Heliyon 9 (2023) e19656

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Farmers response to climate variability and change in rainfed farming systems: Insight from lived experiences of farmers

Enoch Yeleliere [a,*], Philip Antwi-Agyei [a], Lawrence Guodaar [b]

[a] Department of Environmental Science, College of Science, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
[b] Department of Geography and Rural Development, College of Humanities and Social Sciences, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

ARTICLE INFO

Keywords:
Climate variability
Coping
Adaptation
Food security

ABSTRACT

Climate adaptation, while urgent, is complicated by a slew of unknowns and uncertainties through insufficient scholarship. This study addresses these slews of unknowns surrounding local adaptation to climate change and associated determinants among rainfed smallholder farmers in rural Ghana. We utilized a mixed-method approach to collect primary data from 410 households, 15 key informants and 10 focus group participants coupled with meteorological data from the Ghana Meteorological Agency, Accra (GMet). Results from meteorological analysis from 1989 to 2020 and farmers' perceptions showed a consistent pattern exemplifying a temperature rise, and a decline in rainfall pattern in the study area over the period. Rainfed smallholder farmers employed multiple coping strategies including—cognitive restructuring, resource seeking, experiential avoidance, expressive coping, capital disinvestment and relying on social networks to deal with current and future climate shocks. Also, key adaptation interventions implemented by rainfed smallholder farmers based on lived experiences include farm and crop management, soil and water conservation, conservation agricultural practices, smart-farming practices and cropping decisions, livelihood diversification and indigenous knowledge application. Market access, access to climate information/services, access to extension services, use of indigenous knowledge and practice, risk perception, and government support, livestock ownership, asset ownership, credit access, and farm insurance significantly increase rainfed smallholder farmers' decision to cope/adapt to climate variability in rural Ghana. However, improved soil fertility and farm labour significantly influenced rainfed smallholder farmers' adaptation response but not coping. The findings have implications for developing effective adaptation interventions to build resilient agricultural systems and sustainable livelihood in rainfed farming areas.

1. Introduction

Climate change is global in nature with complicated occurrences involving interconnected local, national, and regional circumstances that provoke severe and intensifying social, economic, and environmental consequences [1,2]. The Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) offers irresistible scientific evidence of the changing climate and the risk it has on humanity, livelihoods, and critical infrastructure particularly in the 21st century [3]. Global temperatures have reached alarming levels in the last decade coupled with rising sea levels and erratic rainfall patterns leading to extreme variability and climatic events

* Corresponding author.
E-mail address: enochyeleliere.ye@gmail.com (E. Yeleliere).

https://doi.org/10.1016/j.heliyon.2023.e19656
Received 3 October 2022; Received in revised form 26 August 2023; Accepted 29 August 2023
Available online 1 September 2023

(such as floods, drought, windstorms, and heatwaves) [4,5]. This continues to disrupt society's cohesion and pose a significant threat to agricultural livelihoods in sub–Saharan Africa (SSA), where most households are exposed to food and nutritional insecurities [6,7]. Agricultural productivity in SSA is characterised by complex choices due to an increase in extreme events, population growth, urbanisation, land use pressures, institutional and technical developments which put governments and societies in a position where they must make difficult decisions about agricultural production [8]. Due to this intricacy, decision-makers are confronted with the challenge of defining and prioritizing trade-offs and synergies of climate change relevant to agriculture. Despite this, agriculture is expected to offer more and various food varieties to meet the expanding food needs while guaranteeing ecological sustainability.

There is broad consensus that SSA must increase agricultural productivity while reducing the environmental impacts across scales for improved social outcomes [6,9,10], as this is contingent on achieving the Nationally Determined Contributions (NDCs) and the United Nations Sustainable Development Goals (particularly Goal 1-no poverty, Goal 2-achieve food security and improved nutrition, and Goal 13-Climate action) [7]. However, the West Africa enclave of SSA is projected to experience a 10%–40% decline in crop yields and the growing season will shrink by 20% on average by 2050 [9,11]. This will likely exacerbate food and nutritional securities, cause income and consumption losses, intensify poverty levels, threaten rural livelihoods [12], and, in most rural contexts, cause the depletion of productive assets to control consumption [13]. In SSA, agriculture is the main source of livelihood for over 60% of the workforce [14]. These projections, combined with lower crop yields, hinder the region's progress in reducing poverty and ensuring food security. As such, multiple strategies are spiritedly promoted with varying emphasis on responding to current and anticipated changes including the use of conservational agricultural practices, external inputs, and agroecological principles, improved agronomic practices, livelihood diversification, and soil management practices [15,16].

In light of the escalating climate crises, national and municipal governments, particularly in Ghana appear to champion multiple strategies through policies, programmes, and plans for resilient systems [13]. Notable examples include the National Climate Change Master Plan Action Programmes for implementation (2015–2020), the National Adaptation Policy Plan Framework (2018), the Nationally Determined Contributions (2015), the National Climate Change Policy (2013), the National Climate Change Adaptation Strategy (2012) etc [13]. These policies/plans are not realising the desired outcomes in tackling climate change in the local context. This could be because of the lack involvement and participation of all relevant stakeholders to incorporate their views and priorities particularly the local people who are the recipient/main victims of climate disaster or extremes and are exposed to the local climatic conditions and realities. Adaptation responses that encompasses local vulnerabilities, needs, capacities and actionable evidence and

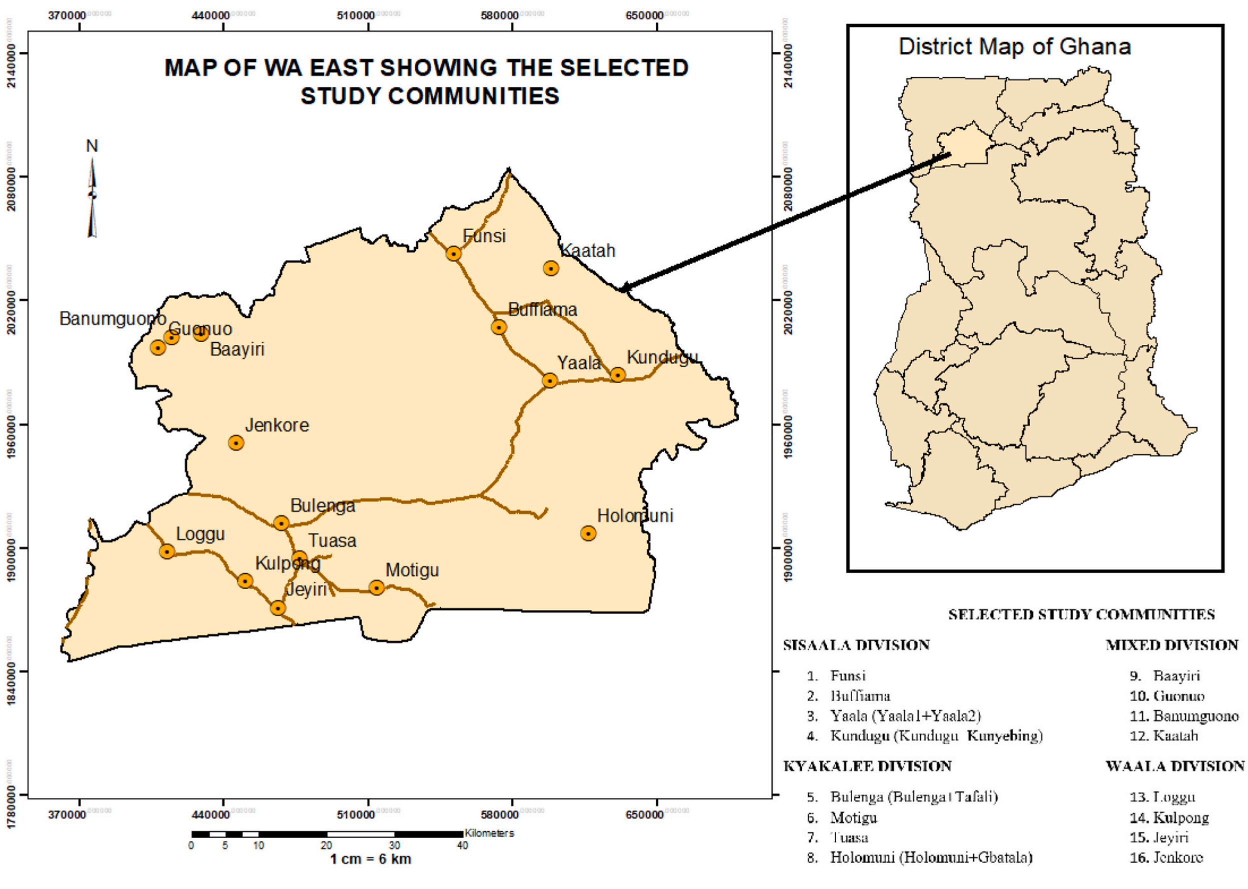

Fig. 1. Location of study communities.
Source: Author's construct (2022)

experience tend to be more successful [17]. If properly planned and executed, locally led adaptation intervention prioritise farmers' livelihood by utilizing local resources, expertise, and practises, and provide the local people's capacity to influence adaptation activities and promote collaborative and participatory action against the brunt of climate variability for resilient agricultural systems [18,19]. Promoting local adaptation action through a participatory and all-inclusive process can produce democratic, equitable, and context-specific solutions to climate crises at all levels.

Taking action to adapt to climate risks is crucial and needs to be done urgently [19]. However, some many unknown factors and uncertainties make this process rather complicated. One of the reasons for these uncertainties is that current studies on climate variability do not provide enough information about the risks at a local level. Also, climate adaptation scholarship undermines the experiences of rainfed smallholder farmers who are already dealing with the upshots of climate change and the complexity of factors that shape coping and adaptation decision. As such, it is paramount to consider the lived experience and local realities of climate change in designing adaptation interventions for farmers rather than rely solely on literature. Moreover, a few scholars have reported on farmers' responses to climate variability and change [19–21]. Nonetheless, empirical literature neglects farmers' short-term responses to extreme events and the determinants. As such, it is imperative to systematically characterise farmers' response to climate variability as well as establish a balance between adaptation and coping because doing so makes it possible to posit the various coping and adaptation strategies used by farmers, the ones that are sustainable and can be upscaled for policy uptake and societal progress to live and thrive in current and future climate risk. Hence, the study answers specific questions: i) what is the extent of climate variability in the Upper West Region (UWR) compared to rainfed smallholder farmers' lived experience and perception of climate change variability? ii) what key coping/adaptation strategies are employed by rainfed smallholder farmers to respond to the threat of climate variability in rural Ghana? iii) which factors influence smallholder farmers' decision to cope or adapt to climate extremes and variability? Addressing these research questions will guide and support policymakers, Non-governmental Organisations (NGOs), and Pan-African Organisations (PAOs) to understand current climatic risks and future uncertainties and promote climate action in Ghana and SSA.

2. Materials and methods

2.1. Study area description

The district has a population of about 91457 (thus 51% male and 49% female) [22]. Rainfed agriculture remains the predominant source of employment in the district, with over 94.4% of households engaged in agriculture [23]. Livestock husbandry (2%) and crop production (98%) are the main agricultural pursuits by households in the district [24]. Typified as a Guinea Savanna ecosystem, the district (Fig. 1) is characterised by rising temperatures and erratic rainfall patterns with annual averages ranging from 33.48 to 35.4 °C and 767.3–1295.8 mm respectively [7]. During the crop growing season that starts from May, peak in June through to July and end in October, farmers cultivate several food crops however, from November–May the dry season set in with limited opportunities for farmers (e.g., irrigational facilities, off-farm opportunities). The soils are predominantly sandy loam and suitable for the cultivation of legumes, cereals, and tubers [24]. The district has a unimodal rainfall pattern and is noted for anthropogenic activities like deforestation, bush burning, sand mining, and illicit logging that have severely compromised the ecosystem and its services [24]. These anthropogenic activities coupled with the erratic nature of rainfall and extreme weather events threaten crop production in the district with associated difficulty in food and water access [25,26]. That notwithstanding, the district is characterised by a high illiteracy rate, persistent poverty, inequalities and under-resourced which exacerbates the challenge of food security and even makes it difficult to stimulate economic growth [25]. This makes the region and district even more vulnerable to climate change variability and extreme events as evidence suggest periodic floods, droughts and windstorm which continue to wreak havoc in farmlands in the area [13]. The effects of climate changes on agriculture necessitate farmers to initiate local action to address the negative impact of extreme weather events. By doing so, they can sustain their livelihoods and build agricultural systems that are resilient to climate change. These local actions emanate from farmers' inherent experiences with their local environmental and climatic conditions which remain critical in promoting collective and all-inclusive response to climate variability and change.

2.2. Data collection and methods

The study adopted pragmatic research philosophy as it conflates both qualitative and quantitative research methods (mixed methods) with a particular interest in practical outcomes targeted at solving real-world issues [27]. Understanding and overcoming difficulties that arise in our uncertain world is central to pragmatism [28]. Climate change is one such uncertain global real-world issue that requires collective and concerted action across all fronts and levels to realise practical outcomes for resilient systems. A time series design was used to establish the extent of climate change variability in the Wa East district from 1989 to 2020 whereas a cross-sectional design was used to canvass insights into farmers' lived experience of climate change and their response to current and future climate risk. The cross-sectional design intrinsically combines both quantitative and qualitative methods as an integrated set of methods which allowed for the comparison of several variables at the same time. Using the exploratory mixed-method design, the study concurrently blends interviews (from October to November 2021), household survey (from December 2021 to February 2022), and focus group discussion (February to April 2022) to explore farmers perception of climate variability and response (both short-term and long-term) to current and future climate risks in the Wa East district. The district was of particular interest in this study because it is the most productive in terms of agricultural output in the region and serves as a major supply of food crops in and outside the region, yet it remains the most vulnerable to the whims of climate change in Ghana according to the Environmental Protection Agency (EPA) vulnerability assessment [29]. The focus on farmers' response to climate change was also informed by the praxis of pushing adaptation interventions on farmers rather than promoting farmers' innovations that resonates with the local context and realities.

The data collection was conducted in four-interconnected phases. First, we obtained secondary data in the form of meteorological data (1989–2020) from Ghana Meteorological Agency (GMet), Accra. Guided by the pragmatic research philosophy, we relied on our experiences in the field to structure the methods and timeline of activities. For instance, preliminary interviews and meetings were held with the district director of Ministry of Food and Agriculture (MoFA), monitoring and evaluation officers of MoFA (M&E) (regional and district representatives), the district agricultural extension officers (DAEOs), and NGOs (agriculture and climate change related) with their presence in the region and district. The insights gained from these key informant interviews provided the basis for selecting the study communities. As such, the next stage of the data collection was household survey, followed by focus group discussions (FGDs).

2.2.1. *Sourcing historic rainfall and temperature data*

First, we obtained quantitative historic climate data including daily rainfall and temperature from the GMet, Accra (Wa Meteorological station). We chose a 31-year interval to compute change over time between 1989 and 2020 for quantitative trend analysis. Data on rainfall and temperature were presented in daily averages which were cleansed and further computed into monthly and annual averages using Microsoft Excel Version 16. 61.1. To create the complete datasets needed for time series analysis, especially when using Mann-Kendall's trend, the study used the Normal Ratio Approach (NRA). The NRA has been widely used to complete and check the quality of missing climate data [30,31].

2.2.2. *Key informant interviews*

The initial data collection started with face-to-face interviews with key actors in agriculture production in the region and district. The preliminary interviews were centred around understanding the agriculture portfolio and climate issues in the area and establish the ongoing adaptation interventions in the district to posit the selection of the study communities. This focus resonates with the aim of key informant interviews which allows researchers to seek clarification and enhance the understanding of issues in perspective [32]. On pragmatic grounds, informants were selected based on their knowledge, experience and perceived involvement in climate change, rural development and agricultural production in the region and district using snowball sampling (i.e., the purposive peer referral sampling approach). For instance, we started with the regional MoFA M&E officer who provided yield records of the various districts in the UWR and recommended the Wa East district in the face of the data. Then, the officer helped identify other relevant and resourceful persons to respond to the interviews. We conducted 15 semi-structured interviews, five (5) at the regional office of MoFA and ten (10) based on referrals to district representatives). The insights gained from these interviews provided the basis for the selection of the study communities as well as validating insights from secondary sources where reference was made to Ghana's Fourth National Communication to the United Nations Framework Convention on Climate Change (UNFCC) which touted the region and district as the most vulnerable in Ghana. Preliminary data showed that some farmers perceived coping and adaptation as imperative considering the intensiveness of the farming activities in these areas and exposure to climate variability. Each interview lasted for 30 min guided by the interview guide.

2.2.3. *Household survey*

We administered a household survey to assess the farmers' perception of climate, their live experience and realities in adaptation interventions and the factors that influence farmers coping/adaptation intervention response. The reason for selecting a household survey is that it attracts a wider number of participants, capture a wide range of occurrences, and improve the validity of study results [33]. With assistance from the agricultural extension officers, we design a sample frame to consist of crop farmers for each community. The study barred farmers with less than 10 years of farming experience and a minimum age of 30 because climate change data span a minimum of 30 years and farmers must have aged at least 30 to stand any chance of responding to climate change perception questions. The determined the sample size using [34] formula for estimating sample size. A total of 410 smallholder farmers in 16 communities of the Wa East district were surveyed from December 2021 to February 2022. An integrated suite of sampling methods was used: First, we purposively sampled the Wa East district due to the intensiveness of agriculture activities, production output, and the presence of NGOs championing improved agricultural practices and adaptation interventions. Second, we sampled 16 communities from 4 strata based on the cultural characteristics, tribe and local dialect of these communities using stratified sampling. Given that the population of farmers in the sixteen (16) selected communities from the 4 strata were unequal, proportional sampling was used to estimate the sample size of each community using the population of the district as a reference (see Fig. 1 for sampled communities). Then, we employed a systemic sampling method to select participating households using the "every other fourth house selection criteria". Based on the specification of the sample frame, we sampled 410 smallholder farmers using a simple random sampling method. The questionnaire was administered digitally using the kobo collect toolbox with the aid of 5 trained research assistants. The questionnaire was structured with a set of open and closed-ended questions sectioned into 4 parts including household demographics, farm, sociocultural, physical, and financial characteristics; farmers' perception of climate change variability; experience and response to current and future climate risks; and determinants of coping/adaptation choices (see Appendix 5).

2.2.4. *Focus group discussion*

We conducted ten (10) focus group discussions (FGDs) across seven (7) communities in the study district. The lead researcher led the interaction with participants between 8 and 12 in each community. The study reached the point of data saturation at the 10th FGD from the 7th community. The FGDs provided insights based on lived experience from participants on the issues under study, which the questionnaire survey could not otherwise provide. Traditional authorities and farmers who demonstrated considerable knowledge of crop farming and climate issues during the questionnaire survey were given relevance and considered in the FGDs. For diversity of opinions, we incorporated the gender, age, and economic status dynamics of participants. We also held two female-only sessions to encourage different perspectives of the issues since cultural dynamics in some communities prevented women from speaking freely. However, we conducted eight (8) mixed group sessions in communities where this challenge was not prevalent, as both males and females openly expressed their views. We organised and held the focus group meetings in public locations such as community centres, the chief's house, or a prominent farmer's house. We used a checklist to guide the conversations and probe for more details.

Ethical statement

The authors were resolute in their commitment to principles, protocols, and ethical standards. As a first step, we secured ethical approval from the Ethic Review Committee of the Kwame Nkrumah University of Science and Technology in Kumasi, Ghana. We made it abundantly clear that participation in the study was entirely voluntary, and participants had the right to withdraw from the process at any time. Moreover, we ensured that participants were given a comprehensive overview of the study's purpose and their role in data collection. Both the participants and community leaders provided informed consent for their involvement before questionnaires, interviews and/or FGDs were administered.

2.3. Analytical framework

The study used the Mann-Kendall trend test and the Sen slope estimator to determine the trend and magnitude of rainfall and temperature. The Mann-Kendall test assumes no autocorrelation in the time series. The study applied continuity correction. We used the coefficient of variation to determine the variability in rainfall and temperature in the district. The study used XLSTAT 2020 statistical software, a Microsoft Excel extension designed for trend analysis.

Interviews and focus group discussions were audio-taped with consent obtained from participants, and then we transcribed the data into readable format on Microsoft Word and anonymised it. The audio recordings were named with codes and corresponded to that of the word files for easy identification. For instance, the first interview was coded KAI-1 (thus interview 1), and the focus group was coded FG-1 (focus group discussion 1). The Microsoft Word files were uploaded onto NVivo 12 pro qualitative analysis Software, and we inductively coded the transcribed data to generate themes. We adopted six-step thematic analysis approach to develop themes [35].

For quantitative analysis, the survey data from the Kobo Toolbox repository were exported in CSV file format into Microsoft Excel for cleaning and later transposed to SPSS to create relevant tables and conduct further analysis. For the second objective, the survey data were subjected to PCA analysis to condense the data into a set of uncorrelated dimensions. The PCA analysis reduced the number of coping (20) and adaptation (36) practices identified by farmers into six (6) uncorrelated dimensions respectively while retaining as much information as possible. The uncorrelated factors (principal components—PCs) were combined to create composite variables and identified as the key coping or adaptation measures used by rainfed farmers in rural Ghana. The Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test of sphericity were employed to test the sample adequacy. In this study, datasets with a KMO index of 0.700 or more and an estimate of a p-value of less than 0.01 for Bartlett's test of sphericity were considered eligible for PCA [36]. The purpose of Bartlett's test of sphericity was to determine whether there is redundancy in the variables [37]. We applied the PCA technique to a data matrix, and PCs with eigenvalues greater than one (1) were extracted [38]. The Monte Carlo analysis for the parallel test was used to identify significant PCs. Six (6) PCs were retained for coping and adaptation, respectively. Further, the VARIMAX rotation technique facilitated the interpretation of the PCs. The rotated factor loadings of the factors with significant values were presented in Tables 3 and 4, respectively.

In the fourth phase of the analysis, the study used the probit model to assess the factors influencing rainfed smallholder farmers coping or adaptation decision-making to combat climate variability and change. The probit model has widely been applied in climate change and adaptation scholarship to assess determinants of climate change perception and thoughts on agricultural multi-functionality [39]. For example, the probit model has been used to predict socio-demographic factors affecting agriculture adaptation choices [39], hence the reason this approach was adopted. In the probit model, the expected outcome for coping or adapting to the threat of climatic variability is the latent variable (Eq. (1)) indicated by y* and expressed as:

$$y_i^* = \beta X + \varepsilon \qquad \text{Eq. (1)}$$

However, the latent variables cannot be observed directly, as such equation (1) could be expressed in terms of observable variables (Eq. (2)) and dependent variable y_i (Eq. (3)) as:

$$y_i = 1, \mathit{if}\ \beta_i X_j + \varepsilon_i > 0 \qquad \text{Eq. (2)}$$

and

$$y_i = 0, \mathit{if}\ \beta_i X_j + \varepsilon_i \leq 0 \qquad \text{Eq. (3)}$$

Here y_i represents dependent variable and shows rainfed smallholder farmer will cope or adapt to climatic variability and change ($y_i = 1$) on the condition that the expected outcome from coping or adaptation are positive (thus $y_i^* > 0$). Otherwise, a rainfed smallholder farmer will not cope or adapt to climate variability and change ($y_i = 0$) if the expected outcome from coping or adaptation are negative or zero (thus $y_i^* \leq 0$). Also, X represents a vector of the explanatory variables, βs denotes the parameters to be estimated, and the random errors have a normal distribution with a zero mean and a unit variance and are denoted by ε.

A test of multicollinearity was conducted to determine whether the independent variables were highly correlated using the Variance Inflation Factor (VIF) and Tolerance (Eq. (4)).

$$VIF = \frac{1}{TOL} \tag{4}$$

Where VIF (Eq. (4)) denotes variance inflation factor, tolerance which is the inverse of VIF is denoted by TOL. A VIF exceeding 4.0 and a Tolerance of less than 0.25 are suggested as unacceptable, indicating a problem of multicollinearity [40].

2.3.1. *Empirical specification of variables used in the econometric approach*

2.3.1.1. Dependent variables. The dependent variables employed in this model are rainfed smallholder farmers coping and adaptation decisions. Coping strategies are short-term reactive actions that mitigate the negative impacts of current climatic risks. While coping strategies are not substitutes for adaptation measures, coping measures can complement adaptation efforts by helping individuals and communities manage the immediate consequences of climate change and build adaptive capacity over time [41]. In the context of this study, adaptation strategies are measures that farm households employ to adjust to current and anticipated changes to reduce the threat of climate variability on agricultural production [42]. In addition to reducing climate vulnerabilities and boosting adaptive capacity, adaptation actions maximise climate synergies, minimise trade-offs and limit maladaptation [43,44]. In the probit model, we used binary variables for both coping and adaptation decision, where the value of one (1) is assigned if rainfed farmer adopted a coping or adaptation measure and zero (0) if otherwise.

2.3.1.2. Explanatory variables. The factors influencing farmers' adaptation decisions and choices, particularly farmers' sociodemographic characteristics, have been comprehensively researched in both local, regional, and global contexts [45–52]. The present study discounted these sociodemographic characteristics and focused on emerging determinants of farmers' adaptation decisions such as farm, sociocultural, information/services, physical and financial capital on farmers coping and adaptation planning and decisions. Recent studies [17,44,53–56] have provided insight into farmers' evolving adaptation choices and the factors influencing their decisions. Specifically, the study adopts farm, sociocultural, information/services, physical and financial characteristics peculiar to the microclimatic conditions and local realities of rainfed farmers in rural Ghana, as this may differ in other geographical settings.

2.3.1.3. Farm characteristics. Farm characteristics contribute to farmers' willingness to adjust their farming/adaptation practices. Contrasting opinions exist regarding the influence of farm characteristics on farmers' coping/adaptation decisions. These perspectives

Table 1
Description of model variables (explanatory variables).

Variables	Description
Farm characteristics	
Farming experience	Number of years rainfed smallholder farmer has been farming
Farm size	Total land area cultivated by household in hectares
Soil fertility	Dummy = 1 if household cultivate in fertile land, 0 otherwise
Farm infrastructure	Dummy = 1 if household own or have access to farm infrastructure, 0 otherwise
Farm labour	Dummy = 1 if household has farm labour, 0 otherwise
Market access	Dummy = 1 if household has access to market, 0 otherwise
Informational/services characteristics	
Access to climate information/services	Dummy = 1 if household has access to climate information and services, 0 otherwise
Access to extension service	Dummy = 1 if household has access to extension services (both public and private), 0 otherwise
Socio-cultural characteristics	
Indigenous knowledge and practices	Dummy = 1 if household rely on indigenous knowledge and practices in farming, 0 otherwise
Belief in reality or impact of climate change	Dummy = 1 if rainfed smallholder farmer belief in the reality of climate change, 0 otherwise
Shared values	Dummy = 1 if household holds some shared values that guide their agronomic and adaptation decision, 0 otherwise
Social network	Dummy = 1 if rainfed smallholder farmer is a member of social group in the society or receive social support, 0 otherwise
Risk perception	Dummy = 1 if rainfed smallholder farmer perceive risk associated to climate change, 0 otherwise
Migration	Dummy = 1 if rainfed smallholder farmer migrate, 0 otherwise
Government support	Dummy = 1 if household receive support from government, 0 otherwise
Physical characteristics	
Livestock ownership	Dummy = 1 if household owns livestock, 0 otherwise
Asset ownership	Dummy = 1 if household own assets, 0 otherwise
Land tenure	Dummy = 1 if household own land, 0 otherwise
Financial characteristics	
Off farm income	Dummy = 1 if rainfed smallholder farmer has other off farm source of income, 0 otherwise
Access to credit	Dummy = 1 if rainfed smallholder farmer has access to credit facilities for agricultural production, 0 otherwise
Remittance	Dummy = 1 if rainfed smallholder farmer receives regular remittance, 0 otherwise
Farm Insurance	Dummy = 1 if rainfed smallholder farmer has any form of farm insurance, 0 otherwise

Source: Author's construct (2022)

may vary depending on the specific variables, the immediacy and severity of the impacts, the geographical location, and the current resources available to farmers [48,57]. For instance, there are two opposing views on the influence of farming experiences on adaptation decisions: First, farmers with more experience are more likely to adopt adaptive measures because they are believed to have a thorough understanding of agronomic practices, the reality of climate change, and the importance of adaptation to farmers' livelihoods [58] and; Second, farmers with extensive farming experience may remain attached to traditional, conservative, and unsafe agricultural practices that they are more comfortable with and not willing to change these practices or adopt emerging technological and adaptation interventions [59]. Farming experience, farm size cultivated, soil fertility, farm infrastructure, farm labour and market access were derived from the theory of reasoned action [60] and used in this model (see Table 1). Farm capital significantly impacts farmers' decisions on current and future adaptation practices and are critical in determining how farmers respond to the threat of climate variability [61].

2.3.1.4. Information/services characteristics. Farmers can better adapt to climate change with timely access to climate information from trusted and accurate sources. The illustration in Table 1 depicts two information/services variables (thus access to climate information/services and access to extension services) derived from the theory of co-production [62] and communication [63]. Access to climate information keeps farmers informed on the current and future climate conditions, which is critical in stimulating farmers response to climate variability [64]. When climate information is reliable, timely, accurate, and tailored to farmers' needs, it plays a more significant role in their ability to adapt to the changing climate and maximise gains from agricultural production [65]. On the other hand, access to extension services improves farmers' knowledge and understanding of agriculture/farm management practices and exposes rainfed farmers to innovations and adaptation interventions. Also, farmers with access to extension services are likely to make adaptation interventions, adopt innovation and modify their farming practices [20,55].

2.3.1.5. Sociocultural characteristics. Farmers' adoption of agronomic and adaption strategies is substantially influenced by sociocultural characteristics, especially when such factors have both social and cultural repercussions for farmers and their livelihoods [66,67]. The utilization of indigenous knowledge and practices, belief in the reality of climate change, shared values, social networks, risk perception, migration, and government support (see Table 1); are all examples of sociocultural factors derived from the theories of planned behaviour [68] and values-beliefs-norms [69], which we included in the present model. Studies have demonstrated the importance of these sociocultural factors in affecting farmers' adaptation decisions [70,71]. Adapting to the threat of climate variability is a complex yet multifaceted process encompassing climatic, cultural, social, and economic attributes [17]. As a result, sociocultural variables intuitively influence how farmers react to present and potential climatic risks hence the reason to include it in the model.

2.3.1.6. Physical characteristics. Scholarly evidence has referenced farmers' physical characteristics as determinants of farmers' adaptation decisions [44,54]. Household assets, land, farmers' belongings, and agricultural machinery are measurable indicators of physical capital. These variables are crucial for farmers' adaptation decisions because farmers earn income from these assets and boost their capacity to adopt new farming practices, technology, innovation, or adaptation interventions [44]. As presented in Table 1, land ownership, livestock, and asset ownership were considered critical physical capital in the context of this study. Imperatively, farmers who own lands adopt long-term adaptation practices such as afforestation, agroforestry, plantation, or establishing woodlots to reduce the threat of climate variability and build resilient food systems [44]. Nonetheless, farmers with temporary leases of the land attempt to maximise gains in a small piece of land over a limited period and may be adamant in pursuing long-term farming investment beyond their productive use of the land [15].

2.3.1.7. Financial capital. Previous scholars emphasized the significance of financial capital as a relevant determinant of farmers' adaptation decisions [44,55]. Farmers are more resilient to the threat of climate variability with access to financial capital [56]. We focussed on off-income, access to credit, remittance, and farm insurance (see Table 1) in the probit model as these variables are peculiar to rural Ghana. Off-income, credit access, remittance, and farm insurance strengthen the financial capacity of farmers and enable farmers to purchase farm inputs (like early maturing varieties, improved varieties, drought tolerant crops, fertilizers, and agrochemicals), afford farm labour and access relevant climate information/services and by extension making the likelihood of adaptation higher [15].

3. Results and discussion

3.1. Descriptive statistics

Appendix 1 shows the descriptive statistics of the sampled farm households. Over 74% of respondents were males, and 26% were females. Respondent farmers had an average of 15 years of farming experience. The age of the respondents ranged between 30 and 80 years. About 56% of the farmers were married. Most respondents had family members of either less than 5 (43.7%) or between 6 and 10 (43.9%) and over (61%) cultivated between 1 and 5 acres of farmland. Most of the respondents (81%) had no formal education.

3.2. Climate variability and change

3.2.1. Observed climate trends from meteorological data

Fig. 2 (a, b) illustrates the temperature and rainfall trends during the growing season (May to October) from 1989 to 2020 in the Wa East district of the UWR. The trends are characterized by variability in nature and magnitude, with a positive (warming) trend in the average temperature during the growing season (see Fig. 2b) and a negative trend (decreasing amount) in rainfall (see Fig. 2a). The decrease in rainfall by 85 mm between the 1990s and the last two decades (2000s and 2010s) (Fig. 2a) suggests a reduction in rainfall during the growing season between 1989 and 2020. These climate trends can significantly impact crop production as they alter yields, crop water demand, irrigation management, risk of pests and diseases, soil temperature, length of the growing season, and other crop and soil management practices hence, understanding the dynamics of climate variability is critical in metering appropriate adaptation response [72]. Farmers strive to intensify agricultural production may also be affected by reduced rainfall levels, causing changes in water availability, water stress, and the aridity rate, which can significantly affect crop production and yields, particularly during the developmental phases [7,9,72]. As almost all the population in the district and more than half in the region work in the agricultural sector, the variability in climate change could endanger food security, threaten farmers' livelihoods, and reduce farmer and household income and economic growth.

3.2.2. Rainfed smallholder farmers lived experience of climate variability and change

Table 2 illustrates the observed changes in climate among rainfed farmers in the study area. Over the past 30 years, rainfed farmers have noticed various changes in their local climate. For instance, the study found that most rainfed farmers in the study district experienced unpredictable rainfall patterns (52.2%), with a decrease in rainfall amounts across the district and rising temperatures (58.0%). During the FGD, a group recounted: *"We used to experience first rains in late February, which they called 'vunvuglun saa'. This served two purposes: to wash away ashes and debris and to signal farmers' preparations for the new season. This period is critical for the start of serious farming business in our community; we begin to source farm inputs, prepare, and plough farmlands awaiting the full commencement of the season. However, in recent years, the first rain has come in late April or early May, catching farmers off guard, and giving them a false start to the season" (FGD1, January 2022).* Another group accentuated this by saying: *"Previous rainfall had better outcomes for farming, beginning in late February/early March and continuing at regular intervals throughout the season. However, now the rain begins in late April and early May, often ending either earlier than expected, leading to drought, or later than anticipated, causing flash floods as witnessed in August 2021. These changes make it difficult for us (farmers) to plan and make decisions, affecting our production output and livelihoods" (FGD3, January 2022).* These observations from rainfed smallholder farmers align with meteorological data from the same study area (see Fig. 2a and b, above). Several studies including [7,31,73–75] corroborated these findings as the authors reported decreasing rainfall pattern and rising temperature across most agroecological zones in Ghana. The rising temperature reported in this study reflects the global trend of increasing temperatures, with the last seven hottest years recorded between 2012 and 2022 [76].

Most of the farmers in the district have experienced late onset (74.0%), early cessation (70.7%), and a short rainy season (60.2%) over the past 30 years. One group of farmers explained: *"We used to experience early onset of rains at irregular intervals about 30 years ago, but in recent years we have witnessed a late onset and early cessation, which has delayed our season start" (FGD2, January 2022).* Another group emphasized: *"It has become difficult to predict rainfall onset or cessation during a growing season. For instance, you experience the first rains and begin to prepare your field, then the rains suddenly stop causing prolonged dry spell, or you follow the regular rainfall pattern and cultivate your crops, at the time of harvest, the intensity of rains increases. Either ways, we lose our crops either through poor yields, inability to harvest due to continuous rains or post-harvest losses. These dynamics tend to confuse us (farmers) and make it difficult to adjust to deal with this threat" (FGD5, January 2022).* Previous studies [7,73,75,77], reported erratic rainfall onset and cessation in most agroecological

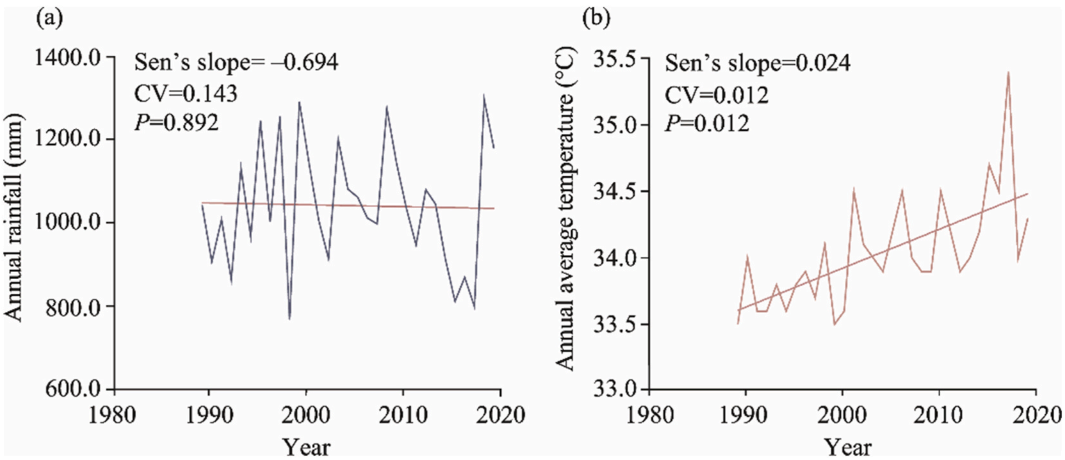

Fig. 2. Climate trend; a) rainfall trends and b) temperature trends.
Source: Author's construct using data from GMet (2022)

Table 2
Rainfed smallholder farmers lived experience of climate variability and change.

Climate variables (observe changes in)	Gender		Total (N = 410)
	Male (n = 303)	Female (n = 107)	
Rainfall			
Erratic rainfall	152 (50.2)	62 (57.9)	214 (52.2)
Decrease rainfall	102 (33.7)	30 (28.0)	132 (32.2)
Increase rainfall	49 (16.2)	15 (14.0)	64 (15.6)
Temperature			
No change in temperature	51 (16.8)	18 (16.8)	69 (16.8)
Decrease temperature	79 (26.1)	24 (22.4)	103 (25.1)
Increase temperature	173 (57.1)	65 (60.7)	238 (58.0)
Rainfall onset			
No change in onset	30 (9.9)	11 (10.3)	41 (10)
Early-onset	51 (16.8)	15 (14.0)	66 (16.1)
Late-onset	222 (73.3)	80 (74.7)	302 (73.6)
Rainfall cessation			
No change in cessation	21 (6.9)	16 (14.9)	37 (9.0)
Early cessation	225 (74.3)	65 (60.7)	290 (70.7)
Late cessation	57 (18.8)	26 (24.3)	83 (20.2)
Length of the rainy season			
No change in the length the of the rainy season	52 (17.2)	14 (13.1)	66 (16.1)
Short rainy season	177 (58.4)	70 (65.4)	247 (60.2)
Long rainy season	74 (24.4)	23 (21.5)	97 (23.7)
Drought occurrence			
No change in drought occurrence	32 (10.6)	17 (15.9)	49 (12.0)
Decrease drought occurrence	75 (24.8)	28 (26.2)	103 (25.0)
Increase drought occurrence	196 (64.7)	62 (57.9)	258 (63.0)
Flood occurrence			
No change in flood occurrence	28 (22.4)	11 (19.6)	39 (9.5)
Decrease incidence of flood	31 (30.0)	32 (29.9)	63 (15.4)
Increase incidence of flood	244 (47.5)	64 (50.47)	308 (75.1)

NB. Values in parenthesis are in percentage relative to the sub-total of males (303) and females (107) denoted by "n" and the sample population (410) denoted by "N"
Source: Author's construct (2022)

zones of Ghana, which affects farmers' plans for the season and their capacity to make climate-responsive decisions at the start of the growing season, such as seed selection (early or late maturing seeds), planting dates, and on-farm adaptation decisions [7,78].

Most farmers in the district have experienced extreme climate events, including floods (75.1%) and droughts (63%) (see Table 2.) One group highlighted: *"Nowadays, the rainy season is shorter but more intense leading to floods in recent years" (FGD9, January 2022).* Similar to previous studies [73,79], most farmers in Ghana have perceived floods and droughts as extreme events over the last 20 years. Climate extremes, such as floods and droughts, are dependent on the dynamics of rainfall onset, cessation, and length of the rainy season [75]. Farmers' awareness and perception of these dynamics are important to recognise the threat of climate change on food production and to take appropriate adaptation measures. Rainfed farmers' response to climate risk is framed on their perception of observed changes in the climate coupled with local indicators. Climate change perception is complex and influenced by psychological factors such as beliefs, knowledge, information, attitude, and anxieties about climate change [80]. Farmers' experiences, culture, and geography affect their perception of climate variability, highlighting the subjective nature of perception [81]. Different farmers in the same location might experience the same weather conditions but with different constructs [82]. These different constructs feed into household perceive awareness, action, and response to climate risk [83]. Farmers' perception is vital for the successful implementation of adaptation policies as it promotes social learning for collective adaptation action [13]. However, a contradiction between farmers' perceptions and policymakers' measured climate trends could result in maladaptation and failure in implementing adaptation interventions.

3.3. Rainfed smallholder farmer response to climate variability and change

3.3.1. Key coping response by rainfed smallholder farmers in the face of climate shocks

Rainfed farmers have developed 20 different methods to cope with severe weather conditions like floods, droughts, and bushfires (see Appendix 2). Some of the most common ways they deal with these challenges include gathering wild fruits and vegetables, seeking help from family and friends, avoiding social events, petty trading and agro-businesses, sharing resources, migrating, and selling livestock. On the other hand, they tend to use renting land, insurance, NGO support, and government support less frequently. The study subjected all 20 coping strategies to PCA analysis. The PCA revealed nine (9) components which explained 66.3% of the original data variance and had eigenvalues greater than 1 (Table 3). However, Monte Carlo Parallel tests (Fig. 3) indicated that six (6) of these components and were retained. Varimax Rotated Factor Analysis showed that the six (6) main components explained 50.3% of the variance in their ability to respond to these challenges. Therefore, components 7–9 were not included in further analysis.

Table 3
Principal component of rainfed smallholder farmers' coping response.

Coping response (key)	Components (factor)						Communalities (%)
	Cognitive restructuring coping (1)	Resources seeking coping (2)	Experiential avoidance coping (3)	Expressive coping (4)	Capital disinvestment coping (5)	Relying on social networks coping (6)	
Household transfers and loans	0.834						77
Harvesting edible fruits and vegetables	0.733						62
Renting farm tools/animals	−0.649						57
Reduce social gatherings	0.562						63
Government support		0.847					74
Begging for food or support		−0.836					72
Sale of livestock			−0.851				76
Migration in search of job			0.806				71
Wage labour				0.804			73
Petty trading and agro business				−0.674			59
Charcoal burning				0.497			54
Renting land					0.802		71
Support from NGOs					0.682		63
Aid or Gifts from friends						0.818	69
Hunting						0.79	65
Eigenvalues (%)	2.428	1.937	1.575	1.475	1.44	1.204	
Explained variance (%)	12.14	9.687	7.874	7.373	7.199	6.018	

Extraction Method: Principal Component Analysis (PCA); Rotation method: VARIMAX with Kaiser Normalisation; Kaiser-Meyer-Olkin Measure of Sampling Adequacy (0.70, chi-square = 640.51, Sig = 0.001).
Source: Author's construct (2022)

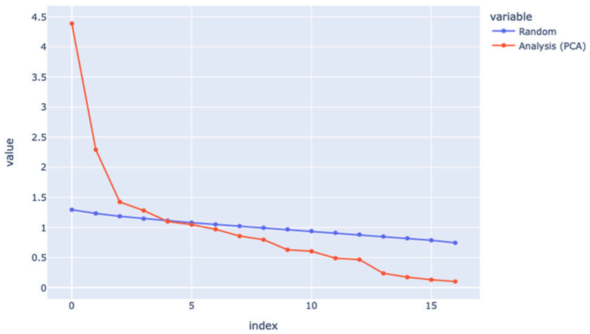

Fig. 3. Monte Carlos Parallel tests for significant components (coping).
Source: Author's construct (2022)

Table 3 illustrate the principal components (PCs) with their respective loadings. The analyses only considered a factor loading of 0.48 and above, and we excluded factors that appeared in more than one component (cross-loaded) from the PCs to avoid duplication. The first component accounts for 12.14% of the total variance, and it has positive loadings on "household transfers and loans", "gathering wild edible fruits and vegetables", and "reducing social gathering," but negative loading on "renting farm tools and animals". The negative loading implied that farmers with farm tools did not gather fruits and vegetables or household transfer and loans or reduce social gathering and vice versa. All four-factor loadings consist of coping techniques that elicit the socio-cognitive behaviour of individual farmers to combat the impacts of a climate shock. We identified this factor as "cognitive restructuring." Cognitive restructuring involves rationalizing behaviours; developing creative and optimistic solutions to save households and livelihoods. This is consistent with the theory of planned behaviour [84] and earlier studies on the importance of developing a positive attitude and appraisal for comforting alternatives as a coping mechanism for rural farmers [85].

PC2, which accounts for 9.687% of the total variance, shows a positive correlation with "government support" but a negative association with "begging for food and support". This suggests that farmers who received help are not benefiting from government support concurrently. Rainfed farmers sought resources externally to cope with climate shocks in the district, which we refer to as "resource seeking". Farmers, in seeking resources gets financial assistance, capacity-building, food items, and agricultural inputs from the government, friends/relatives, and Aid organisation, to alleviate hardship particularly food insecurity and economic hardships. This is consistent with the findings [86] who reported that over 44% of farmers in northeast Ghana received support from aid organisations to help cope with climate extremes. However, resource-seeking has affected farmers' cognitive ability to cope with weather extremes and created a sense of entitlement that leads farmers to demand support even from visitors.

In our analysis, PC3 explains 7.874% of the variance. This component showed a positive relationship with "migrating in search of a job" and a negative relationship with "sales of livestock," which we identified as "experiential avoidance". It means farmers who migrated for work did not sell their livestock to cope with extreme weather conditions and vice versa. Experiential avoidance is when

Table 4
Principal components of rainfed smallholder farmers' adaptation response.

Adaptation strategies	Components (factors)						Communalities (%)
	Agronomic practice (1)	Soil/water management practice (2)	Conservation agricultural practice (3)	Smart farming/ cropping decision (4)	Livelihood diversification (5)	Use of IKP (6)	
Replanting or resowing	0.86						78
Crop rotation	0.785						70
Row planting	0.764						63
Use of indigenous knowledge and practices	0.612						56
Use of improved varieties	0.601						58
Use of fertilizer, chemicals, and pesticides	0.592						52
Crop diversification	0.503						73
Double ploughing		−0.675					63
Mulching		0.775					72
Farmer managed natural regeneration		0.571					62
Migration		−0.554					56
Intercropping		0.508					54
Village savings and loans		−0.402					37
Mixed farming			0.721				64
Planting of trees (Afforestation)			0.638				54
Home or backyard garden			0.559				57
Use of compost and manure			0.541				61
Mixed cropping			0.324				28
Cultivating both low and high lands				−0.708			59
Early burning and creation of fire-belts				0.652			58
Planting early, medium, and long duration varieties				−0.527			61
Carpentry					0.845		76
Masonry					0.776		68
Creating farm drainage systems						−0.667	69
Use of indigenous seeds						−0.533	59
Eigenvalues (%)	5.042	2.932	2.043	1.846	1.734	1.497	
Explained variance (%)	14.005	8.145	5.674	5.129	4.815	4.159	

Extraction Method: Principal Component Analysis (PCA); Rotation method: VARIMAX with Kaiser Normalisation; Kaiser-Meyer-Olkin Measure of Sampling Adequacy (0.702, chi-square = 2403.356, Sig = 0.0001). PCs with factor loadings of less than 0.30 were not considered.
Source: Author's construct (2022)

farmers try to control the situation outside their immediate environment by avoiding feelings of distress, disappointment, and frustration caused by climate shocks.

Component 4 explains 7.373% of the total variance. The component exhibited positive loading on "wage labour", and "charcoal burning", and a negative loading on "petty trading and agro-business". The negative correlation indicates that farmers who earn wages from labour or burn charcoal do not engage in petty trading and agro-business as coping strategies and vice versa. As such, we identified the factor as 'expressive coping'. In response to the impacts and risks associated with climate change and extreme events, farmers resorted to experiential avoidance. Rainfed farmers are receptive to extreme events and act promptly to cope with the harsh conditions of climate shocks [87,88]. Moreover [89,90], identified similar coping mechanisms by farmers and categorised them as 'expressive coping' mainly because farmers employ such strategies to temporarily adjust to the adverse impact of climate shocks (droughts, floods, pest and disease infestation and bushfires) whilst preparing for long-term measures. Expressive coping mechanisms are short-term survival strategies that encapsulate the prevailing socio-economic conditions of rural farmers when hit with climate shock [91].

PC5 contributes 7.199% of the total variance and is positively associated with "renting land" and "support from NGOs". This was known as 'capital disinvestment'. Through capital disinvestment, many farmers rent out some properties like land, farm animals or tools or even sell a property when confronted with climate shock to raise income and provide food for the household. It implies that farmers lose a whole or part of these properties to enable them to cope. The loss of such assets or properties for consumption purposes characterised capital disinvestment.

PC6 consists of gifts from family, friends and relatives and hunting which had high positive loadings and accounts for 6.018%. This is known as relying on social networks for support. Social network support provides a sense of community where farmers affected by weather/climate extremes reach out for assistance. Individual farmers, community, and group social capital (being a member of FBO or village saving and loans) are significant for social expressions of risk and vulnerability management [92]. The social network provides social capital for farmers to address climate risks. For instance, social capital develops buffer systems like the "susu" and VSLA to improve livelihood and support farmers when confronted with difficulty.

3.3.2. Key adaptation response employed by rainfed smallholder farmers to address the threat of climate variability

The findings revealed that farmers adopted various adaptation techniques to address the threats of climate variability and change (Table 4). Thirty-six (36) adaptation measures were identified (see Appendix 3), and the prevalent practices employed by rainfed smallholder farmers in the district include indigenous knowledge and practices, trading, afforestation (tree planting), crop rotation, village saving and loans, mixed farming, reducing or zero tillage, planting early maturing varieties, contour ploughing, and the use of fertilizers, chemicals, and pesticides. On the other hand, basket weaving, carpentry, renting agricultural land, masonry, and irrigated farming were the least popular adaptation methods in the district. All 36 adaptation measures were subjected to PCA analysis to reduce them into uncorrelated factors. The PCA initially yielded fourteen (14) components that explained 68.7% of the original data variance with eigenvalues greater than one (1). Nonetheless, six (6) factors were significant in explaining rainfed farmers' adaptation response to climate variability after executing Monte Carlo PCA for parallel analysis (Fig. 4).

Table 4 shows the factors loadings of the 36 adaptation strategies adopted by rainfed smallholder farmers. Factors that appeared in more than a component (cross-loaded) were excluded from the PCs to avoid duplication. The first PC accounted for 14.005% of the total variance. Agronomic practices, such as replanting or resowing, crop rotation, row planting, use of improved crop varieties, use of fertilizer, chemicals and pesticides, and crop diversification, had a positive factor loading in PC1. These practices are crucial for agricultural adaptation as they help reduce risk, make efficient use of resources such as soil nutrients and water, control pests and diseases, and maximise land use. Our findings align with previous studies [93,94], which highlighted the importance of crop management practices in promoting climate-smart agriculture and improving smallholder farmers' livelihoods in Africa.

PC2 represents 8.145% of the total variance and is positively associated with mulching, farmer-managed natural regeneration, and intercropping. However, it correlated negatively with double ploughing, migration, and village savings and loans. The implication is that farmers who use double ploughing, migration, and village savings and loans do not typically employ farmer-managed natural regeneration, intercropping or mulching as adaptation strategies, and vice versa. Therefore, we identified the factor as 'soil and water management practice'. Soil and water conservation practices are the second most important agricultural adaptation practice utilized

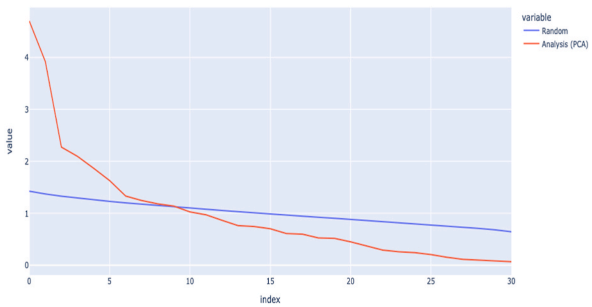

Fig. 4. Monte Carlos Parallel test for significant components (Adaptation).
Source: Author's construct (2022)

by smallholder farmers in rural Ghana. These practices are popular among farmers because they support ecosystem services, improve soil quality, and promote efficient use of soil nutrients and water while regulating soil temperature and extremes [21].

PC3 constituted 5.674% of the total variance and was positively associated with mixed farming, afforestation, home or backyard garden and use of compost and manure. Therefore, we identified PC3 as conservation agriculture practices. Conservation agriculture has been reported to enhance agricultural outcomes while conserving farmer resource base and the environment [95,96]. Conservation agriculture as a popular adaptation strategy among smallholder farmers in Africa can reduce production costs and increase output whilst ensuring food security and mitigating future crop management challenges [17]. Conservation agriculture is rooted in indigenous knowledge and utilizes local and traditional knowledge to achieve practical results [45].

PC4 accounts for 5.129% of the variance and is positively correlated with early burning and creating fire belts but associated negatively with cultivating low and high lands and planting early maturing crop varieties. As such, we identified this factor as a smart farming and cropping decision. Essentially, farmers who cultivate on low and high lands or use early maturing varieties do not practice early burning/creating fire belts simultaneously.

PC5 accounts for 4.815% of the total variance and is associated with carpentry and masonry work. This finding suggests that rainfed farmers are exploring livelihood diversification options outside farming to mitigate the impact of climate change and improve their living standards [97]. As farmers diversifying their livelihoods, they spread the risk and reduce the likelihood of total production failures [20,98].

PC6, representing the utilization of indigenous knowledge and practices (IKP), accounted for 4.159% of the total variance and was found to have a negative correlation with the implementation of farm drainage systems and the use of indigenous seeds. Indigenous with its intrinsic heritage values and practical use, contains unique information sources and solutions that directly resonate with farmers local climatic conditions and realities [3]. And this serves as a powerful tool to stimulate local adaptation action, contribute towards the achievement of goal 13 of the Sustainable Development Goals (SDGs), enhance agricultural output, food and nutritional security and livelihoods particularly in rural communities of Africa [99].

3.4. *Factors influencing rainfed smallholder farmers coping and/or adaptation decision and choices*

After analysing for multicollinearity, the VIF values ranged from 1.0 to 1.60, and the Tolerance levels were between 0.5 and 0.95. These results indicate that there was no violation of the regression assumption of multicollinearity prior to the logit regression analysis (see Appendix 4). Table 5 shows the factors that influence farmers' coping/adaptation choices. These factors include farm, information/services, sociocultural, physical, and financial characteristics.

Table 5
Parameters estimates of a Probit model (odd ratios) for estimating determinants of coping with and adapting to climate shocks.

Variables	Coping with climate shocks	Adapting to climate shocks
Farm characteristics		
Farming experience	0.037 (0.334)	0.063 (0.113)
Farm size	−0.012 (0.514)	−0.009 (0.607)
Soil fertility	−0.049 (0.262)	−0.111 (0.014)*
Farm infrastructure	−0.072 (0.100)	−0.079 (0.079)
Farm labour employment	0.108 (0.133)	0.149 (0.045)*
Market access	0.212 (0.000)*	0.228 (0.000)*
Informational/services characteristic		
Access to climate information/services	0.111 (0.042)*	0.112 (0.047)*
Access to extension service	0.165 (0.000)*	0.108 (0.016)*
Socio-cultural capital		
Indigenous knowledge and practices	0.203 (0.019)*	0.197 (0.028)*
Belief in reality of climate change	−0.255 (0.056)	−0.335 (0.015)*
Shared values	−0.004 (0.978)	−0.006 (0.972)
Social network and membership	0.096 (0.159)	0.066 (0.346)
Risk perception	0.153 (0.025)*	0.196 (0.005)*
Migration	0.068 (0.078)	0.036 (0.363)
Government support	−0.445 (0.000)*	−0.442 (0.000)*
Physical Capital		
Livestock ownership	0.363 (0.000)*	0.278 (0.000)*
Asset ownership	0.142 (0.027)*	0.218 (0.001)*
Land tenure	0.012 (0.661)	−0.032 (0.271)
Financial capital		
Off farm income	−0.060 (0.402)	−0.055 (0.458)
Access to credit	0.359 (0.023)*	0.399 (0.014)*
Remittance	−0.033 (0.413)	−0.037 (0.370)
Farm Insurance	0.291 (0.003)*	0.244 (0.015)*

NB. p-values and odds ratio are illustrated within and outside parentheses (p-value is at 5% significance level).
Source: Author's construct (2022)

3.4.1. Farm characteristics

The characteristics of a farm play a crucial role in how rainfed farmers react to the potential impact of climate variability and change. Among the farm variables, soil fertility negatively correlates with rainfed farmers' adaptation to the threat of climate variability. This suggests that farmers who work on fertile soils may believe that their farm soil can withstand changes in climate and may not adjust. On the other hand, rainfed farmers who farm on infertile soils are more likely to take steps to improve their land's productivity, such as using manure and inorganic fertilizers. Contrary to this finding [21,54], reported that farmers in sub-Saharan Africa are more likely to use adaptation measures if their soil is fertile. However, soil fertility was not statistically significant in influencing rainfed farmers coping response to climate shock. Conversely, farm labour positively influenced rainfed farmers' adaptation decisions but not their coping responses. Rainfed farm households with more labour were more likely to initiate labour-intensive adaptation practices against the threat of climate variability by adjusting production activities like livestock rearing, crop diversification, soil, and water conservation practices, and creating farm drainage systems and irrigation. However, farm labour was not a significant determinant of rainfed farmers' coping response to climate extremes. Also, market access had a substantial positive influence on the probability of rainfed farmers' coping and adaptation response to the threat of climate variability. Farmers can improve their knowledge of new technologies, innovations, and farming inputs, such as drought-tolerant seed varieties and irrigation technology by accessing the market. This access also expands their social network, providing them with valuable advisory services and information to adapt to the challenges of climate variability. Market access (input market) enables farmers to access farm inputs such as seeds, fertilizers, and pesticides, enhancing their capacity to adapt to the threat of climate variability. Also, having access markets (output market) induces farmers to grow cash crops (such as cashews, soybeans, cowpea, groundnuts, and yams) that help them diversify their resource and asset base and, as a result, increase their adaptive capacity. In terms of coping, farmers' actions associated with the theory of reasoned action make market access a vehicle to build cognitive strength through the exchange of information, skills, innovation, and technology; and build social cohesion for collective but distinct actions to reduce the threat of climate variability and change to agricultural livelihoods. Proximity to the market facilitates the exchange and acquisition of information among farmers and service providers, ultimately leading to the adoption of innovative practices [100,101]. The availability of a market is an endowment for farmers to adopt climate change adaptation and coping practices compared to farmers who have no access to the market and may incur extra costs and hustle to acquire farm inputs. The local market serves not only as a place to buy and sell products but as a valuable opportunity for farmers to network and build social connections with others.

3.4.2. Information/services characteristics

Information and services play a significant role in the coping/adaptation response of rainfed farmers to the threat of climate variability and extremes. The model revealed that access to climate information/services and extension services positively influence rainfed farmers coping and adaptation response in rural Ghana. For instance, rainfed farmers with access to climate information are more likely to adopt practices such as early or late farming, farming in low or high lands, use of early maturing crops, use of drought tolerant crops, planting trees (e.g., cashews) and irrigation because of farmers awareness and knowledge in climatic trends (thus current and future projections or forecast) and the possible response. Farmers can make informed decisions based on weather forecasts. For instance: If farmers know that rains will be early, they can start planting crops earlier; If the rainy season is predicted, to be short, farmers can plan by building additional irrigation systems or using early maturing crops. And if the rains are expected to come late, farmers can adjust their planting schedules accordingly. Providing farmers with crucial climate information can increase their commitment to adopting adaptation practices and prevent them from making experimental choices and decisions [102]. Access to climate information and services is critical for farmers to prepare for and cope with climate shocks. This information empowers farmers to make informed decisions such as seeking employment elsewhere, selling livestock, or taking up wage labour. Also, access to climate information promotes knowledge co-production and effective communication [103]. Collaborating with key players in the industry and utilizing trustworthy sources of information is absolutely crucial for farmers looking to improve their farming techniques. By doing so, they can greatly enhance agricultural productivity and create more sustainable food systems [103]. Farmers who access extension services are more likely to adapt to the challenges of climate variability. These services help increase farmers' understanding and awareness of climate change, bringing them closer to the reality of the situation and inspiring them to act through better farm management practices such as intercropping, crop rotation, row planting, double ploughing, and mulching. Extension services that are easily accessible are essential for rural farmers to cope and adapt successfully. Rainfed farmers have a greater chance of adopting improved agricultural and agronomic practices and innovative adaptations when they learn from extension agents and resource persons, which promotes social learning [104].

3.4.3. Sociocultural characteristics

The model revealed that indigenous knowledge/practices and risk perception positively and significantly influence rainfed farmers coping/adaptation response, whereas government support negatively influences rainfed farmers coping/adaptation response to the threat of climate variability. Rainfed farmers with access to indigenous knowledge and practices are better equipped to cope with and adapt to the threat of climate variability. For instance, farmers can use their knowledge of the local environment base on experience and generational transfers to make weather forecasts and predictions, which helps them decide on the appropriate response to the threat of climate variability. Indigenous knowledge is a strategic resource for coping with climate shock and adapting to climate change and variability. Smallholder farmers in Africa are faced with the challenge of adopting mainstream adaptation practices due to high costs, poor technology, and infrastructure. By using indigenous knowledge and practices, it is possible to counteract the harmful effects of climate change on agricultural output and promote local adaptation action in rural Ghana [21]. Also, rainfed farmers who perceived the risk of climate change to their farm and livelihood and the efficacy of adaptation response increases their likelihood of responding to the threat of climate variability and change implying that farmers adopt coping and adaptation management behaviour when perceive a likely threat to their livelihood. Risk perception is another critical determinant of farmers' climate change and variability adaptation and/or coping decisions. Perceived adaptive capacity is determined by perceived risk through cognitive thinking, psychological construct, experiences, and cultural dynamics framed from the theory of values-belief-norms and planned behaviour which modulates the impact of perceived risk. Smallholder farmers may consider the risk of not adapting as bigger than the risk of adapting, even if they are concerned about other non-climatic risks [105,106]. In terms of coping, rainfed farmers who perceive a threat (e.g., flood or drought) that they presume to have consequences on them, and others socially, economically, and physically will take the negative impact seriously and adopt risk-mitigating measures to combat the impact. Conversely, government support related negatively to rainfed farmers' adaptive and coping behaviour implying farmers who depend on the government in times of climate adversity are less motivated to act or respond to the threats of climate variability. They push the burden and responsibility of the adversity to the government and depend on government intervention whereas farmers who do not rely on government support take their own initiative and act on their own to combat the threat of climate variability and change. Although, external support from the government could help farmers transform the process of social learning for expanding adaptation and building resilient agricultural systems. Also, rainfed farmers' belief in the reality of climate change significantly and negatively affected rainfed farmers' adaptation decisions but not coping decisions. This implies that rainfed farmers who believe in the reality of climate change tend to adopt measures that will reduce its adverse impact whereas farmers who do not believe in the reality of climate change do not adopt any measures.

3.4.4. Physical characteristics

As presented in Table 5, livestock and asset ownership were positively and significantly associated with rainfed farmers' response to the threat of climate variability in rural Ghana. Rainfed farmers who rely on livestock and assets are more prone to adapt to climate changes by investing in on-farm practices like double ploughing, soil conservation, manure usage, improved seed varieties, fertilisers, pesticides, drainage systems, and irrigation farming. Farmers tend to increase their financial security by owning assets and livestock. The income from these assets, either through sales or rent, is reinvested in their farms, which build resilient farming systems and improve farmers' adaptive capacity [44]. Livestock ownership provides rainfed farmers with essential resources, such as manure, which they use to fertilise their soils. Manure from livestock is especially beneficial to low-income farmers who struggle to afford inorganic fertilisers, as it helps them maintain soil quality and increase crop production. For coping, when rainfed farmers experience climate shocks or disasters, they usually depend on their assets and livestock to earn money for their households. However, land tenure is negative and insignificant to rainfed farmers' adaptation decisions, implying no statistical relationship between land tenure and climate adaptation. Even though the correlation was not statistically significant, having land tenure had a positive impact on the coping behaviour of rainfed farmers. This contradicts the findings [54] that land tenure or ownership positively influences adaptation action as farming activities are designed to be implemented on a large scale. This may be due to the increasing level of technology and farm innovation to maximise and intensify agricultural production in small pieces of land considering the rapid population growth and urban sprawl. Also, the positive association of land tenure to coping response although not statistically significant may be because rainfed farmers can relocate their farms in the event of climate shock or disaster. Also, long-term adaptation measures such as tree planting (e.g., cashews), supplementary irrigational schemes etc can offer farmers a lifeline by providing alternatives in the event of climate crises.

3.4.5. Financial capital

Financial capital plays a critical role in farmers' adaptation to the threat of climate variability and shocks. The model predicted access to credit and farm insurance as positive and significant factors influencing farmers' adaptation to climate shocks. For instance, access to credit implies an increase in financial capital for farmers, which increases farmers' capacity to purchase farm inputs (such as improved seeds varieties, drought-tolerant, early maturing varieties, fertilisers, and pesticides), access climate information and services (through various pathways including television, radio, newspaper, daily phone weather updates), and patronise agricultural extension services hence, increasing the probability of farmers implementing improved agronomic and adaptation interventions. Increased credit access and cash flows incentivise farmers to adopt or invest in more costly but rewarding adaptation alternatives, adopt innovation and even modify existing ones to reduce the threat of climate variability on food security and agricultural livelihood [107]. Examples include soil and water conservation, changing planting dates, crop diversification, irrigation, tree planting and agroforestry [55]. When rainfed smallholder farmers are better placed financially, they do not only implement specific adaptations but combine adaptation measures to improve production [108]. Farmers with access to credit are better equipped to cope with climate shocks by diversifying their farming and livelihood practices (thus mixed farming, petty trading, agribusiness, and purchasing livestock for rearing). During a climate crisis, having access to credit is crucial for enhancing the financial capabilities of farmers. The significance of credit access to farmers and their adaptation decisions calls into action the critical role of institutional support in making available funds for the operational adoption of adaptation interventions to reduce the threat of climate variability to agriculture and food security in rural Ghana [109]. Also, farmers with farm insurance were more likely to adopt measures that reduce the impact of climate variability. The insurance goes beyond risk transfer to include measures that will help farmers reduce the risk and crop failure by stimulating reactive and proactive adaptation response. In terms of coping, farm insurance tends to provide a safety net for rainfed smallholder farmers amid climate shock or disaster. Although not statistically significant, the results revealed that off-farm income has a negative impact on farmers' ability to respond to climate variability. This suggests that rainfed farmers with access to off-farm income are less likely to adopt or implement adaptation interventions, as they have diversified or alternative sources of income and are not entirely dependent on climate-sensitive rainfed agriculture. Therefore, they may be less adaptive. Also, remittance was negative and unrelated to the rainfed farmer's adaptation decision. The reason may be that access to remittance is primarily to satisfy farmers' existential and subsistence needs instead of investing in agricultural production and adaptation.

4. Conclusion and policy implications

Climate variability is accelerating at a fast pace and challenges all sectors of the economy but for agricultural production and food security. The study posits that climate variability and trends affect crop yields at national, regional, and global levels with varied impacts on farmers depending on their location, crop type, resources, and safety nets. The farmers' observations and understanding of climate changes in the study align with scientific analysis of meteorological data. Over the past 30 years, farmers noticed higher temperatures and less rainfall with rippling effects on crop production and livelihoods. To better understand the reality of climate change, policymakers can learn about the perspectives of smallholder farmers and their experiences with climate conditions. This knowledge can encourage collaborative action to address climate change. This provides a roadmap for making climate adaptation decisions in agriculture that is practical and effective. It can help farmers develop innovative and sustainable solutions for adapting to climate change and building resilience.

The potential for transforming economies and everyday practices is hinged on more urgent participatory actions to effect behavioural, socio-political, and regulatory changes that support the status quo. As such, climate action through coping and adaptation cannot be ignored as it remains a living reality for millions of farmers. This makes climate understanding climate variability and trends an important feed for climate action across all levels of governance and policy. However, a lack of action or even ineffective action will lower the ability to sustain adaptation interventions for climate-resilient livelihoods and lifestyles. The study reports that rainfed farmers have applied multiple coping and adaptation strategies to avert climate conditions that lead to distress-driven crises. For instance, the findings suggest that rainfed farmers used various methods to deal with changes in the climate. Specifically, they employed six distinct coping and adaptation strategies out of a total of 20 coping practices and 36 adaptation practices. These include—cognitive restructuring, resource seeking, experiential avoidance, expressive coping, capital disinvestment and relying on social networks for coping and: farm and crop management, soil and water conservation, conservational agriculture practices, smart-farming practices and cropping decisions, livelihood diversification and indigenous knowledge for adaptation. This is important for increasing sustainability agendas in Ghana and developing countries respectively (e.g., SDSs particularly goals 1, 2 and 13; the NDCs, the Paris agreement etc). Planning for adaptation is now more important than ever in order to better take into account the lived experience of rainfed farmers, the ingrained local connections that underpin livelihoods, and the need to reduce such risks. The implication for policy is that policymakers could interrogate these key coping and adaptation practices used by farmers and upscale the best practices for effective and sustained use by farmers. These practices are locally generated and resonate with the local climatic conditions and realities, which could be robust in addressing climate change and variability if given the needed support. The study identified effective farming and adaptation practices that could be targeted for intervention to boost farmers' confidence and empower them to find solutions to their problems.

Finally, the decision to cope with or adopt these techniques in rural Ghana is motivated by multiple factors including market access, access to climate information/services, access to extension services, use of indigenous knowledge and practice, risk perception, and government support, livestock ownership, asset ownership, credit access, and farm insurance. The factors that influence how farmers in rural Ghana cope with and adapt to changes can help policymakers understand which actions are most effective. By prioritizing key drivers of adaptation, policymakers can focus their resources on the most important factors and reduce wasteful interventions. The study, therefore, recommends that further studies on the level of coping or adaptation by farmers having determined adaptation decisions will give policymakers an indication of what type of support and/or level of support can be offered to farmers for robust adaptation. At the farmer and community level, farmers whose livelihoods are threatened by climate change will require proper institutional training, support for alternative livelihoods, access to farm inputs and weather and climate information. Scaling up coping and/or adaptation practices necessitates a suitable enabling environment, which includes legislative and technical frameworks to assist smallholder farmers in overcoming barriers to adoption.

Credit author statement

Enoch Yeleliere: Conceived and design the experiments; performed the experiments; analysed and interpreted the data; wrote paper.

Philip Antwi-Agyei; Lawrence Guodaar: Performed the experiments; analysed and interpreted the data; contributed materials, analysis tools or data; wrote paper.

Data availability statement

The data used in the study is available on request.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

We would like to convey our sincere gratitude to all the study communities in the Wa East district of the Upper West Region who took part in the study and granted interviews. We appreciate the MoFA regional and district staff at Wa Municipal and Wa East for helping us choose the study communities. We sincerely thank Ghana Meteorological Agency (GMet), Accra, for sharing rainfall and temperature data with us.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e19656.

References

[1] Intergovernmental Panel on Climate Change (IPCC), Climate Change 2022: Impacts, Adaptation, and Vulnerability, 2022. https://www.ipcc.ch/report/ar6/wg2/. (Accessed 3 August 2022).
[2] W. Cramer, J. Guiot, M. Fader, J. Garrabou, J.P. Gattuso, A. Iglesias, E. Xoplaki, Climate change and interconnected risks to sustainable development in the Mediterranean, Nat. Clim. Change 8 (11) (2018) 972–980.
[3] Intergovernmental Panel on Climate Change (IPCC), Climate Change 2023: Synthesis Report Summary for Policymakers, 2023. https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf. (Accessed 13 June 2023).
[4] R. Hoffmann, R. Muttarak, J. Peisker, P. Stanig, Climate change experiences raise environmental concerns and promote Green voting, Nat. Clim. Change 12 (2) (2022) 148–155.
[5] World Meteorological Organisation (WMO), Global Temperature Anomalies Warmest Years in History, 2021. https://public.wmo.int/en/media/press-release/global-temperatures-set-reach-new-records-next-five-years. (Accessed 11 June 2023).
[6] S.B. Bedeke, Climate change vulnerability and adaptation of crop producers in sub-Saharan Africa: a review on concepts, approaches, and methods, Environ. Dev. Sustain. 25 (2) (2023) 1017–1051.
[7] E. Yeleliere, P. Antwi-Agyei, F. Baffour-Ata, Impacts of climate change on the yields of leguminous crops in the Guinea Savanna agroecological zone of Ghana, Regional Sustainability 4 (2) (2023) 139–149.
[8] Organisation for Economic Cooperation and Development/Food and Agricultural Organisation (OECD/FAO), Agriculture in sub-Saharan Africa: prospects and challenges for the next decade, OECD-FAO Agricultural Outlook 2025 (181) (2016) 1–39. https://espas.secure.europarl.europa.eu/orbis/sites/default/files/generated/document/en/a-i5778e.pdf.
[9] Intergovernmental Panel on Climate Change (IPCC), Special Report on Global Warming of 1.5°*C (SR1.5)*, 2018. https://www.ipcc.ch/sr15/. (Accessed 11 November 2021).
[10] R. Lamboll, V. Nelson, M. Gebreyes, D. Kambewa, B. Chinsinga, N. Karbo, A. Martin, Strengthening decision-making on sustainable agricultural intensification through multi-stakeholder social learning in sub-Saharan Africa, Int. J. Agric. Sustain. 19 (5–6) (2021) 609–635.
[11] B. Shiferaw, K. Tesfaye, M. Kassie, T. Abate, B.M. Prasanna, A. Menkir, Managing vulnerability to drought and enhancing livelihood resilience in sub-Saharan Africa: technological, institutional and policy options, Weather Clim. Extrem. 3 (2014) 67–79.
[12] J. von Braun, K. Afsana, L.O. Fresco, M.H.A. Hassan, Food systems: seven priorities to end hunger and protect the planet, in: Science and Innovations for Food Systems Transformation, Springer International Publishing, Cham, 2023, pp. 3–9.
[13] E. Yeleliere, P. Antwi-Agyei, A.B. Nyamekye, Mainstreaming Indigenous Knowledge Systems and Practices in Climate-Sensitive Policies for Resilient Agricultural Systems in Ghana, Society & Natural Resources, 2023, pp. 1–21.
[14] M. Shuaibu, M. Nchake, Impact of credit market conditions on agriculture productivity in Sub-Saharan Africa, Agric. Finance Rev. 81 (4) (2021) 520–534.
[15] E. Yeleliere, T. Yeboah, P. Antwi-Agyei, P. Peprah, Traditional agroecological knowledge and practices: the drivers and opportunities for adaptation actions in the northern region of Ghana, Regional Sustainability 3 (4) (2022) 294–308.
[16] F. Sinclair, A. Wezel, C. Mbow, S. Chomba, V. Robiglio, R. Harrison, The Contribution of Agroecological Approaches to Realizing Climate-Resilient Agriculture, GCA, Rotterdam, The Netherlands, 2019.
[17] E. Yeleliere, A.B. Nyamekye, P. Antwi-Agyei, E.F. Boamah, Strengthening climate adaptation in the northern region of Ghana: insights from a stakeholder analysis, Clim. Pol. 22 (9–10) (2022) 1169–1185.
[18] A. Alemayehu, W. Bewket, Smallholder farmers' coping and adaptation strategies to climate change and variability in the central highlands of Ethiopia, Local Environ. 22 (7) (2017) 825–839, https://doi.org/10.1080/13549839.2017.1290058.
[19] H. Nyantakyi-Frimpong, R. Bezner-Kerr, The relative importance of climate change in the context of multiple stressors in semi-arid Ghana, Global Environ. Change 32 (2015) 40–56, https://doi.org/10.1016/j.gloenvcha.2015.03.003.
[20] P. Antwi-Agyei, A.J. Dougill, J. Doku-Marfo, R.C. Abaidoo, Understanding climate services for enhancing resilient agricultural systems in Anglophone West Africa: the case of Ghana, Climate Services 22 (2021), 100218, https://doi.org/10.1016/j.cliser.2021.100218.
[21] B.Y. Fosu-Mensah, P.L. Vlek, D.S. MacCarthy, Farmers' perception and adaptation to climate change: a case study of Sekyedumase district in Ghana, Environ. Dev. Sustain. 14 (4) (2012) 495–505, https://doi.org/10.1007/s10668-012-9339-7.
[22] Ghana Statistical Service (GSS), Provisional Ghana Statistical Service (GSS) Released a Preliminary Report, 2021. https://census2021.statsghana.gov.gh/. (Accessed 8 February 2023).
[23] Ministry of Finance and Economic Planning (MoFEP), Composite Budget for 2020-2023 Programme Based Budget Estimates for 2020, Wa East District Assembly, 2020. https://mofep.gov.gh/sites/default/files/composite-budget/2020/UW/Wa-East.pdf. (Accessed 23 February 2022).
[24] Ministry of Food and Agriculture (MoFA), Agriculture in Ghana: facts and figures, in: Accra, Ministry of Food and Agriculture, first ed., 2018, 2018, http://mofa.gov.gh/site/. (Accessed 28 April 2022).
[25] W. Adzawla, A. Kane, Effects of climate shocks and climate adaptation through livelihood diversification on gendered welfare gaps in northern Ghana, IntJ Environ Climate Change 9 (2019) 104–119, https://doi.org/10.9734/IJECC/2019/v9i230100.
[26] E. Yeleliere, S.J. Cobbina, A.B. Duwiejuah, Review of Ghana's water resources: the quality and management with particular focus on freshwater resources, Appl. Water Sci. 8 (2018) 1–12.
[27] D.L. Morgan, Pragmatism as a paradigm for social research, Qual. Inq. 20 (8) (2014) 1045–1053.

[28] M. Yvonne Feilzer, Doing mixed methods research pragmatically: implications for the rediscovery of pragmatism as a research paradigm, J. Mix. Methods Res. 4 (1) (2010) 6–16.
[29] Environmental Protection Agency (EPA), Ghana's Fourth National Communication to the United Nations Framework Convention on Climate Change, Government of Ghana, 2020. https://unfccc.int/sites/default/files/resource/Gh_NC4.pdf. (Accessed 5 May 2022).
[30] J.L. Paulhus, M.A. Kohler, Interpolation of missing precipitation records, Mon. Weather Rev. 80 (8) (1952) 129–133.
[31] A.T. Kabo-Bah, C.J. Diji, K. Nokoe, Y. Mulugetta, D. Obeng-Ofori, K. Akpoti, Multiyear rainfall and temperature trends in the Volta river basin and their potential impact on hydropower generation in Ghana, Climate 4 (4) (2016) 49.
[32] J.W. Creswell, A Concise Introduction to Mixed Methods Research, SAGE publications, 2014.
[33] C.A. Moser, G. Kalton, Survey Methods in Social Investigation, Routledge, 2017.
[34] T. Yamane, Statistics: an Introductory Analysis, second ed., Harper and Row, New York, 1967.
[35] V. Braun, V. Clarke, Using thematic analysis in psychology, Qual. Res. Psychol. 3 (2) (2006) 77–101, https://doi.org/10.1191/1478088706qp063oa.
[36] H.F. Kaiser, J. Rice, Little jiffy, mark IV, Educ. Psychol. Meas. 34 (1) (1974) 111–117.
[37] M.S. Bartlett, Tests of significance in factor analysis, Br. J. Psychol. 3 (1950) 77–85.
[38] R.B. Pickson, G. He, Smallholder farmers' perceptions, adaptation constraints, and determinants of adaptive capacity to climate change in Chengdu, Sage Open 11 (3) (2021), 21582440211032638. https://journals.sagepub.com/doi/pdf/10.1177/21582440211032638.
[39] L. Roco, A. Engler, B.E. Bravo-Ureta, R. Jara-Rojas, Farmers' perception of climate change in mediterranean Chile, Reg. Environ. Change 15 (2015) 867–879.
[40] J.F. Hair, Multivariate Data Analysis, 2009.
[41] V. Karimi, E. Karami, M. Keshavarz, Climate change and agriculture: impacts and adaptive responses in Iran, J. Integr. Agric. 17 (1) (2018) 1–15.
[42] R. Nelson, P. Kokic, S. Crimp, P. Martin, H. Meinke, S.M. Howden, U. Nidumolu, The vulnerability of Australian rural communities to climate variability and change: Part II—integrating impacts with adaptive capacity, Environ. Sci. Pol. 13 (1) (2010) 18–27.
[43] P. Antwi-Agyei, J. Atta-Aidoo, P. Asare-Nuamah, L.C. Stringer, K. Antwi, Trade-offs, synergies and acceptability of climate smart agricultural practices by smallholder farmers in rural Ghana, Int. J. Agric. Sustain. 21 (1) (2023), 2193439.
[44] N. Arunrat, C. Wang, N. Pumijumnong, S. Sereenonchai, W. Cai, Farmers' intention and decision to adapt to climate change: a case study in the Yom and Nan basins, Phichit province of Thailand, J. Clean. Prod. 143 (2017) 672–685.
[45] P. Antwi-Agyei, E.M. Abalo, A.J. Dougill, F. Baffour-Ata, Motivations, enablers and barriers to the adoption of climate-smart agricultural practices by smallholder farmers: evidence from the transitional and savannah agroecological zones of Ghana, Regional Sustainability 2 (4) (2021) 375–386.
[46] A.A. Lopes, A. Viriyavipart, D. Tasneem, The role of social influence in crop residue management: evidence from Northern India, Ecol. Econ. 169 (2020), 106563.
[47] M. Esfandiari, H.R.M. Khalilabad, H.M. Boshrabadi, M.R.Z. Mehrjerdi, Factors influencing the use of adaptation strategies to climate change in paddy lands of Kamfiruz, Iran, Land Use Pol. 95 (2020), 104628.
[48] A. Belay, J.W. Recha, T. Woldeamanuel, J.F. Morton, Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia, Agric. Food Secur. 6 (1) (2017) 1–13.
[49] E.W. Mugi-Ngenga, M.W. Mucheru-Muna, J.N. Mugwe, F.K. Ngetich, F.S. Mairura, D.N. Mugendi, Household's socio-economic factors influencing the level of adaptation to climate variability in the dry zones of Eastern Kenya, J. Rural Stud. 43 (2016) 49–60.
[50] E. Bryan, C. Ringler, B. Okoba, C. Roncoli, S. Silvestri, M. Herrero, Adapting agriculture to climate change in Kenya: household strategies and determinants, J. Environ. Manag. 114 (2013) 26–35.
[51] T.T. Deressa, R.M. Hassan, C. Ringler, Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia, J. Agric. Sci. 149 (1) (2011) 23–31.
[52] G.A. Gbetibouo, Understanding Farmers' Perceptions and Adaptations to Climate Change and Variability: the Case of the Limpopo Basin, Intl Food Policy Res Inst, South Africa, 2009 vol. 849.
[53] M.I. Nor Diana, N.A. Zulkepli, C. Siwar, M.R. Zainol, Farmers' adaptation strategies to climate change in Southeast Asia: a systematic literature review, Sustainability 14 (6) (2022) 3639.
[54] M. Abid, A. Ali, M. Raza, M. Mehdi, Ex-ante and ex-post coping strategies for climatic shocks and adaptation determinants in rural Malawi, Climate Risk Management 27 (2020), 100200.
[55] T.T. Deressa, R.M. Hassan, C. Ringler, T. Alemu, M. Yesuf, Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia, Global Environ. Change 19 (2) (2009) 248–255.
[56] T.W. Abraham, W.M. Fonta, Climate change and financing adaptation by farmers in northern Nigeria, Financial innovation 4 (1) (2018) 1–17.
[57] Y. Nakano, T.W. Tsusaka, T. Aida, V.O. Pede, Is farmer-to-farmer extension effective? The impact of training on technology adoption and rice farming productivity in Tanzania, World Dev. 105 (2018) 336–351.
[58] R.M. Hassan, C. Nhemachena, Determinants of African farmers' strategies for adapting to climate change: multinomial choice analysis, African Journal of Agricultural and Resource Economics 2 (311–2016-5521) (2008) 83–104.
[59] B. Shiferaw, S.T. Holden, Resource degradation and adoption of land conservation technologies in the Ethiopian highlands: a case study in Andit Tid, North Shewa, Agricultural economics 18 (3) (1998) 233–247.
[60] M. Fishbein, I. Ajzen, Belief, Attitude, Intention, and Behavior: an Introduction to Theory and Research, 1977.
[61] B. Öhlmér, Models of Farmers' Decision Making. Problem Definition, Swedish Journal of Agricultural Research, 1998 *(Sweden)*.
[62] S. Jasanoff, States of Knowledge: Science, Power, and Political Culture, 2004.
[63] S.C. Moser, Communicating climate change: history, challenges, process, and future directions, Wiley Interdisciplinary Reviews: Clim. Change 1 (1) (2010) 31–53.
[64] A.P. Williams, R. Seager, J.T. Abatzoglou, B.I. Cook, J.E. Smerdon, E.R. Cook, Contribution of anthropogenic warming to California drought during 2012–2014, Geophys. Res. Lett. 42 (16) (2015) 6819–6828.
[65] C. Vaughan, S. Dessai, Climate services for society: origins, institutional arrangements, and design elements for an evaluation framework, Wiley Interdisciplinary Reviews: Clim. Change 5 (5) (2014) 587–603.
[66] S.S. Meijer, D. Catacutan, G.W. Sileshi, M. Nieuwenhuis, Tree planting by smallholder farmers in Malawi: using the theory of planned behaviour to examine the relationship between attitudes and behaviour, J. Environ. Psychol. 43 (2015) 1–12.
[67] Intergovernmental Panel on Climate Change (IPCC), Climate Change 2022: Synthesis Report Summary for Policymakers, 2007.
[68] I. Ajzen, The theory of planned behavior, Organ. Behav. Hum. Decis. Process. 50 (2) (1991) 179–211.
[69] P.C. Stern, T. Dietz, T. Abel, G.A. Guagnano, L. Kalof, A value-belief-norm theory of support for social movements: the case of environmentalism, Hum. Ecol. Rev. (1999) 81–97.
[70] J. Atta-Aidoo, P. Antwi-Agyei, A.J. Dougill, C.E. Ogbanje, E.K. Akoto-Danso, S. Eze, Adoption of climate-smart agricultural practices by smallholder farmers in rural Ghana: an application of the theory of planned behavior, PLOS Climate 1 (10) (2022), e0000082.
[71] F.J. Dessart, J. Barreiro-hurlé, R.V. Bavel, Behavioural factors affecting the adoption of sustainable farming practices, a policy-oriented review 46 (2019) 417–471.
[72] M.S. Kukal, S. Irmak, Climate-driven crop yield and yield variability and climate change impacts on the US Great Plains agricultural production, Sci. Rep. 8 (1) (2018) 1–18.
[73] P. Asare-Nuamah, E. Botchway, Understanding climate variability and change: analysis of temperature and rainfall across agroecological zones in Ghana, Heliyon 5 (10) (2019), e02654, https://doi.org/10.1016/j.heliyon.2019.e02654.
[74] N.A.B. Klutse, K. Owusu, F. Nkrumah, O.A. Anang, Projected rainfall changes and their implications for rainfed agriculture in northern Ghana, Weather 76 (10) (2021) 340–347, https://doi.org/10.1002/wea.4015.

[75] W.A. Atiah, F.K. Muthoni, B. Kotu, F. Kizito, L.K. Amekudzi, Trends of rainfall onset, cessation, and length of growing season in northern Ghana: comparing the rain gauge, satellite, and farmer's perceptions, Atmosphere 12 (12) (2021) 1674.
[76] National Oceanic and Atmospheric Administration (NOAA), National Centres for Environmental Information. 2021. Climate at a Glance: Global Time Series, 2021. https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/global/time-series.
[77] F. Baffour-Ata, P. Antwi-Agyei, E. Nkiaka, A.J. Dougill, A.K. Anning, S.O. Kwakye, Effect of climate variability on yields of selected staple food crops in northern Ghana, J Agri Food Res 6 (2021), 100205, https://doi.org/10.1016/j.jafr.2021.100205.
[78] B. Getachew, M. Teshome, Markov chain modeling of daily rainfall in lay gaint woreda, south gonder zone, Ethiopia, J Degraded and Mining Lands Management 5 (2) (2018) 1141.
[79] F. Ndamani, T. Watanabe, Determinants of farmers' adaptation to climate change: a micro level analysis in Ghana, Sci. Agric. 73 (2016) 201–208, https://doi.org/10.1590/0103-9016-2015-0163.
[80] L. Whitmarsh, S. Capstick, Perceptions of climate change, in: Psychology and Climate Change, Academic Press, 2018, pp. 13–33.
[81] S. Van der Linden, The social-psychological determinants of climate change risk perceptions: towards a comprehensive model, J. Environ. Psychol. 41 (2015) 112–124.
[82] C.L. Clarke, S.E. Shackleton, M. Powell, Climate change perceptions, drought responses and views on carbon farming amongst commercial livestock and game farmers in the semiarid Great Fish River Valley, Eastern Cape province, South Africa, Afr. J. Range Forage Sci. 29 (1) (2012) 13–23.
[83] E. Simelton, C.H. Quinn, N. Batisani, A.J. Dougill, J.C. Dyer, E.D. Fraser, L.C. Stringer, Is rainfall really changing? Farmers' perceptions, meteorological data, and policy implications, Clim. Dev. 5 (2) (2013) 123–138.
[84] K. Caldwell, C.P. Boyd, Coping and resilience in farming families affected by drought, Rural Rem. Health 9 (2) (2009) 1–10. https://doi/10.3316/informit.496419638887416.
[85] H. Karimi, P. Ataei, Farmers' cultural biases and adaptation behavior towards drought: a case in sistan plain, J. Agric. Sci. Technol. (2022) 791–807.
[86] E. Assan, M. Suvedi, L. Schmitt Olabisi, A. Allen, Coping with and adapting to climate change: a gender perspective from smallholder farming in Ghana, Environments 5 (8) (2018) 86, https://doi.org/10.3390/environments5080086.
[87] J.F. Helgeson, S. Dietz, S. Hochrainer-Stigler, Vulnerability to weather disasters: the choice of coping strategies in rural Uganda, Ecol. Soc. 18 (2) (2013). https://www.jstor.org/stable/26269323?seq=1&cid=pdf-.
[88] J.P. Reser, J.K. Swim, Adapting to and coping with the threat and impacts of climate change, Am. Psychol. 66 (4) (2011) 277. https://psycnet.apa.org/buy/2011-09485-004.
[89] D.K. Macon, S. Barry, T. Becchetti, J.S. Davy, M.P. Doran, J.A. Finzel, L.M. Roche, Coping with drought on California rangelands, Rangelands 38 (4) (2016) 222–228, https://doi.org/10.1016/j.rala.2016.06.005.
[90] D.S. Thomas, C. Twyman, H. Osbahr, B. Hewitson, Adaptation to climate change and variability: farmer responses to intra-seasonal precipitation trends in South Africa, Climatic Change 83 (3) (2007) 301–322, https://doi.org/10.1007/s10584-006-9205-4.
[91] A. Quandt, Coping with drought: narratives from smallholder farmers in semi-arid Kenya, Int. J. Disaster Risk Reduc. 57 (2021), 102168, https://doi.org/10.1016/j.ijdrr.2021.102168.
[92] W.N. Adger, J. Barnett, Four reasons for concern about adaptation to climate change, Environ. Plann. 41 (12) (2009) 2800–2805.
[93] R.N. Armah, R.M. Al-Hassan, J.K. Kuwornu, Y. Osei-Owusu, What influences farmers' choice of indigenous adaptation strategies for agrobiodiversity loss in Northern Ghana? (2013).
[94] B.K. Kogo, L. Kumar, R. Koech, Climate change and variability in Kenya: a review of impacts on agriculture and food security, Environ. Dev. Sustain. 23 (1) (2021) 23–43, https://doi.org/10.1007/s10668-020-00589-1.
[95] B. Adolph, M. Allen, E. Beyuo, D. Banuoku, S. Barrett, T. Bourgou, A.F. Zongo, Supporting smallholders' decision making: managing trade-offs and synergies for sustainable agricultural intensification, Int. J. Agric. Sustain. 19 (5–6) (2021) 456–473.
[96] C. Thierfelder, L. Rusinamhodzi, A.R. Ngwira, W. Mupangwa, I. Nyagumbo, G.T. Kassie, J.E. Cairns, Conservation agriculture in southern Africa: advances in knowledge, Renew. Agric. Food Syst. 30 (4) (2015) 328–348.
[97] S. Ghazali, H. Azadi, K. Janečková, P. Sklenička, A. Kurban, S. Cakir, Indigenous knowledge about climate change and sustainability of nomadic livelihoods: understanding adaptability coping strategies, Environ. Dev. Sustain. 23 (11) (2021) 16744–16768, https://doi.org/10.1007/s10668-021-01332-0.
[98] F. Dapilah, J.Ø. Nielsen, K. Lebek, S.A.L. D'haen, He who pays the piper calls the tune: understanding collaborative governance and climate change adaptation in Northern Ghana, Climate Risk Management 32 (2021), 100306, https://doi.org/10.1016/j.crm.2021.100306.
[99] W.L. Filho, F. Wolf, E. Totin, L. Zvobgo, N.P. Simpson, K. Musiyiwa, D.Y. Ayal, Is indigenous knowledge serving climate adaptation? Evidence from various African regions, Dev. Pol. Rev. 41 (2) (2023), e12664.
[100] F. Atube, G.M. Malinga, M. Nyeko, D.M. Okello, S.P. Alarakol, I. Okello-Uma, Determinants of smallholder farmers' adaptation strategies to the effects of climate change: evidence from northern Uganda, Agric. Food Secur. 10 (1) (2021) 1–14, https://doi.org/10.1186/s40066-020-00279-1.
[101] B. Vorley, M. Lundy, J. MacGregor, Business models that are inclusive of small farmers, in: Agro-industries for Development, CABI, Wallingford UK, 2009, pp. 186–222.
[102] P.S. Birthal, D.S. Negi, M.T. Khan, S. Agarwal, Is Indian agriculture becoming resilient to droughts? Evidence from rice production systems, Food Pol. 56 (2015) 1–12.
[103] R. Hill, F.J. Walsh, J. Davies, A. Sparrow, M. Mooney, C.L. Council, M. Tengö, Knowledge co-production for Indigenous adaptation pathways: transform post-colonial articulation complexes to empower local decision-making, Global Environ. Change 65 (2020), 102161.
[104] T.G. Conley, C.R. Udry, Learning about a new technology: pineapple in Ghana, Am. Econ. Rev. 100 (1) (2010) 35–69.
[105] M. Burnham, Z. Ma, Climate change adaptation: factors influencing Chinese smallholder farmers' perceived self-efficacy and adaptation intent, Reg. Environ. Change 17 (2017) 171–186.
[106] C.M. Tucker, H. Eakin, E.J. Castellanos, Perceptions of risk and adaptation: coffee producers, market shocks, and extreme weather in Central America and Mexico, Global Environ. Change 20 (1) (2010) 23–32.
[107] B.M. Campbell, S.J. Vermeulen, P.K. Aggarwal, C. Corner-Dolloff, E. Girvetz, A.M. Loboguerrero, E. Wollenberg, Reducing risks to food security from climate change, Global Food Secur. 11 (2016) 34–43.
[108] L.C. Stringer, E.D. Fraser, D. Harris, C. Lyon, L. Pereira, C.F. Ward, E. Simelton, Adaptation and development pathways for different types of farmers, Environ. Sci. Pol. 104 (2020) 174–189.
[109] J. Hansen, J. Hellin, T. Rosenstock, E. Fisher, J. Cairns, C. Stirling, B. Campbell, Climate risk management and rural poverty reduction, Agric. Syst. 172 (2019) 28–46.

Enoch Yeleliere is a commonwealth scholar and holds an MSc and MPhil in Environmental Management from Sheffield Hallam University, United Kingdom and Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. His research interest is in climate change adaptation, collaborative dynamics in climate governance and policy perspective using innovative and multi-scale research methodologies. orcid.org/0000-0003-3126-9021

Prof Philip Antwi-Agyei is a senior lecturer at the Department of Environmental Science, College of Science, Kwame Nkrumah University of Science and Technology. He was a Lead Author for the Intergovernmental Panel on Climate Change (IPCC) Special Report on the impacts of global warming of 1.5 C above pre-industrial levels and has published in leading international journals including nature climate. He is an interdisciplinary environmental scientist whose research involves developing innovative multi-scale approaches for assessing vulnerability to climate change for dryland farming systems. orcid.org/0000-0002-8599-474X

Lawrence Guodaar (PhD.) is a lecturer at the department of Geography and Rural Development, College of Humanities and Social Sciences, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. He is an interdisciplinary researcher whose research output has been published in leading scientific research journals. Lawrence research is focused on climate change adaptation and food security in indigenous societies in sub-Sahara Africa and Ghana.