social Sci 8(2):31. https://doi.org/10.3390/socsci8020031
33. Jost C, Kyazze F, Naab J, Neelormi S, Kinyangi J, Zougmore R, Aggarwal P, Bhatta G, Chaudhury M, Tapio-Bistrom M-L, Nelson S, Kristjanson P (2016) Understanding gender dimensions of agriculture and climate change in smallholder farming communities. Climate Dev 8(2):133–144. https://doi.org/10.1080/17565529.2015.1050978
34. Kates RW, Travis WR, Wilbanks TJ (2012) Transformational adaptation when incremental adaptations to climate change are insufficient. Proceedings of the National Academy of Sciences, 109(19), 7156–7161. https://doi.org/10.1073/pnas.1115521109
35. Manoranjitham SD, Jacob KS, Abraham S (2007) Focus group discussion. Nurs J India 98(6):125–127
36. Menard S (2002) Applied logistic regression analysis (2nd ed.). Sage. https://doi.org/10.4135/9781412983433
37. Mertz O, Mbow C, Reenberg A, Diouf A (2009) Farmers' perceptions of climate change and agricultural adaptation strategies in rural Sahel. Environ Manage 43(5):804–816. https://doi.org/10.1007/s00267-008-9197-0
38. Naazie GK, Agyemang I, Tampah-Naah AM (2024) Characterization of urban agriculture and farmers' climate change adaptation: The case of urban Wa. Ghana Discover Sustain 5:227. https://doi.org/10.1007/s43621-024-00227-0
39. Nhemachena C, Nhamo L, Matchaya G, Nhemachena CR, Muchara B, Karuaihe ST, Mpandeli S (2020) Climate change impacts on water and agriculture sectors in southern Africa: Threats and opportunities for sustainable development. Water 12(10):2673. https://doi.org/10.3390/w12102673
40. Nielsen JØ, Reenberg A (2010) Cultural barriers to climate change adaptation: A case study from Northern Burkina Faso. Glob Environ Change 20(1):142–152. https://doi.org/10.1016/j.gloenvcha.2009.10.002
41. Nkoranza South Municipal Assembly (2023) Programme-based composite budget estimates for 2023 of Nkoranza South Municipal Assembly. Composite Budget 2023–2026.
42. Nunnally JC, Bernstein IH (1994) Psychometric theory, 3rd edn. McGraw-Hill
43. Nyantakyi-Frimpong H, Bezner Kerr R (2015) The relative importance of climate change in the context of multiple stressors in semi-arid Ghana. Glob Environ Change 32:40–56. https://doi.org/10.1016/j.gloenvcha.2015.03.003
44. Odame Appiah D, Akondoh ACK, Tabiri RK, Donkor AA (2018) Smallholder farmers' insight on climate change in rural Ghana. Cogent Food Agric 4(1):1436211. https://doi.org/10.1080/23311932.2018.1436211
45. Opoku Mensah S, Osei-Acheampong B, Jacobs B, Cunningham R, Akoto AB (2025) Smallholder farmers' climate change adaptation in Ghana: A systematic literature review and future directions. J Environ Manage 384:125598. https://doi.org/10.1016/j.jenvman.2025.125598

46. Quarshie PT, Abdulai A, Abdulai S, Antwi-Agyei P, Fraser EDG (2023) Why formal climate adaptation strategies fail in sub-Saharan Africa: Ignoring adapters' agency in the case of smallholding agriculture farming practices in Bono East Region of Ghana. Clim Resil Sustain 2(4):e53. https://doi.org/10.1002/cli2.53
47. Rodríguez-Cruz LA, Niles MT (2021) Awareness of climate change's impacts and motivation to adapt are not enough to drive action: A study of Puerto Rican farmers. PLoS ONE 16(1):e0244512. https://doi.org/10.1371/journal.pone.0244512
48. Sadiq MA, Kuwornu JKM, Al-Hassan RM, Alhassan SI (2019) Assessing maize farmers' adaptation strategies to climate change and variability in Ghana. Agriculture 9(5):90. https://doi.org/10.3390/agriculture9050090
49. Schunk DH, DiBenedetto MK (2020) Motivation and social cognitive theory. Contemp Educ Psychol 60:101832. https://doi.org/10.1016/j.cedpsych.2019.101832
50. Smit B, Wandel J (2006) Adaptation, adaptive capacity and vulnerability. Glob Environ Change 16(3):282–292. https://doi.org/10.1016/j.gloenvcha.2006.03.008
51. van Valkengoed AM, Steg L, Perlaviciute G (2021) Development and validation of a climate change perceptions scale. J Environ Psychol 76:101652. https://doi.org/10.1016/j.jenvp.2021.101652
52. Vittinghoff E, McCulloch CE (2007) Relaxing the rule of ten events per variable in logistic and Cox regression. Am J Epidemiol 165(6):710–718. https://doi.org/10.1093/aje/kwk052
53. Zakaria A, Azumah SB, Appiah-Twumasi M, Dagunga G (2020) Adoption of climate-smart agricultural practices among farm households in Ghana: The role of farmer participation in training programmes. Technol Soc 63:101338. https://doi.org/10.1016/j.techsoc.2020.101338

Figures

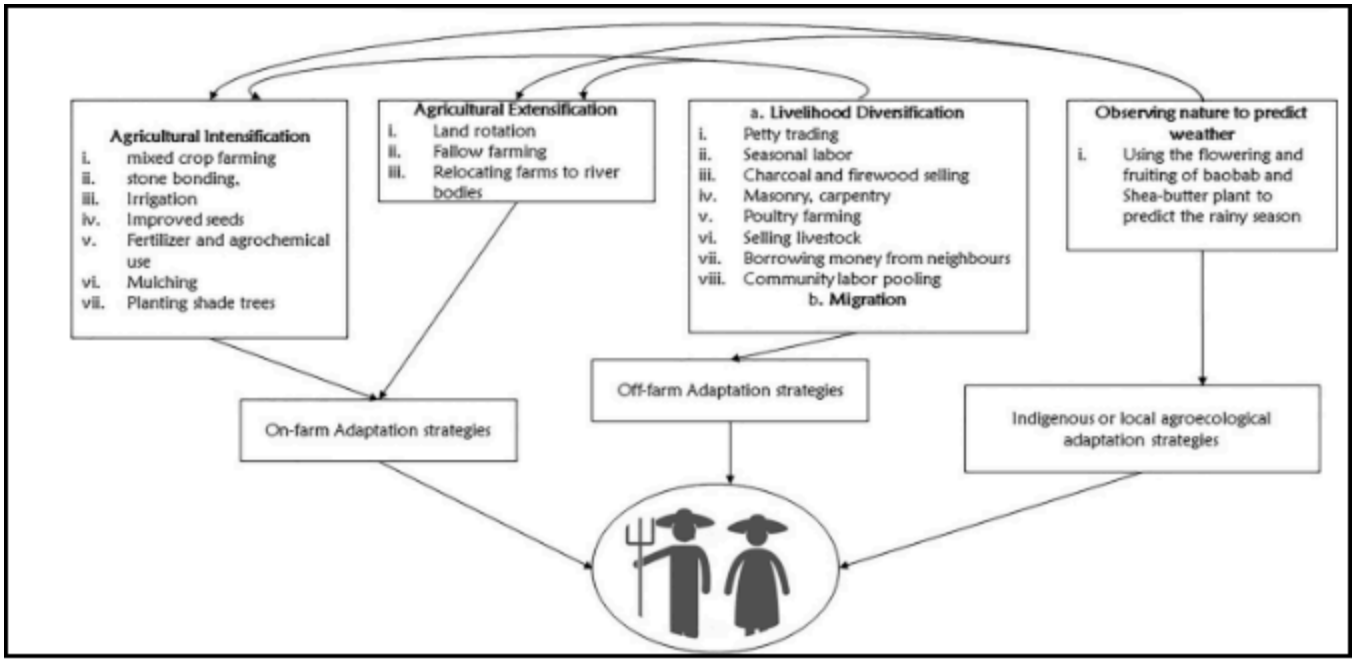


Figure 1

Climate adaptation practices of smallholder farmers.

Source: Quarshie et al. (2023)

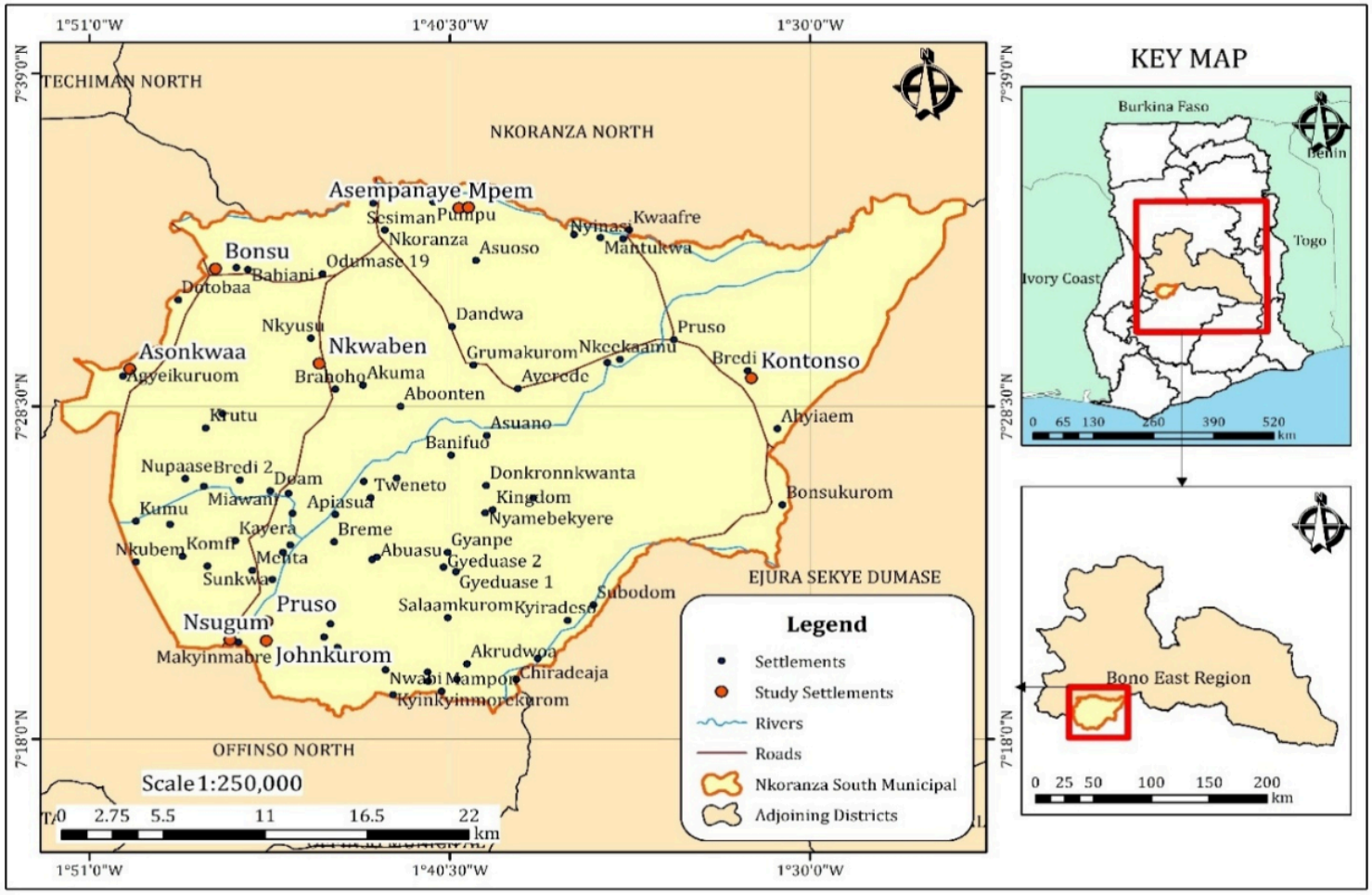


Figure 2

Map of the study area.

Source: Author's construct (2025)

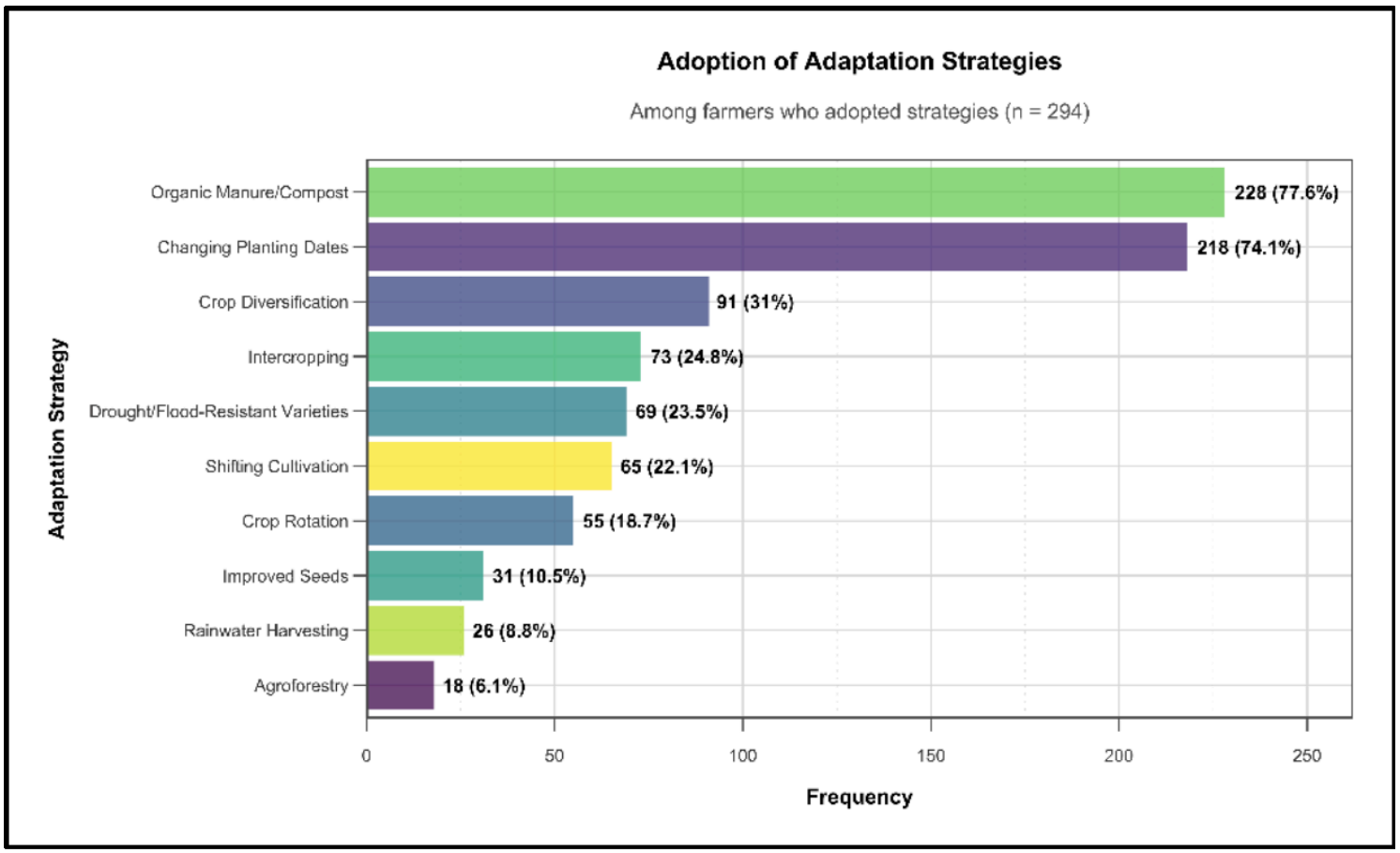


Figure 3

Adoption of individual climate change adaptation strategies among adopting smallholder farmers (n = 294).

Source: Field Survey (2025)