

Does climate information source matter in smallholder farmers' climate resilience? Comparative insights from Malawi and Ghana[☆]

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ABSTRACT

Due to increasing climate variability and change, the need for more accessible, timely, and reliable climate information has risen, particularly in African rain-fed smallholder farming communities. Yet, studies on the role of information sources in climate resilience are limited. Given the plurality of climate information sources, it is uncertain which medium offers better chances to build resilience against the changing climate. To fill this gap, we employed quantitative survey data from smallholder agricultural households in the Mzimba District in Malawi ($n = 1090$) and the Upper West Region of Ghana ($n = 1100$). Our findings reveal that in Malawi, households whose primary source of climate information was the mass media ($OR = 2.37$; $p \leq 0.001$) and external organizations (government, private sector, and nonprofit sector) ($OR = 2.11$; $p \leq 0.001$) were over two times more likely to rate their resilience as good compared to those who relied primarily on self-experience. While in Ghana, interpersonal sources (other farmers, friends/relatives, special activities by the community) significantly increased a household's odds ($OR = 3.46$; $p \leq 0.001$) of reporting good resilience, while external sources reduced farmers' likelihood of reporting climate resilience ($OR = 0.06$; $p \leq 0.001$) compared to those who relied primarily on self-experience. Farmers in Malawi who practiced intercropping were also more likely to rate their resilience as good than those engaged in monocropping. The findings suggest that the relevance of information sources on climate change resilience is place-specific and that some sources may impede resilience-building if contextual factors are sidelined. This finding reaffirms the need for context-specific policies due to the heterogeneity of agrarian communities across Africa.

1. Introduction

Agriculture remains a crucial sector for poverty eradication, rural development, and livelihood sustenance in sub-Saharan Africa (SSA) (Shimeles et al., 2018). While 53% of the population in SSA are employed in the agricultural sector (Food and Agriculture

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Organization of the United Nations [FAO], 2018), this figure masks spatial variations between countries and rural and urban areas. Malawi, for instance, has an agriculture sector that employs 80% of the population and contributes about 25% of the country's gross domestic product (GDP) (World Bank, 2021). Given the centrality of agriculture in many SSA countries, the industry represents one of the critical pathways to sustainable livelihoods and rural development. Yet, the agricultural sector remains vulnerable amid increasing climate change stressors in SSA, hindering their capacity to maximize the full potential of agriculture (Kotir, 2011; Zadawa and Omran, 2020).

Climate change resilience denotes a system's (i.e., a country's, community's, or household's) ability to anticipate, absorb, and recover from climate-related stressors without comprising the system's function (Folke, 2006; Ruiz-Ballesteros and Ramos-Ballesteros, 2019). Amid rising climatic stressors in SSA, current literature suggests that the threat of climate change outpaces current adaptations and resilience efforts, especially amongst smallholder farming communities (Adaawen, 2021; Thompson et al., 2010). For predominantly rain-fed agricultural contexts like SSA, access to relevant, reliable, and valuable climate information is crucial for improving farm productivity and avoiding crop failure (Ahmed et al., 2013; Boyd et al., 2013). Rising climatic variability, droughts, erratic rainfall, severe storms, and other environmental hazards could jeopardize agricultural productivity without proper anticipation and on-farm preparations (Intergovernmental Panel on Climate Change [IPCC], 2021). For example, rainfall variability and increases in mid-season dry-spells are linked to crop failure (Kyei-Mensah et al., 2019; Mbow et al., 2019), seed insecurity (McGuire and Sperling, 2013), and food insecurity (Dickerson et al., 2021; Tankari, 2020). Similarly, an increase in temperatures has the potential to trigger elevated levels of evapotranspiration and wildfires and establish an environment conducive for the breeding of novel pests, pathogens, and diseases, which can adversely affect crop development and yield (Hatfield et al., 2011; Nkomwa et al., 2014).

Climate information is of utmost importance in enhancing agricultural productivity. Amid rising climatic stressors, farmers must actively seek for such information, including yearly climate outlook, and agro-meteorological advisories, to stay informed and to enhance their skills (Elly and Silayo, 2013; Ndimbwa et al., 2021; Oladele, 2015). To boost productivity, there is a need for the co-production of timely and reliable information on rainfall patterns, crop types, production techniques, and market information (Milovanović, 2014), as well as locally appropriate farming practices, post-harvest loss mitigation, credit access, and general farm planning (Sam et al., 2017). A study in Malawi found that farmers with access to nutrition information reported higher household dietary diversity scores and were more food secure (Ragasa et al., 2019). Meanwhile, Boyd et al.'s (2013) study of rainfall variability in the African Sahel revealed that the *rain watch* project, an early warning prediction system that provided farmers with accurate rainfall predictions, contributed to building climate resilience among farming households. Yet, a key driver of agricultural vulnerability in Ghana (Dankwah and Hawa, 2014; Sam et al., 2017), Malawi (Phiri et al., 2019; Ragasa and Kaima, 2017), and elsewhere (Elly and Silayo, 2013; Mtenga, 2021; Parmar et al., 2019) is attributed to the insufficient access to climate information. Farmers face constraints that limit their access to critical and relevant climate information. These constraints include the lack of timely access, unawareness of the availability of climate information, complicated television programming, sporadic extension service visitations, illiteracy, and language barriers (Amadu, 2022; Naveed and Hassan, 2020). The needs and constraints of smallholder farmers are precise, but the extent to which these information sources contribute to climate resilience is uncertain. Addressing the information needs of smallholder farmers by exploring the different information sources available to them to determine which medium offers the best chances for resilience may be one of the crucial steps to future-proofing Africa's agricultural potential in the face of climatic uncertainty.

Despite numerous sources of climate information, a significant yet unanswered question is: Do the smallholder farmers in harsh-climatic zones in SSA access adequate climate information from mass media, interpersonal sources, and external sources, and does this information improve adaptation to climate change stressors? This paper examines the different types of climate information sources available to smallholder farmers to determine how these sources affect a household's resilience to climate change stressors such as extreme droughts, floods, storms, and erratic rainfall. Amid looming climatic catastrophes, mapping and tailoring information sources to specific farmers may be critical for climate change resilience. Generating nuanced knowledge of the realities of farmers' information access in Africa, particularly the disaggregation of information sources, could reveal complexities not seen previously. Due to the significant variability in farmers' information access in emergency scenarios (see Abukari et al., 2021), we use Malawi and Ghana as the focal areas because of their relatively stable democracies and similar rural-urban dynamics, freedom of the press, and peace and security. These stable countries are ideal for studying the relative strength of each information medium and the spatiality of climate information sources.

Findings from this study provide novel, disaggregated data that can better fit public policy to the needs of communities and countries. Given the limited budgetary allocations for climate knowledge co-development that often characterizes many SSA governments, our findings could aid in effective agricultural policy planning that leverages the co-development of climate information between smallholder farmers and other stakeholders to improve resilience to climate change. The subsequent section presents the theoretical framework and a brief overview of the study areas to elucidate the physical, economic, and sociocultural context we situate our study. We then proceed with the methodology to thoroughly discuss our data collection process, methods, and materials. The results are then presented, followed by a discussion of the findings.

2. Theoretical framework: resilience thinking

This study draws insights from developments in the resilience literature. Although a concept with an extensive application history in several fields at its core, resilience has often tried to answer one fundamental question: Why do some systems or objects perform better or maintain their functionality even in common external perturbations? From the earlier origins of resilience in physics and true to its Latin roots, the concept focused on the notion of "bouncing back," which denotes a spring's ability to expand or contract to its original state when pulled or released (Pizzo, 2015). In this setting, a more resilient system was characteristic of malleability and

quicker recovery times. A critical period in the historical evolution of resilience can be attributed to the pioneering research on ecological systems, where C.S. Holling (1973) explains resilience to mean the capacity of a “system to withstand and adapt to changes in state variables, driving variables, and parameters, and still persist” (p. 17).

Several domains in the social sciences, starting earlier in psychology and later in sociology and human geography (Davoudi et al., 2013), also adapted resilience—coined as “social resilience”—to interrogate how individuals and groups cope and recover from crises while identifying key attributes that facilitate this process (Kelly and Adger, 2000). Carl Folke and other scholars later called for recognizing the inseparability of sociopolitical systems and the environment in deploying social resilience (Folke et al., 2003; Kelly and Adger, 2000; Mahmood, 2016). Heading to environmental considerations of resilience, “socio-ecological resilience” (SER) has emerged since the late 1990s as a robust analytical framework in human-environmental relations. However, unlike the “bouncing-back” perception that previously underpinned resiliency, SER instead comes from a “bouncing-forward” perception characterized by iterative adaptation and transformation (Scott, 2013). Consistent with this conceptualization, the IPCC (2018) defines resilience as the ability of a “social, ecological, or socio-ecological system and its components to anticipate, reduce, accommodate, or recover from the effects of a hazardous event or trend in a timely and efficient manner, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation” (p. 557).

Resilience is thus a dynamic evolutionary process that entails developing the capacity to minimize crises and maximize opportunities simultaneously (Fingleton et al., 2012). Referring to the two pillars of SER mentioned earlier is relevant to situating any further discussion. According to Walker and Salt (2012), adaptation connotes behavioral adjustments, typically through gradual changes and learning from prior hindrances, in order to lessen crisis and vulnerability, whereas transformation requires dramatic adjustments that may jeopardize the system’s survival (Darnhofer, 2014). Nonetheless, it is crucial to note that the capacity for adaptation or transformation is not inherent. Instead, the development of adaptive and transformational skills is contingent upon the access to capital—human, social, natural, physical, and financial (Scoones, 1999)—and the potential for their acquisition within an environment characterized by heightened exposure and susceptibility.

In analyzing smallholder agriculture and rural livelihoods, resilience encompasses the diverse capital that smallholder farmers can access to continually benefit from the natural environment despite the rapidly declining conditions. This study conceptualizes climate information as a form of capital with a symbiotic relationship with all five categories. Our interest in associating smallholder resilience with climate information is underscored by the co-evolving nature and availability of relevant information significantly influences the synergies between the interconnectedness of climatic and ecological systems. Further, place-based characteristics, which are shown to substantially facilitate or impede resilience building (Wilson, 2010), are also a function of capitals, and their variety thereof is available and culturally acceptable (Klein et al., 2015). Smallholders can build resilience by transforming their agricultural practices to harmonize them with the ecological carrying capacities of available natural resources. However, this potential cannot be realized without adequate information—scientifically informed, apolitical, timely, contextual, relatable, and understandable—against which they can make critical and weighted decisions (Daniels et al., 2020).

3. Materials and methods

3.1. Study context

This study is based on farmer insights from Malawi’s Mzimba District (MD) in South-Eastern Africa and Ghana’s Upper West Region (UWR) in West Africa. The MD and the UWR are agricultural regions, with smallholder agriculture employing approximately 80% of the population (CIAT & World Bank, 2018; GSS, 2019). Furthermore, the collective impact of rainfed agriculture, rising capitalist monocultural agriculture, and minimal irrigational development makes these regions highly vulnerable and susceptible to climate change (see Mumin, 2017; Mwase et al., 2014).

The MD, located in Northern Malawi, is the largest in terms of total land area, despite being among the most sparsely populated regions of the country, with a population density of 111/km² (Malawi Statistical Office, 2019). The predominant soil type is sandy-loamy, and temperatures range between 27 °C and 33 °C in the cropping season, making it suitable for cultivating staple crops, including maize, cassava, groundnuts, soya, and cowpea, and cash crops like tobacco. But, in the winter months, temperatures drop significantly and range between 0 °C and 10 °C. The rainfall season is usually between November and May. Notwithstanding the increased unpredictability in the rainfall regime, rainfall amounts fluctuate between 650 mm and 1300 mm (Li et al., 2017; Mzimba District Planning Department, 2008). Similar to Ghana, Malawi is considered a relatively peaceful country that has maintained political stability since attaining independence in 1964. Agriculture contributes to a large portion of employment in rural areas. Moderate and severe food insecurity declined in 2021 (World Bank, 2021), though the poorest populations continue to be the most food insecure. The poverty rate in MD stands at 51%, mirroring the national poverty rate of 50.7%. However, poverty and inequality persist at elevated levels, especially in rural MD (Malawi Statistical Office, 2019; World Bank, 2021).

Located in North-Western Ghana, the UWR has a unimodal rainfall season that starts in April and ends in October, and records about 800 mm–1000 mm as one moves North to South in the region (Mwinkom et al., 2021). Temperatures also typically range between 35 °C and 40 °C (Ghana Statistical Service [GSS], 2014). Some authors contend that the UWR’s climatic sensitivity and inadequate adaptation capability have resulted in rising food insecurity and deteriorating health over time, affecting both children and adults (Atuoye and Luginaah, 2017; Kuire et al., 2013). Other negative socioeconomic markers that have been associated with the region, including high multidimensional poverty (65.5%) and illiteracy (54%) rates, are also among the highest in the country (GSS, 2020; 2021). In comparison, MD has a literacy rate of 75% (Government of Malawi, 2020). The UWR’s persistent deprivation is the cumulative consequences of harsh climatic conditions and the legacy of colonial policy prescriptions in post-independence Ghana

(Songsore, 2011).

The high incidence of poverty and relative underdevelopment in MD and the UWR has been traced to many factors, including land grabbing (Nyantakyi-Frimpong and Bezner Kerr, 2017), disparate access to agricultural inputs (Kansanga, 2017) and gender disparities in access to resources (Bezner Kerr, 2014; Fisher and Kandiwa, 2014) and outmigration (Baada et al., 2021; Luginaah et al., 2009). Male outmigration in search of wage labour remains a critical livelihood activity in our study context in Malawi (Kangmennaang et al., 2018) and Ghana (Baada et al., 2021). During the lean season in Northern Ghana, many farmers (typically, rural male youths) from the UWR travel to the country's southern regions. Their goal is to make the most of the second agricultural season, by engaging in shared cropping agreements or working as wage laborers in order to send food and money back to their families (Luginaah et al., 2009). In Malawi, however, farmers (mostly men) tend to migrate outside of the country, primarily to South Africa, in pursuit of non-farm employment opportunities (Kangmennaang et al., 2018). Both MD and UWR practice the patrilineal system of inheritance. Men often inherit and wield custodial rights over land under patrilineal land tenure systems. In many cases, women can only obtain usage rights through male relatives like husbands, brothers, and sons (Bezner Kerr, 2005; Kansanga et al., 2019).

Geographically, UWR is relatively isolated compared to MD. For instance, UWR is approximately 750 km from the nation's capital, Accra, making it the remotest region in Ghana (GSS, 2021). About 85% of the people live in rural areas. The region has some of the worst road networks in Ghana (typically unpaved feeder roads), making access to essential services including healthcare centers, schools, markets, and extension services difficult (Atuoye et al., 2015; World Bank, 2022). In contrast, MD is about 290 km to Lilongwe, the capital city of Malawi. The relative proximity to administrative capitals has implications for timely diffusion of information and resources, especially for regions in sub-Saharan African that are characterized by poor road and telecommunication infrastructure (World Bank 2021, 2022). A World Bank study assessed that Malawi is also characterized by extensive road connectivity with most villages in MD situated in proximity to major highways (Lall et al., 2009). These highways serve as a crucial link, connecting the villages to various trading centers and major cities, and government agencies.

Information access is a significant factor for smallholders in Ghana and Malawi and one of the structural impediments to climate change resilience. In Malawi, for instance, the Ministry of Agriculture, Irrigation and Water Development (2016) reports that bridging the gap between information availability and farmers' adoption and utilization remains a crucial problem in the fight against climate change. Particularly, Malawi suffers from a shortage of extension service workers in largely undeveloped areas like the MD. The case is somewhat similar in the UWR. Extension service workers tend to concentrate their presence and services in the urban and peri-urban areas of the UWR, leaving the rural areas underserved, even though a significant number of the region's farmers reside in rural UWR (Anaglo et al., 2014). Access to and knowledge of smart technology for agriculture information is significantly low, especially for female farmers, which may be partly driven limited information sources (Anaglo et al., 2014; Etwire et al., 2017). This context presents a compelling case to investigate the link between farmers' principal climate information sources and their resilience outcomes.

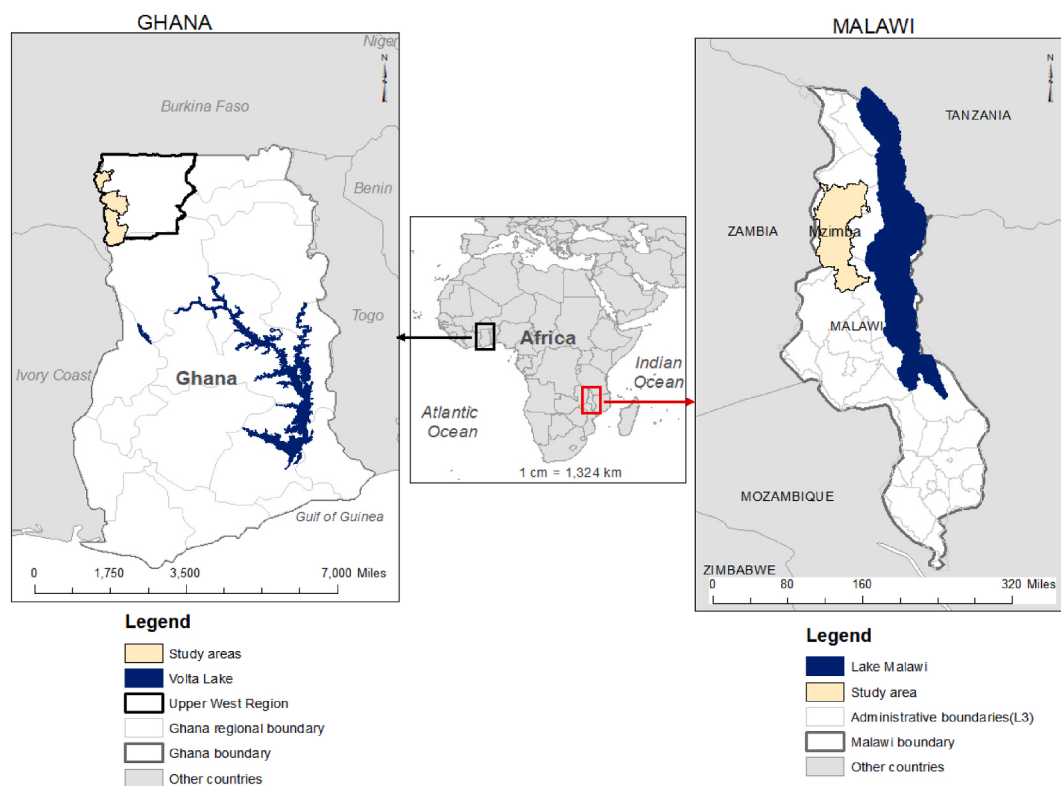


Fig. 1. Maps of Ghana and Malawi showing the study areas.

3.2. Data and sampling

The choice of study areas was informed by national data on climate change and variability. The [Ministry of Food and Agriculture \(2016\)](#) report considered the UWR the most susceptible to climate extremes in Ghana. In Malawi, the Ministry of Food Security, Irrigation and Water Development ([Government of Malawi, 2017](#)) also identified Northern Malawi as one of the regions most vulnerable to climatic impacts. This study used a multi-stage systematic sampling approach. First, a purposive sampling technique was used to select the study communities: Wa West, Nadowli-Kaleo, and Lawra in Ghana's UWR, and the MD in Malawi. In choosing these districts, we intended to capture the local vertical climatic variability of the region (seen in [Fig. 1](#)). Next were the sample villages (32 in UWR; 30 in MD), selected based on a gradient of semi-natural habitats within a 1 km radius surrounding the study site. The rationale was to keep the sample locations about 2 km apart to prevent spatial autocorrelation. Overall, data from this study come from 2190 smallholder farming households gathered from Malawi and Ghana. Of the total number, 1090 farming households in 30 villages in MD make up the Malawian sample, while 1100 households from three districts (Lawra, Nadowli-Kaleo, and Wa West) in the UWR constitute the Ghanaian sample. In both study areas, we employed systematic sampling whereby from the entry point of each village, every fifth house was selected to participate in the survey. The study targeted 1100 farmers in both countries. However, 10 surveys in Malawi were discontinued midway by respondents due to the respondent having other activities to carry out, leading to 1090 responses.

The data were collected in Malawi as part of a Farmer-led Agroecological Research using Scenarios for Biodiversity and Ecosystem Services (FARMS4Biodiversity) project and in Ghana through the Farmer Livelihoods and Agricultural Production (FLAP) project. To reduce recall bias, data were collected when farmers were preparing for the upcoming planting season, including accessing the latest information on agriculture. Hence, the data were collected between July and August 2019 in Malawi and in Ghana between February and March 2019.

In Ghana and Malawi, our research team consisted of the principal investigator, two co-investigators and six research assistants (RA). The Ghana survey employed a team of six RAs, with two members in each team, representing the three sampled districts. In Ghana, a key criterion was that RAs reside in their select district and must have obtained higher education. This ensured that they were familiar with the local context and had a high degree of command over English and the local language. In Malawi, however, the six RAs were recruited from a notable NGO operating in Mzimba District where they worked as Community Promoters. Despite the RA's depth of knowledge of the study contexts, they underwent five days of intensive training on the survey instrument, ethical considerations and other data collection protocols which was led by the lead investigator. The RAs underwent training with survey instruments provided in both English and the local languages (Tumbuka or Dagaare), with questionnaire translation carried out by language experts in their respective countries.

Following the training, we pretested our survey questions in two farming communities each in MD and the UWR, distinct from those chosen for the survey. After pretesting, the necessary technical and linguistic adjustments were made, including rectifying ambiguities, ensuring that the questions were understandable to the farmers and rectifying any cultural insensitivities. This process also exposed us to different response formats and helped us to present the questions in a coherent and organized way. A community entry ritual was performed in each community before data collection. This involved meeting with the community leaders (e.g., chiefs or traditional authorities) to introduce ourselves, explain our purpose and to seek permission to undertake the research. We also reiterated that participation in the research was strictly voluntary and that respondents were free to end the survey at any time. The research questionnaire was administered to only participants who consented to the study. Oversight was provided by the investigators who were on site. This involved field visits, monitoring Qualtrics—the data-collection platform—in real-time, and providing refresher training to RAs as needed, and addressing issues or misunderstanding that arise.

Data collection involved the in-person administration of structured questionnaires targeting household heads or their representatives. The RAs administered the questionnaires in the local languages (Tumbuka and Dagaare) to the identified participants. This ensured that language barriers and power imbalance challenges were minimized. Overall, the surveys covered central themes on smallholder livelihoods, such as crop production factors, food security, climate change resilience, crop management practices, seed varieties and seed sources, agroecological practices, and agriculture information access and utilization. Ethical approval was sought from Western University's Research Ethics Board.

3.3. Measures

Our dependent variable is self-rated resilience to climate stressors. This measure has been shown to be an accurate subjective depiction of a household's ability to evaluate its resilience to climate change and variability following exposure ([Jones and Samman, 2016](#); [Jones et al., 2018](#); [Mohammed et al., 2021](#)). The question asked was, "how will you rate your household's resilience to climate change¹" with standard response categories of "good," "satisfactory," or "poor." Although historically, understanding climate change resilience in the context of rural households has been measured using secondary data, spatial datasets, and standardized biophysical data ([Chun et al., 2017](#); [Duveneck and Scheller, 2016](#); [Leandro et al., 2020](#)), we contend that it is important to also take into consideration the depth of knowledge that agrarian households hold regarding their resilience. Another benefit of using a self-reported

¹ Consistent with [Jones et al. \(2018\)](#), resilience to climate change in this context was explained to the farmers to mean their capacity to prepare, capacity to recover, and capacity to adapt to climatic stressors (floods, severe storms, droughts, and erratic rainfall), and their access to early warning information.

measure is that it circumnavigates the inordinate data unavailability challenges that often characterize climate change studies in SSA (Jones and Tanner, 2015).

The focal independent variable, “primary information source,” is determined by asking respondents: What is your primary source of climate information? We explained to farmers that climate information comprised: long-term weather information; seasonal climate outlooks, including predictions about weather patterns and climatic conditions in short and long periods; agro-meteorological advisories, such as crop management practices that hinge on current and anticipated weathers and climatic conditions; early warning systems that alert farmers regarding upcoming extreme weather events; climate smart-agricultural information sharing, including on agroecology and water management practices; and information on training and capacity building, and knowledge sharing sessions on climate-related information. The options were: self-experience, friends and relatives, other farmers, nonprofits, radio, TV, government, special activities by the community, newspaper, and private sector. Based on existing literature, the information sources were sub-categorized into four main groups: 1 = self-experience, 2 = mass media (TV, radio, newspaper), 3 = interpersonal sources (other farmers, friends/relatives, special activities by the community), 4 = external sources (government, private sector, nonprofit sector). Consistent with Ndimbwa et al. (2021), interpersonal sources refer to all those avenues where information (and the financial resources required) is generated from within the community, while external sources constitute avenues where information and financing are developed outside the community.

Drawing insights from climate change resilience and smallholder agriculture literature (Batung et al., 2021, 2022; Lwoga et al., 2011; Mtega, 2021; Ruzzante et al., 2021), we identified some covariates, which we categorized under two groupings: socioeconomic and cultural factors (education, wealth, household labor, credit, remittances); and agricultural-related factors (experience of climate stressors, cropping type, decision-making). We also identified demographic factors (age, gender, marital status, household size, and household type) as our control variables. The demographic variables were coded as follows: Gender of household head (0 = female; 1 = male) and age (1 = 15–25; 2 = 26–35; 3 = 36–45; 4 = 46–59; and 5 = 60 and older). Household income was measured using a composite scale of household assets such as tractors, cars, motorbikes, hoes, TVs, and radios (Atuoye et al., 2019; Mohammed et al., 2021). Educational attainment measured the highest level of education a productive household member achieved and was also categorized as (1 = no education/preschool; 2 = primary; 3 = secondary; 4 = tertiary). The household types were (1 = nuclear family; 2 = extended family; 3 = household with an absent father; 4 = household with an absent mother). Household decision-making structure, which was used as a proxy for gender equity, was categorized as (1 = male head only; 2 = female head only; 3 = joint-decision-making) (Batung et al., 2021; Mohammed et al., 2022). Households’ access to credit, as seen in Batung et al. (2022), was as follows: (1 = no access, 2 = informal credit sources (i.e., family and friends, local lenders), and 3 = formal sources (i.e., regulated financial institutions). Climatic events and environmental exposures reported in the last 12 months by farmers were also composed of “severe storms,” “erratic rainfall,” “droughts,” and “floods” and measured as binary (1 = yes or 2 = no) responses. Lastly, we accounted for the type of farming activity the households engaged in (1 = monocropping; 2 = intercropping). Responses with missing variables were dropped, resulting in 1090 respondents in Malawi and 1100 in Ghana.

3.4. Analytical approach

We analyzed our data by employing univariate analysis and ordered logistic regression to explore the correlation between different information sources accessed by farmers on household resilience. Descriptive statistics were used to describe the sample attributes by calculating the mean and percentages. In addition to descriptive statistics, we ran bivariate and multivariate logistic regression analyses. We used bivariate ordered logistic regression (Table 2) to assess the independent relationship between all predictors and perceived climate change resilience. At the multivariate level, nested models were used, including only demographic factors, socioeconomic and cultural factors, and environmental exposures and on-farm factors. These variables have been demonstrated to strongly affect household resilience (Jones et al., 2018; Mohammed et al., 2021). The regression equation is adopted from Hedeker et al. (2000) and given as follows:

$$\log \frac{P(Y_{ij} \leq 1)}{(1 - P(Y_{ij} \leq 1))} = a_0 + \sum_{k=1}^{p-1} (a_{jk} X_{ijk} + V_{ij}, C = 1, \dots, \Omega - 1)$$

$P(Y_{ij} \leq 1)$ represents the probability that a household will report good resilience (versus reporting satisfactory or poor resilience). $(1 - P(Y_{ij} \leq 1))$ denotes the probability that a household will not report good resilience (but rather satisfactory or poor resilience). The coefficient term a_{jk} represents the impact of explanatory variables X_{ijk} where k ranges from 1 to $p-1$, on the probabilities. Additionally, a_0 and $\Omega-1$ represent the intercept terms, and V_{ij} represents the error term within the logistic model.

4. Results

4.1. Sample characteristics

Table 1 describes the characteristics of smallholder farmers in Malawi and Ghana. Approximately 29% of households rated their resilience as good in Malawi compared to nearly half (47%) in Ghana. Meanwhile, most households in Ghana and Malawi have experienced some form of climate change event. About 75% of households in Malawi reported experiencing drought conditions in the last 12 months, while 51% reported erratic rains. In Ghana, the leading climatic events experienced by the households were drought (41%) and the second were severe storms (37%). The most common source of information for smallholder farmers in Malawi was mass

Table 1
Sample characteristics of smallholder farming households in Malawi and Ghana.

	Malawi % (Mean)	Ghana % (Mean)
Climate Resilience		
Poor	35	26
Satisfactory	36	27
Good	29	47
Climate information source		
Self-experience	8	21
Media (radio, TV, newspaper)	68	4
Interpersonal	16	62
External sources	8	13
Age		
15–25	14	9
26–35	22	20
36–45	22	35
46–59	18	31
60+	24	6
Gender of household head		
Male	82	93
Female	18	7
Marital Status		
Single	4	12
Married	81	82
Divorced/Widowed	15	6
Household size		
1–4	37	16
5–8	54	45
>8	9	39
Household type		
Nuclear	55	70
No wife	2	1
No husband	10	2
Extended	33	27
Education		
Higher	1	4
Secondary	18	12
Primary	77	17
No formal	4	67
Active household labor force	(3)	(5)
Wealth quintile		
Richest	17	19
Richer	16	17
Middle	28	22
Poorer	17	22
Poorest	22	20
Credit source		
None	64	54
Informal	12	10
Formal	24	36
Remittance		
No	90	96
Yes	10	4
Decision-making		
Male head only	48	75
Female head only	23	9
Joint	29	16
Experience of severe storms in the past 12 months		
No	97	63
Yes	3	37
Experience of erratic rains in the past 12 months		
No	49	77
Yes	51	23
Experience of floods in the past 12 months		
No	96	86
Yes	4	14
Experience of droughts in the past 12 months		
No	25	59
Yes	75	41
Cropping type		
Mono-cropping	41	47
Mixed cropping	59	53
N	1090	1100

Table 2

Bivariate ordered logistic regression of predictors of climate change resilience among smallholder farmers in Malawi and Ghana.

	Malawi	Ghana
	Odds Ratio (SE)	Odds Ratio (SE)
Climate information source		
Self-experience	1.00	1.00
Media (radio, TV, newspaper)	1.101 (0.222)	1.720 (0.604)
Interpersonal	1.073 (0.260)	2.980 (0.453) ***
External sources	2.1889 (0.635) **	0.096 (0.251) ***
Age		
15–25	1.00	1.00
26–35	1.429 (0.274)	0.799 (0.195)
36–45	1.459 (0.278) *	1.011 (0.233)
46–59	1.543 (0.294) *	0.462 (0.107) ***
60+	1.234 (0.243)	0.444 (0.134) **
Gender of household head		
Male	1.00	1.00
Female	1.059 (0.151)	0.484 (0.106) ***
Marital Status		
Single	1.00	1.00
Married	1.189 (0.926)	0.531 (0.102) ***
Divorced/Widowed	1.152 (0.918)	0.309 (0.090) ***
Household size		
1–4	1.00	1.00
5–8	1.241 (0.151)	1.368 (0.221) *
>8	1.227 (0.208)	2.093 (0.349) ***
Household type		
Nuclear	1.00	1.00
No wife	0.680 (0.283)	1.306 (0.648)
No husband	1.450 (0.277)	0.620 (0.219)
Extended	1.470 (0.184) **	1.012 (0.128)
Education		
Higher education	1.00	1.00
Secondary education	0.090 (0.069) **	1.139(0.351)
Primary education	0.053 (0.040) ***	0.562 (0.165) *
No formal education	0.034 (0.028) ***	1.457 (0.393)
Active household labor force	1.095 (0.033) **	1.241 (0.033) ***
Wealth quintile		
Richest	1.00	1.00
Richer	1.264 (0.223)	1.071 (0.200)
Middle	1.599 (0.252) **	1.063 (0.188)
Poorer	1.546 (0.290) *	2.019 (0.359) ***
Poorest	3.132 (0.581) ***	6.700(1.381) ***
Credit source		
None	1.00	1.00
Informal	6.929 (2.824) ***	1.798 (0.342) **
Formal	2.120 (0.259) ***	2.134 (0.261) ***
Remittance		
No	1.00	1.00
Yes	1.143 (0.209)	0.881 (0.236)
Decision-making		
Male head only	1.00	1.00
Female head only	1.276 (0.178)	0.870 (0.175)
Joint	1.685 (0.225) ***	1.375 (0.229) *
Experience of severe storms in the past 12 months		
No	1.00	1.00
Yes	3.575 (1.233) ***	2.037 (0.236) ***
Experience of erratic rains in the past 12 months		
No	1.00	1.00
Yes	1.877 (0.211) ***	0.686 (0.082) **
Experience of floods in the past 12 months		
No	1.00	1.00
Yes	3.039 (0.927)	7.972 (1.774) ***
Experience of droughts in the past 12 months		
No	1.00	1.00
Yes	0.838 (0.103) ***	2.495 (0.289) ***
Cropping type		
Mono-cropping	1.00	1.00
Mixed cropping	4.217 (0.509) ***	0.524 (0.060) ***

*p < 0.05, **p < 0.01, ***p < 0.001; SE = Standard Error.

Table 3

Odds ratios from nested ordered logistic regression of predictors of climate change resilience among smallholder farming households.

	MALAWI	GHANA	MALAWI	GHANA	MALAWI	GHANA
	Odds Ratio (SE)	Odds Ratio (SE)	Odds Ratio (SE)	Odds Ratio (SE)	Odds Ratio (SE)	Odds Ratio (SE)
	Model 1		Model 2		Model 3	
Climate information source						
Self-experience	1.00	1.00	1.00	1.00	1.00	1.00
Media (radio, TV, newspaper)	1.211 (0.254)	2.006 (0.718) *	1.843 (0.421) **	1.676 (0.618)	2.377 (0.564) ***	1.843 (0.706)
Interpersonal	0.983 (0.248)	2.813 (0.455) ***	1.064 (0.281)	2.467 (0.447) ***	1.265 (0.343)	3.460 (0.721) ***
External sources	1.802 (0.548)	0.097 (0.026) ***	1.640 (0.522)	0.077 (0.023) ***	2.117 (0.692) *	0.066 (0.200) ***
Age						
15–25	1.00	1.00	1.00	1.00	1.00	1.00
26–35	1.198 (0.243)	0.705 (0.213)	1.038 (0.217)	0.797 (0.246)	0.923 (0.199)	0.727 (0.228)
36–45	1.380 (0.286)	0.765 (0.241)	1.137 (0.247)	0.770 (0.249)	1.019 (0.227)	0.758 (0.250)
46–59	1.509 (0.310) *	0.459 (0.148) *	1.130 (0.243)	0.408 (0.135) **	0.922 (0.205)	0.524 (0.177) *
60+	1.315 (0.288)	0.563 (0.221)	1.199 (0.276)	0.527 (0.212)	1.004 (0.237)	0.729 (0.298)
Gender of household head						
Male	1.00	1.00	1.00	1.00	1.00	1.00
Female	1.102 (0.252)	0.556 (0.181)	1.128 (0.288)	0.537 (0.188)	1.053 (0.281)	0.542 (0.202)
Marital Status						
Single	1.00	1.00	1.00	1.00	1.00	1.00
Married	1.851 (0.600) *	0.427 (0.112) ***	2.274 (0.779) **	0.548 (0.147) *	2.379 (0.849) **	0.610 (0.170)
Divorced/Widowed	1.341 (0.505)	0.366 (0.160) *	1.828 (0.733)	0.439 (0.198)	2.017 (0.840)	0.423 (0.200)
Household size						
1–4	1.00	1.00	1.00	1.00	1.00	1.00
5–8	1.171 (0.155)	0.797 (0.155) ***	0.968 (0.139)	0.630 (0.130) *	0.881 (0.129)	0.568 (0.121) **
>8	1.068 (0.200)	1.023 (0.224)	0.794 (0.169)	0.453 (0.116) **	0.665 (0.145)	0.297 (0.810) ***
Household type						
Nuclear	1.00	1.00	1.00	1.00	1.00	1.00
No wife	0.799 (0.367)	0.685 (0.426)	0.908 (0.453)	0.939 (0.454)	1.049 (0.540)	1.292 (0.893)
No husband	1.814 (0.523) *	1.178 (0.544)	1.672 (0.501)	1.660 (1.057)	1.600 (0.500)	1.406 (0.720)
Extended	1.391 (0.193) **	0.822 (0.128)	1.296 (0.188)	0.598 (0.101) **	1.405 (0.212) *	0.714 (0.128)
Education						
Higher education			1.00	1.00	1.00	1.00
Secondary education			0.106 (0.087) **	0.873 (0.322)	0.090 (0.082) **	1.023 (0.382)
Primary education			0.064 (0.053) ***	0.693 (0.243)	0.056 (0.051) **	0.782 (0.280)
No formal education			0.043 (0.038) ***	1.471 (0.484)	0.043 (0.041) ***	1.503 (0.508)
Active household labor force			1.113 (0.041) **	1.241 (0.033) ***	1.079 (0.038) *	1.275 (0.055) ***
Wealth quintile						
Richest			1.00	1.00	1.00	1.00
Richer			1.213 (0.226)	0.879 (0.188)	1.204 (0.232)	1.006 (0.227)
Middle			1.291 (0.221)	0.891 (0.186)	1.203 (0.212)	0.876 (0.193)
Poorer			1.226 (0.253)	1.205 (0.260)	0.992 (0.210)	1.412 (0.323)
Poorest			2.303 (0.487) ***	3.375 (0.841) ***	1.767 (0.384) **	2.748 (0.719) ***
Credit source						
None			1.00	1.00		
Informal			4.888 (2.186) ***	0.671 (0.109) **	3.709 (1.697) **	0.692 (0.165)
Formal			1.939 (0.268) ***	0.791 (0.177)	1.608 (0.232) ***	0.758 (0.136)
Remittance						
No			1.00	1.00	1.00	1.00
Yes			1.157 (0.233)	1.850 (0.621)	1.060 (0.221)	1.893 (0.676)
Decision-making						
Male head only			1.00	1.00	1.00	1.00
Female head only			1.131 (0.240)	1.896 (0.550) *	0.977 (0.214)	1.704 (0.528)
Joint			1.216 (0.180)	2.544 (0.520) ***	0.954 (0.149)	1.359 (0.321)
Experience of severe storms						
No					1.00	1.00
Yes					2.920 (1.071) **	1.220 (0.565)
Experience of erratic rains						
No					1.00	1.00
Yes					1.731 (0.217) ***	0.037 (0.014) ***
Experience of floods						
No					1.00	1.00
Yes					2.314 (0.795) **	3.019 (0.848) ***
Experience of droughts						
No					1.00	1.00
Yes					0.619 (0.088) ***	6.884 (2.917) ***
Cropping type						
Mono-cropping					1.00	1.00
Mixed cropping					3.794 (0.523) ***	1.164 (0.224)

(continued on next page)

Table 3 (continued)

	MALAWI	GHANA	MALAWI	GHANA	MALAWI	GHANA
	Odds Ratio (SE)	Odds Ratio (SE)	Odds Ratio (SE)	Odds Ratio (SE)	Odds Ratio (SE)	Odds Ratio (SE)
	Model 1		Model 2		Model 3	
Log-Likelihood	-1178.145	-975.137	-1091.224	-901.600	-1021.614	-804.406
R ²	0.120	0.162	0.170	0.203	0.231	0.285

*p < 0.05, **p < 0.01, ***p < 0.001; SE = Standard error.

media (68%), followed by interpersonal sources (16%). In contrast, the primary source of climate information for farmers in Ghana is interpersonal sources (62%), while self-experience (21%) was the second dominant source. The most common household size was between five or more members in both countries, accounting for 54% and 45% of surveyed households in Malawi and Ghana, respectively.

In terms of socioeconomic characteristics, it is observed that about 24% of respondents in Malawi had access to formal credit institutions and just 12% sourced credit from informal avenues. Approximately 36% of households sourced credit from formal avenues in Ghana, while the informal settings constituted 10%. In both countries, however, over half the respondents reported not having access to any source of credit. The data further show that while patriarchal norms remain dominant in both locations, 29% of respondents in Malawi said that decision-making within the household was done jointly, which sharply contrasts with the situation in Ghana, which reported about 16%. Finally, most respondents in both locations practiced mixed cropping, although 6% higher in Malawi.

4.2. Bivariate analysis

The bivariate regression results between climate change resilience and sources of climate information are presented in Table 2. From the table, households that sourced climate information from external organizations (government, formal, and not-for-profit organizations) in Ghana were twice more likely (OR = 2.18 p ≤ 0.01) to report good resilience compared to those who relied on their own experience. In contrast, those who relied on external sources in Ghana were less likely (OR = 0.09 p ≤ 0.001) to rate their resilience as good compared to those who used self-experience. In Ghana, we also noticed that farmers who received their information through interpersonal sources were almost three times (OR = 2.98; p ≤ 0.001) more likely to report good resilience than their counterparts who rely on self-experience at the bivariate level.

In terms of socioeconomic predictors, the results also suggest at the bivariate level that, in both countries, lower levels of education were associated with lower odds of reporting good resilience. For instance, in Ghana, farmers with primary education were 44% (OR = 0.56 p ≤ 0.05) less likely to rate their resilience as good than those with tertiary education. We also found that farmers in the poorest wealth quintile in both countries were more likely to rate their resilience as good than those in the wealthiest quintile. Furthermore, access to credit from both formal and informal sources was positively correlated with good resilience in both countries. However, informal sources were associated with higher odds in Malawi, while formal sources provided higher odds in Ghana. For instance, farmers who accessed credit through informal sources were almost seven times (OR = 6.92 p ≤ 0.001) more likely to report good resilience than those without access to credit in Malawi. In Ghana, however, farmers who sourced credit through formal channels were only about two times more likely (OR = 2.13; p ≤ 0.001) to rate their resilience as good compared to those without access to credit.

Finally, some agricultural-related factors were significantly associated with good resilience. The results highlight that households that experienced erratic rains within the last 12 months in Malawi were more likely (OR = 1.877; p ≤ 0.001) to rate their resilience as good than those that did not. At the same time, their counterparts in Ghana were less likely (OR = 0.686; p ≤ 0.01) to report good resilience. Similarly, those exposed to drought in the last 12 months in Ghana were more likely (OR = 2.495; p ≤ 0.001) to report good resilience than those that did not experience drought. The case of Malawi is the opposite: farmers exposed to droughts were less likely (OR = 0.838; p ≤ 0.001) to report their resilience as good than those who did not. Finally, the data show that farmers who practiced mixed cropping in Malawi had significantly higher odds (OR = 4.217; p ≤ 0.001) of rating their resilience as good compared to farmers who practiced monoculture. In contrast, farmers in Ghana were relatively less likely (OR = 0.524; p ≤ 0.001) to report good climate change resilience than those who practiced monocropping.

4.3. Multivariate regression

Table 3 shows the results of the nested multivariate regression models. As indicated earlier, Model 1 controlled for demographic characteristics. In Model 2, we controlled for demographic and socioeconomic factors, while Model 3 controlled for all identified predictors. We find in Model 3 that households that relied on mass media (OR = 2.377; p ≤ 0.001) and external organizations (OR = 2.117; p ≤ 0.05) as their source of climate information were all more likely to rate their resilience as good compared to self-experience in Malawi. Similarly, farmers who received information via interpersonal sources (OR = 3.46; p ≤ 0.001) in Ghana were more likely to rate their resilience as good, while information from external organizations was associated with a lesser likelihood of a household reporting good resilience (OR = 0.066; p ≤ 0.001). Thus, in Malawi, the mass media and external organizations are better information sources that increase households' chances of reporting good climate resilience. In contrast, interpersonal sources are better for climate change resilience, and external organizations are worst for climate change resilience building in Ghana.

Aside from the key independent variable, the data show other statistically significant predictors of climate change resilience. Regarding socioeconomic factors, Model 3 shows that households of respondents with secondary, primary, and no formal education were 91%, 94%, and 96%, respectively, less likely to report good resilience than those with tertiary education in Malawi. This contrasts with the situation in Ghana, where the significance of educational attainment on climate resilience was attenuated when we controlled for demographic and agricultural-related factors. Moreso, in both countries, households belonging to the poorest wealth quintile ($OR = 1.608$; $p \leq 0.001$) were still more likely to rate their resilience as good than those in the wealthiest quintile. Households that accessed credit through informal sources were almost four times ($OR = 3.709$; $p \leq 0.01$) more likely to report good resilience, while formal sources increased their chances by 60% ($OR = 1.608$; $p \leq 0.001$) than those that had no access to credit in Malawi. The situation is somewhat different in Ghana; there was no statistically significant association between access to credit and climate change resilience. Lastly, Model 3 suggests that an additional unit of household labor increased the odds of reporting good resilience by about 7% in Malawi and 27% in Ghana, respectively.

In addition, we observe that agricultural-related factors were significantly associated with good resilience at the multivariate level. For instance, when analyzing the specific climatic events in the regions, it was noticed in Model 3 that households that experienced floods in the past were more likely to rate their resilience as good in both Malawi ($OR = 2.314$; $p \leq 0.01$) and Ghana ($OR = 3.019$; $p \leq 0.001$), compared to those that did not. On the contrary, households that experienced droughts in Malawi were approximately 40% ($OR = 0.619$; $p \leq 0.001$) less likely to report good resilience, while farmers in Ghana exposed to droughts were almost seven times ($OR = 6.884$; $p \leq 0.001$) more likely to report their climate resilience as good. The dynamics are different with exposure to erratic rains. The results indicate that farmers in Malawi who experienced intermittent rains were 73% ($OR = 1.731$; $p \leq 0.001$) more likely to rate their resilience as good. In Ghana, however, farmers were 97% ($OR = 0.037$; $p \leq 0.001$) less likely to report climate change resilience when they experience erratic rains. Finally, farmers who practice mixed cropping in Malawi were approximately four times ($OR = 3.794$; $p \leq 0.001$) more likely to rate their resilience as good than those who practiced monocropping. We found no statistically significant association between climate change resilience and intercropping at the multivariate regression level in Ghana.

5. Discussion

Our study found heterogeneous impacts of climate information sources on smallholder farmers' perceived resilience to climate change in Malawi and Ghana. The findings indicate that climate information from the mass media (TV, radio, print) and external sources (government, private sector, and nonprofit) are associated with higher odds of reporting good resilience to climate change than relying on self-experience in Malawi. In contrast, in Ghana, smallholder farmers tended to perceive their resilience to be good when they used interpersonal sources (other farmers, friends and relatives, special community activities), while the use of external sources reduces their odds of rating their resilience as good, compared to those who relied on their own experience. These findings have implications for achieving the sustainable transformation of agriculture for climate resilience and rural poverty reduction in Malawi (IFAD, 2022), and the policy objective of building climate-resilient communities as part of Ghana's Medium-Term National Development Policy Framework (MTNDPF) 2022–2025 (National Development Planning Commission, 2021). Specifically, this study offers rigorous empirical evidence and contributes to the literature on the key climate information sources that enable smallholder farmers to anticipate, prepare, and recover following their exposure to climatic stressors. The results also underscore the necessity of integrating farmer-to-farmer networks as well as information and communication technologies, such as radio, into governmental strategies as crucial means to enhance agricultural extension, learning, and transformative processes.

The relevance of the mass media in perceived climate resilience in Malawi is corroborated by several studies in South and East Africa (Ndimbwa et al., 2021; Ragasa and Kaima, 2017). As identified in other sub-Saharan countries, mass media plays a significant role in climate change awareness and the adaptation of climate-smart agriculture in smallholder households (Abegunde et al., 2019; Nzeadibe et al., 2011). In highly vulnerable climatic regions, accurate and timely weather forecasts, seasonal climate outlook, guidance on crop management practices, and early warning information are essential to help farmers anticipate, recover from, and adapt to adverse climatic stressors. The role of the mass media is beneficial in this regard in Malawi. Climate information from mass media, such as Radio 1's "the new way of farming" program in MD, stems from experts and disaggregated data (linked to research institutions and meteorological services) subjected to quality checks; hence, the information transmitted to farmers is more likely to be accurate. Community members traditionally manage local radio stations and broadcast in the local dialects (Chichewa and Tumbuka), making information sharing easier. As radio devices are relatively inexpensive, farmers can afford them and use them for their information needs. Farmers in Malawi can access free radio programming funded by the government and ask questions by calling toll-free (Ragasa et al., 2021). These programs are offered weekly, enabling farmers to access experts at little to no cost. In some contexts, the radio, TV, and print media have been used to disseminate information on improved crop varieties, early warning signs, and disaster preparedness (Harvey, 2011). In semi-arid regions like Northern Malawi, early warning information is an integral part of the resilience of smallholder agricultural systems since it helps farmers anticipate and prepare for climate change stressors such as drought and erratic rainfalls. Studies have also highlighted that the media can be leveraged for effective messaging on climate change mitigation efforts and enhancing early warning systems in emergency and non-emergency times (Monahan and Ettinger, 2018). TV and radio services also offer program reruns, sometimes within the same day or week, which aids in adopting and circulating climate information. Aside from climate information, other information related to agriculture, such as market dynamics and pest and disease management programs, enables farmers to make informed decisions about their farming practices.

The role of external organizations in bridging the climate information gap in Malawi is promising. Our study shows that Malawi's commitment to revamping extension service delivery in rural areas is helping smallholder farmers become more resilient to climate change. As part of their strategy to boost agricultural production and climate resilience, the Malawi Growth and Development Strategy

III (2017–2022) designated extension service deployment as a key priority area because of the crucial role extension service workers play in linking vital and timely climate information to rural farmers (Government of Malawi, 2017). Consequently, the government, private sector and nonprofit organizations have been working to bridge the gap in connecting farmers with well-timed, relevant information. Notably, Amadu et al. (2020) reported that assistance from external organizations, delivered through investments in climate-smart agriculture in Malawi, has resulted in yield gains for smallholder farmers in the aftermath of the 2016 droughts and is effective in enhancing resilience in regions that are both resource-poor and environmentally sensitive. In the predominant agricultural context of Malawi, farmers reported that extension service workers conducted demonstrations and trained them on new farming practices, disseminated information on climate-smart farming practices, linked farmers to research institutions and executed programs to create awareness of new skills and climate change adaptation technologies (Mkisi, 2014). The farmer-led knowledge production and dissemination approach by the Soils, Foods and Health Communities (SFHC)—a nonprofit organization in Northern Malawi—and its use of community promoters has also contributed towards food security and the uptake of ecologically friendly farming practices for climate change resilience among participating communities (Kpienbaareh et al., 2022; Patel et al., 2015).

In the Ghanaian context, interpersonal sources were significantly associated with farmers' perceived resilience. This finding is consistent with Etwire et al.'s (2017) study of the UWR, which found that farmer-to-farmer extension services successfully delivered weather and market information to farmers and aided farmers in making comprehensive decisions regarding their farming practices. This finding also reinforces the argument that communal integration and participatory learning opportunities are beneficial for adopting innovative and sustainable cultivation practices, as they can be deliberated, prioritized, and catalyzed (Kansanga et al., 2020a, 2020b; Madsen et al., 2021; Ruzzante et al., 2021).

Furthermore, the findings suggest that, in Ghana, households whose primary sources of information are from external sources were less likely to report good resilience. In explaining this observation, Ogunlade et al. (2014) noted that extension services provision did not contribute tangibly towards climate change resilience among smallholder farmers because the agents are not often well-equipped with the requisite knowledge on causes, effects, and methods for adapting to climate change. Apart from lacking the requisite expertise, extension workers are also typically resource-constrained and undertake sporadic visits to farmers. This may not be enough to provide farmers with the timely and accurate climatic information needed to enhance their resilience (Anang et al., 2020). Similarly, Nyadzi et al. (2021) found that farmers in Northern Ghana can predict rainfall cessation in their local communities more accurately than the national meteorological service agency. Codjoe et al. (2013) also reported that indigenous weather monitoring systems, which many residents still use, have so far been successful in helping residents predict the onset of the wet and dry seasons as well as flood and drought events.

Reflecting on the dissimilar impacts of external sources on perceived resilience in Ghana, Taye (2013) explains that assessments of the effects of extension services on farming in SSA are sometimes overstated due to insufficient capacity to conduct robust evaluations of their work and other methodological challenges. In Ghana, the activities of external organizations such as NGOs in smallholder communities have come under question in recent years. There are concerns that their actions reflect donors' wishes rather than the needs of farmers (Kwao and Amoak, 2022). More importantly, this finding suggests that even though certain mediums for climate information dissemination may be relevant in one country, they may be less appropriate in another because of the differences in socio-environmental and other place-based factors. Therefore, it is necessary to employ place-specific initiatives and policies to address the climate concerns of SSA's farmers given the heterogeneity of smallholder farming communities. The need for place-based approaches is evident in the current literature on Africa, which highlights the heterogeneity of the continent and the fact that a one-size-fits-all policy is detrimental to the effective mitigation of developmental challenges in Africa (Kansanga et al., 2020a, 2020b; Todes and Turok, 2018; Vercillo et al., 2020).

In addition to climate information sources, we also found a range of demographic, socioeconomic, and agriculture-related factors associated with farmers' perceived resilience to climate change. For instance, it was revealed in the Malawian context that married people were more likely to rate their resilience as good than their unmarried counterparts. In explaining this observation, family-centered programs such as recipe days which tend to involve transformative educational approaches, including gender equity, used with community members have been shown to result in improved household division of labor and decision-making (Bezner Kerr et al., 2016; Nyantakyi-Frimpong et al., 2017). Such programs may have resulted in the collective actions of married couples in Malawi compared to Ghana, where no such programs are known to have been held in our study context. Some studies have also shown that being married unlocks more access to resources such as land and labor and can leverage the combined household income to diversify their livelihood activities than unmarried people (Kumba, 2015). As observed in Northern Malawi, the husband and wife constitute the primary agricultural labor force and being married partly unlocks access to kin resources (Bezner Kerr, 2005). Notably, cultural dictates grant married couples access to more extensive landholding and resources, enabling them to engage in adaptive strategies and leverage the land for economic purposes. Unmarried individuals, on the other hand, may not have the same advantages and opportunities regarding resource allocation and landholding.

Another noteworthy finding in Ghana and Malawi is that farmers of the lowest wealth quintiles were more likely to rate their resilience as good compared to those in the wealthiest category. The finding, although paradoxical, is corroborated by similar studies in Ghana (Batung et al., 2022; Mohammed et al., 2021), Malawi (Kansanga et al., 2021a, 2021b), and elsewhere (Shi-yan et al., 2018). As explained in previous studies, poorer farmers, with fewer fallback options, tend to be more astute in investing their limited resources, and are more likely to adapt smart-agricultural practices to maximize yields. For instance, Collier and Dercon (2014) found that as a resilience strategy, poorer farmers reduce the plot sizes they cultivate to maximize labour and other resources in the event of climate stressors. Likewise, a longitudinal study on sustainable land management practices adoption to enhance resilience to climate change revealed that more impoverished smallholder farmers had a higher likelihood of engaging with agroecological practices built on the wisdom of traditional farming practices to better adapt to climate shocks than wealthier farmers (Kansanga et al., 2021a,

2021b).

Reinforcing the findings of other studies on Malawi, our results showed that mixed cropping improved climate change resilience (Beets, 2019; Mwase et al., 2014), but the relationship was statistically insignificant in Ghana. It is worth noting that some of the participants in this study were involved in the MAFFA agroecological intervention, which reinforces mixed cropping approaches in the Malawian study context (Kansanga et al., 2021a, 2021b). Multiple cropping is a risk diversification strategy and thus serves as harvest security for farmers. Smallholder farmers have long recognized mixed cropping as a sustainable farming practice. By cultivating multiple crops, farmers increase carbon sequestration and distribute their farm risks (Amoak et al., 2022). Mixed cropping effectively controls pests and diseases (Gaba et al., 2015), improves soil nutrients (e.g., leguminous crops), and may help rejuvenate barren lands. Amid persistent droughts in arid and semi-arid regions of SSA, multiple cropping may be crucial in guarding farmers against crop failure.

6. Limitations

Even though this study's findings offer unique insights and policy pointers on the role of agricultural information in enhancing climate change resilience among smallholder farmers in sub-Saharan Africa, some limitations are worth noting. First, we acknowledge the sampling limitation. This study is not statistically representative of the whole country, or the districts sampled. We recognize that other possible covariates, such as household health, water security, and social protection, influence climate change resilience that was not considered in this paper. Also, even though we tried to minimize recall bias by soliciting information at the peak of the planning stages of the growing season, some households may have understated or overstated some responses. The study is based on cross-sectional surveys in Malawi and Ghana; thus, our findings are limited to only statistical association. There is a need for additional studies, including longitudinal and qualitative analyses to validate and strengthen our findings. We recognize that conducting field experiments and controlled trials would provide more robust evidence by allowing for a more controlled assessment of the impact of different information sources on smallholder farmers' climate resilience. Furthermore, incorporating additional observational data would enhance the generalizability of our findings and provide a more comprehensive understanding of the complex relationships between information sources and climate resilience. Long-term studies encompassing diverse geographic regions and socioeconomic contexts would contribute to a more nuanced understanding of the causal linkages involved.

Additionally, farmers' perceived resilience to climate change may be impacted by contextual factors such as off-farm incomes, water security, distance to a paved road as well as distance to a major city. We recommend that future studies should take these variables into consideration as they could potentially correlate with farmers' perceptions of climate change resilience. Likewise, future researchers exploring climate information sources and perceived resilience adopt a multi-pronged approach to clarify the distinction between weather and climate to farmers. This approach is essential for ensuring that farmers have a clear understanding of the questions posed to them. We further acknowledge that our findings may be influenced by the heterogeneity of our study locations and that because "good resilience" is a self-reported measure, it may be subjected to response bias. Finally, quantitative indicators alone may not adequately assess climate change resilience among smallholder farmers. To explain the contextual factors contributing to climate resilience, we suggest future qualitative approaches. Despite these limitations, our study is among the first to examine the role of climate information sources in resilience building in sub-Saharan Africa.

7. Conclusion

This study assessed the impact of climate information sources available to farmers in Malawi and Ghana on climate change resilience. We found that farmers in Malawi who source climate information from the mass media and external sources are more likely to consider themselves to be resilient to climate change. Meanwhile, in Ghana, interpersonal sources offer a better chance of climate change resilience among smallholder farmers, while external sources could harm resilience building. Our finding reiterates the heterogeneity of African countries and the need to avoid the one-size-fits-all policies that often characterize many interventions in Africa. Because of the differentiated impacts of climate change and variability and the dynamics of information access across geographical spaces, policies must be tailored to fit the local context of the country, guided by disaggregated insights from localized studies. Our findings suggest that greater attention should be given to diffusing agriculture information through Malawi's mass media and external sources. These may include providing brochures that itemize the various agricultural programs run by the media, given the centrality and importance of the mass media in fulfilling farmers' information needs in Malawi. Meanwhile in Ghana, strengthening interpersonal information sharing, such as farmer-to-farmer programs, is integral for boosting household resilience and adaptive capacities to climate change.

Author statement

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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.

Data availability

Data will be made available on request.

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