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Early Warnings and Perceived Climate Change Preparedness among Smallholder Farmers in the Upper West Region of Ghana

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Abstract: The impacts of climate change are already pushing beyond the threshold for sustainable agriculture and rural livelihoods. In Sub-Saharan Africa, smallholder farmers are particularly vulnerable due to limited resources and adaptive capacity. Early warnings are critical in mitigating and reducing climate-related dangers and building resiliency. That notwithstanding, there needs to be higher coverage of early warnings in developing countries, and there is even less knowledge of their contribution to rural development. Using a cross-sectional survey involving smallholder farmer households (n = 517), this study investigates the relationship between early warnings and perceived climate preparedness in Ghana's semi-arid Upper West Region. From ordered logistic regression presented as an odds ratio (OR), factors that influenced climate preparedness in the past 12 months before the study include exposure to early warnings (OR = 2.238; $p < 0.001$) and experiences of prior climate events such as drought (OR = 9.252; $p < 0.001$), floods (OR = 6.608; $p < 0.001$), and erratic rain (OR = 4.411; $p < 0.001$). The results emphasize the importance of early warning systems and various socioeconomic factors in improving the climate resilience of smallholder farmers in Ghana. In conclusion, the study puts forth policy suggestions worth considering.

Keywords: early warning systems; climate risks; perceived climate preparedness; smallholder farmers; socio-ecological resilience; Ghana

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1. Introduction

Climate change is intensifying globally, becoming increasingly evident and causing more frequent weather-related disasters [1–3]. For instance, in 2020 and 2021, the world witnessed several catastrophic events, such as massive wildfires that destroyed almost 5 million acres of the Amazon rainforest, an extreme cold snap that hit Texas, and nine severe storms in Vietnam within just seven weeks [4].

According to the World Meteorological Organization (WMO), weather-related disasters have increased in the last 50 years, resulting in an average of 115 deaths and losses of USD 202 million daily [5]. These effects are particularly evident in vulnerable regions, like Africa, which has experienced 1695 disasters, leading to around 731,747 deaths and USD 38.5 billion in damages [2]. Sub-Saharan Africa, for instance, is especially prone to extreme climate and weather events (erratic rainfall, droughts, floods, dry spells, and storm surges) due to its social, economic, and environmental vulnerability [2]. In Sub-Saharan Africa (SSA), smallholder farmers are threatened by climate variability and changes due to poverty levels, limited adaptive capacity, and heavy reliance on climate-sensitive sectors, such as agriculture, which exacerbate the situation [6,7]. Within the broader SSA region, Ghana is vulnerable to climate-induced challenges, including floods, droughts, storm surges, and unpredictable rainfall patterns [8,9]. Recent forecasts indicate that Ghana's climate sensitivity remains a critical concern as more impacts could affect the livelihoods of smallholder farmers and many other sectors [10,11].

Zooming into Ghana's Upper West Region (UWR) provides insight into climate vulnerabilities experienced across Sub-Saharan Africa. The UWR is a typical representative study area of SSA, characterized by many African climate vulnerabilities due to its frequent experiences of extreme climate events [7]. This semi-arid region (UWR) is also at heightened risk due to poverty, total dependency on rain-fed agriculture, limited technological advancements, and inadequate infrastructure [12–14]. The vulnerability of the UWR has been worsened by unfulfilled government policies such as One Village One Dam (1V1D) and planting for food and jobs. These policies have left smallholder farmers stranded, making them even more susceptible to the impacts of climate variability and change. In addition to failed government interventions, temporary interventions by Non-governmental Organizations (NGOs) have further weakened any prospects of long-term resilient strategies. These challenges have diminished the region's ability to adapt to environmental changes, especially in the face of climatic shifts, significantly affecting the primary occupation in the UWR—smallholder farming. This makes the local population even more vulnerable to the effects of climate change [15,16].

Different adaptation strategies have been implemented to reduce the vulnerability of smallholder farmers to climate risks in various contexts. One prominent method in the UWR is using early warnings for extreme climate and weather events. Early warning systems (EWSs) in smallholder farming are crucial for adapting to climate variability and change. Some scholars have pointed out that the current vulnerability of vulnerable regions like the UWR of Ghana is mainly due to a focus on reactive measures to adverse climate impacts [17]. Therefore, shifting towards prevention through early warning systems remains one of the most important ways to build resiliency and best use the already limited resources [18]. EWSs encompass a range of abilities to generate and share timely prompts that enable individuals, communities, and organizations to prepare and take action to mitigate climate-related harm or loss [19–21]. Despite these advantages, however, access to EWS remains challenging for one-third of the population, especially in developing countries [21,22]. This issue is more pronounced in Africa, where coverage is lacking for about 60% of the population and where EWS is arguably most needed [23]. Recent estimates by the WMO suggest that within a day's notice on early warning, disaster damage can be reduced by up to 30%, potentially saving billions in losses prevented [24].

Although several organizations such as the Ministry of Food and Agriculture (MOFA), National Disaster Management Organization (NADMO), Esoko, Savannah Agriculture Research Institute (SARI), and Ghana Meteorological Agency (GMA) provide early warning systems in the UWR of Ghana, it is unclear whether existing EWSs translate into climate preparedness among smallholder farmers in the UWR. These early warnings are aimed at helping smallholder farmers make informed decisions such as cropping systems, responding to floods, managing pests and diseases, and dealing with crop failures. This study examined the UWR of Ghana as a representative case study for the SSA climate. It explored the relationship between early warnings and the perceived climate preparedness among smallholder farmers in the UWR of Ghana. The study provided insights into other Sub-Saharan African regions facing similar climate challenges.

Given this background, this study hypothesizes that there is a positive association between smallholder farmers' exposure to EWS and their perceived preparedness for climate-related risks. The research is significant in two ways: academically, it contributes to the existing knowledge gap on managing climate risks in Sub-Saharan Africa, and practically, it suggests specific strategies for stakeholders such as policymakers and community leaders to enhance resilience in Ghana's vulnerable areas, such as the northern part of Ghana. By focusing on the Upper West Region's settings and constraints, this study adds to the more extensive discussion on climate adaptation within SSA and other vulnerable regions of Africa.

2. Theoretical Framework: Socio-Ecologic Resiliency

Preparedness for disasters, including climatic events, is a complex undertaking considering the often diverse physical, socioeconomic, and cultural contexts within which they may occur. Therefore, to theorize such a non-linear phenomenon, this study draws from elements underpinning the broader notion of socio-ecologic resiliency (SER) to explore the dynamic connection between EWS and climate change preparedness among smallholders in Ghana's UWR. SER gained prominence as resilience was refined by Folke et al. [25] to highlight the associated link between social systems, natural environments, and their complexities. Folke et al. emphasized how social and natural systems depend on each other in a mutually beneficial way and should be addressed in conjunction and not in isolation [25]. They point out that these systems are highly interlinked and possess feedback loops and shared complexity, allowing them to adapt to changes [25]. Resilience is crucial in this relationship as it determines a system's ability to withstand disruptions and maintain its functions [26]. For instance, smallholder farmers in the UWR region heavily rely on the natural ecosystem to support their livelihoods. They depend on the land for growing crops and rearing livestock, and their farming practices can also influence the health of the soil and the broader ecosystem. Sustainable approaches like intercropping and agroforestry can improve crop yields and enhance the land's resilience against climate-related shocks. However, suppose they resort to unsustainable methods like frequently burning farmlands and heavy machinery. This can lead to soil degradation, negatively affecting the ecological balance and socioeconomic well-being of their households and the community [25,26]. In this new light, SER acknowledges the dynamism of individuals and social systems and their capability for change as an iterative process toward building a buffer against, coping with, and recovering from external stresses and shocks through adaptation or transformation [26].

This study focuses on the first phase of resilience, which surrounds the mitigative role of a system's buffer capacity (BC) at any level—individual, household, or community [27]. The study prioritized the initial stage of resilience as purposeful. This stage entails recognizing potential climate risks and preparing to lay the groundwork for subsequent phases of resilience. Our analysis of how early warnings impact perceived climate preparedness sheds light on the fundamental actions taken by smallholder farmer households in response to climate-related risks.

BC is loosely defined as strategies that resist change or cushion, soften, or neutralize an event's otherwise catastrophic intensity [27]. In this regard, BC goes beyond a system's natural properties to its ability to secure opportunities and mobilize and use tangible and intangible resources [28]. Broadly, these varied resource bases can be grouped into five types of capital, namely human (skills, knowledge, health, and labor availability), financial (monetary assets including livestock, earnings, and remittances), social (networks, group memberships, trust, reciprocity, and informal safety nets), physical (energy and communication infrastructure, and sanitation), and natural (land, forest, water, and biodiversity) [29]. However, the ability of a system to access and use these types of capital is facilitated or constrained by its natural environment and the role of transforming structures, including the efficiency of institutions [28]. Furthermore, these capitals are not static but can be acquired to bolster BC through strategic trade-offs and other arrangements [30].

We draw linkages between EWSs and climate preparedness within these malleable pathways to ensure BC. We operationalize BC in this context to mean a resilience strategy and its underlying capital distribution that enables smallholder farmers to identify risks and disasters to avert crises in a timely and resource-efficient manner. As mainly top-down structures, the availability, efficiency, and accessibility of EWSs are a function of the level of capital acquisition at both the individual and the societal levels. This is because implementing EWSs are only partially rational and logical, as they consist of various social and organizational processes [31]. EWSs also intricately traverse all five forms of capital in a complex manner.

On the one hand, the effective deployment of EWSs at the societal level depends on the stability and adequate measures of relevant capital, incredibly human, financial, and physical. In addition, other crucial factors that need to be considered include contextually relevant dissemination methods against a well-weighted hierarchy of risks [31]. Similarly, EWSs, which may need to be better designed, especially on the language front [32], may not be helpful to rural farmers who are most affected by climatic events, market failures, hunger, and poverty. This is because effective communication is a vital component of resilience, as it can help farmers make informed decisions and take appropriate actions. Thus, a compromise in the structural design of EWSs denotes a center in the intended resiliency outcomes. On the other hand, farmers' ability to engage with EWSs is also contingent on their levels of capital acquisition. This positionality of farmers is vital because the availability does not always translate into accessibility or applicability. For instance, a poor farmer may be unable to purchase a cellphone to leverage EWSs compared to a relatively wealthy farmer [33]. Similarly, a farmer with low financial capital may still be somewhat capable of leveraging EWSs if they have strong social networks compared to a farmer lacking economic and social capital. Hence, climate preparedness and smallholder resilience, which inherently require risk and crisis communication, are either strengthened or weakened through interactions between farmers and their context, where farmers with low capital index will be less likely to leverage the utility of EWSs [28].

3. Method

3.1. Study Context and Data Collection Method

This study is part of a broader research project with identification number 121340 on investigating the impact of Community Resource Management Areas (CREMA) on improving livelihoods and climate change resilience in UWR, Ghana. Ghana is located on the west coast of SSA with an average tropical climate ranging from 24 °C to 30 °C [8]. The country has eight ecological zones. The southern part of Ghana has two rainfall periods, while the northern part, including UWR, has one. Annual precipitation ranges from 700 mm in the north to 2200 mm in the southwest [8,34]. The arid and dusty Harmattan wind from the Sahara desert affects the nation from November to March, especially in the north [8,9,35]. Geographically, the UWR of Ghana is located northwest between 9.8 and 11.0° N and 1.6 and 3.0° W coordinates, covering an area of 18,476 km. The region covers 7.8% of Ghana's land area and borders Burkina Faso, Ghana's Upper East Region, and the Savannah Region to the north, east, and west directions, respectively (Figure 1) [35]. The UWR has a Sudanese-type dry climate with 21 °C to 40 °C temperatures. It has a single rainy season from May to October, with 840 mm to 1400 mm annual precipitation [34,35]. However, rainfall patterns have been irregular, especially between June and September [34,35]. Surface runoff, soil moisture, and cropping season decrease with heavy rainfall. The Harmattan phenomenon, which reduces visibility and humidity, also affects the area.

About 80% of the population works in the agricultural sector, with women comprising 42% [35,36]. Small rainfed plots feed farmers who face poverty, food insecurity, nutrient-deficient soil, out-migration, illiteracy, and low adaptability to climate change [15,16,34,37,38]. Extreme weather poses recurring difficulties, requiring effective adaptation and disaster response systems. The region happens to have the highest poverty rate in Ghana. Shockingly, 90% (thus, 9 out of every 10 persons) of the population survive on less than a dollar per day, as per the statistics from 2019). Women rely mainly on shea for livelihoods, while other residents work in trades, vending, or handicrafts [39,40]. The UWR has faced several climate-related disasters over the years. For instance, in 1997, an outbreak of Cerebro Spinal Meningitis claimed 852 lives in the Upper East Region, 73 in the Upper West Region, and 431 in the Northern Region. In 1999, floods affected over 300,000 people, leading to the outbreak of waterborne diseases and an invasion of black flies. In 2007, floods caused fatalities and waterborne disease outbreaks, while the 2016 outbreak of Fall Armyworms worsened food shortages ([8] p. 126) and [9].

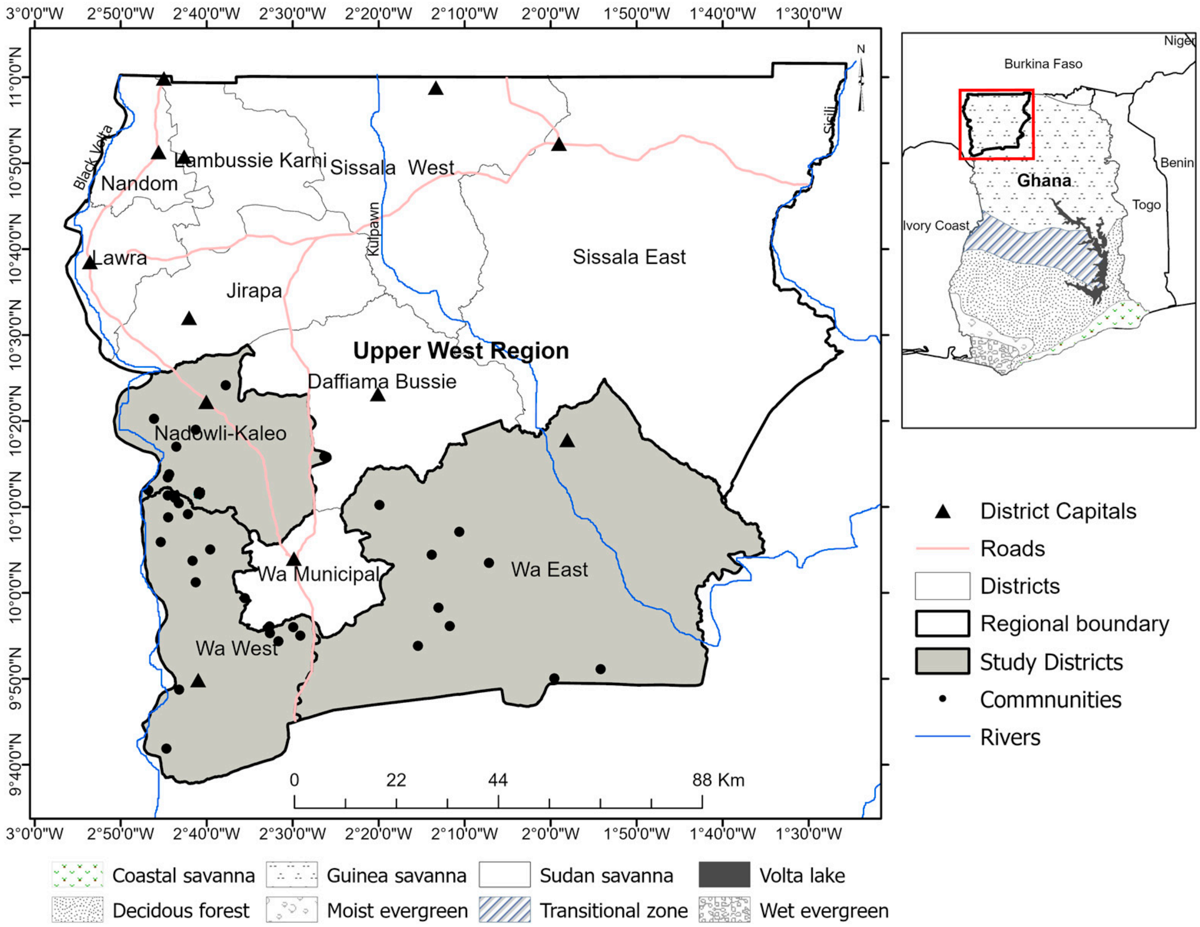

Figure 1. Map of Upper West Region showing study area (prepared in ArcGIS Desktop 10.5.1, Department of Geography, University of Western Ontario, London, ON, Canada).

We collected data from 517 households involved in agriculture based on the criteria specified in the 2017/2018 Census of Agriculture by the Ghana Statistical Services [34]. An agricultural household is one where at least one member is involved in farming. The data were collected between 10 November 2022 and 31 January 2023. Our study was conducted in two phases. First, we purposively selected 36 communities from the Wa East, Wa West, and Nadowli-Kaleo districts with 167, 229, and 121 participants, respectively, in line with the broader study scope. In the second phase, we picked every fifth household from the listed households in these communities. Utilizing a questionnaire, we interviewed 517 participants, who were the primary farmers or agriculturalists from the selected households, aged 18 or older, who participated in our survey as the representative interviewees. Consent was obtained from all research participants through verbal agreement, considering their literacy levels and cultural preferences within the research area and region. To ensure that this agreement was adequately documented, we had each participant acknowledge their consent in the presence of a trusted adult household member and a local community leader knowledgeable about the study's objectives and ethical implications. Our research did not include minors, and participation was voluntary. We collected data on various topics related to the farmers and their households, including demographics, socioeconomic factors, and socio-cultural characteristics. We also investigated climate change adaptation, mitigation, resilience, and preparedness. Additionally, we gathered information on early warnings, agricultural productivity, food security, water insecurity, extreme climate events, community disasters, and climate-related action plans. The study examined government support systems, social networks, and knowledge resources related to climate issues. We also explored financial safety nets and communication networks, gender dynamics within households, and their impact on well-being. The Western University Non-Medical Research Ethics Board (NMREB), Canada, approved the study ethically.

3.2. Measure

3.2.1. Outcome Variables

We adopted the concept of "Subjective resilience, using perceptions to quantify household resilience to climate extremes and disasters" ([41] p. 229). The concept recognizes that households possess knowledge and self-evaluation abilities, enabling them to understand their exposure, vulnerability, and effectiveness in dealing with and adapting to climate-related disturbances. Building upon the work of [41], we constructed the outcome variable for this research, "perceived climate change preparedness", from the question, "On behalf of your household, how would you rate your preparedness to handle droughts/floods/dry spells/erratic rainfall/ and storm surges related stress in the past 12 months?". The responses were categorized into three levels: poor preparedness = 0, satisfactory preparedness = 1, and good preparedness = 2. Other scholars have also employed this subjective measurement framework by [41] (see [16,42–44]) to assess perceived resilience and related concepts.

3.2.2. Predictor Variables

The focal independent variable for this research is the "exposure to the early warning". We specifically asked respondents about their exposure or use of early warning systems on contextually relevant climatic factors, including droughts/floods/dry spells/erratic rainfall/and storm surge. The focal variable was coded as ((no exposure = 0), indicating that the households did not have any exposure to early warnings, or (exposure = 1) which suggests that the households were indeed exposed to early warnings).

We included other theoretically relevant independent variables based on the broader literature on climate change and resilience, as indicated in Table 1 (see [43,45,46]). Households were assessed on their knowledge and involvement in disaster management and planning within their communities to determine whether they have established strategies to handle extreme climate and weather events, like having designated evacuation routes, vulnerability, and risk-exposure assessment for floods. On the other hand, we also assessed household involvement in the community climate action plan that outlines the community's approaches, highlighting individuals' role in addressing climate-related issues, such as organizing tree-planting events to combat deforestation. Likewise, the source of climate information refers to how households gather their climate data through experiences, community consultations, or seeking input from external experts. Support systems were equally assessed, including health and infrastructure initiatives to strengthen health services and infrastructure in the face of climate challenges, for instance, setting up health camps after floods. Providing government support systems such as subsidies, crop insurance, and relief materials was also assessed. Community support and social network systems were also evaluated, encompassing assistance during difficult times, like households' ability to connect with family and friends and share resources when crops fail. We also assessed the opportunities available for households regarding extension and knowledge support systems on climate, focusing on access to expert (extension workers) guidance regarding climate issues, including training on cultivating high-yielding and drought-tolerant crops. Household financial saving as a safety net was also assessed, which refers to strategies individuals employ to save money for complex circumstances. Some rely on banking institutions, while others participate in community savings groups like Village Savings and Loans Associations (VSLAs). We also assessed the improved communication network, which evaluates a household's access to means of communication, such as receiving weather updates through community radio, television (TV), or mobile phone-based alerts.

Table 1. Other predictor variables.

Variable	Coding
Age	(0 = 18–29, 1 = 30–39, 2 = 40–49, 3 = 50–59, 4 = 60 and above)
Educational level	(0 = no formal, 1 = primary, 2 = secondary, 3 = tertiary)
Gender of respondent	(0 = male, 1 = female)
Gender of household headship	(0 = male, 1 = female)
Marital status	(0 = married, 1 = single, 2 = divorced/widowed)
Religion	(0 = Christian, 1 = Muslim, 2 = African tradition)
Residency status	(0 = native, 1 = non-native)
Years of residing in the locality	(0 = 1–10, 1 = 11–20, 2 = 21–30, 3 = 31–40, 4 = 41–50, 5 = 51–60, 6 = 61 and above) (see [46])
Household size	(0 = 1–4, 1 = 5–8, 2 = 9 and above)
Wealth quantile	(0 = poorest, 1 = poorer, 2 = middle, 3 = richer, 4 = richest)
Extreme climate events experienced for the past 12 months	(0 = no extreme event experience, 1 = drought, 2 = flood, 3 = storm surge, 4 = erratic rainfall, 5 = dry spell)
Community action plan for disaster	(0 = no, 1 = yes)
Community Climate Action Plan	(0 = no, 1 = yes)
Source of climate information	(0 = self-experience, 1 = local community, 2 = external experts)
Improved health and infrastructure	(0 = no, 1 = yes)
Government support systems	(0 = no, 1 = yes)
Community support and social network system	(0 = no, 1 = yes)
Extension/knowledge support service on climate	(0 = no, 1 = yes)
Household financial savings as a safety net	(0 = no savings, 1 = formal, 2 = informal)
Improved communication network	(0 = no, 1 = yes)

3.3. Data Analysis

We employed a three-stage analysis. First, we conducted univariate analysis to gain insights into our sample's characteristics. Then, we used bivariate logistic regression to explore the specific association between each predictor and outcome variable. Following previous studies (see [16,42,47]), we finally employed an ordered logistic regression (OLR) model at the multivariate level to investigate the combined effect of the independent variables [47] because of the unconditional and ranked nature of the outcome variable (poor, satisfactory, good) [48]. This analysis helped us examine the association between perceived climate preparedness (the outcome variable), exposure to early warning (the focal independent variable), and other predictor variables. The computation equation for the logistic regression model is provided below.

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

The logistic model uses various explanatory variables (X_{ijk}, where k = 1 to $p-1$) to determine the likelihood ($P(Y_{ij} \leq 1)$) of an event occurring, with ($1 - P(Y_{ij} \leq 1)$) representing the chance of the event not happening. The error term is V_{ij}, and the intercept terms are α_0 and $\Omega - 1$, while α_{jk} defines the coefficient term [47]. Odds ratios are shown for the regression coefficients, where OR > 1 implies a higher likelihood of households reporting good climate preparedness, and OR < 1 indicates a lower likelihood. Before proceeding, we assessed multicollinearity among predictor variables and found no issue with a Variance Inflation Factor score below 10. We also performed the Brant test to confirm that the ordinal logistic regression model satisfied proportional odds. All data analysis was conducted using Stata version 18.0.

4. Results

4.1. Univariate Analysis

In Table 2, we present the univariate results. A majority, 50.68%, of the respondents expressed satisfaction with their preparedness for climate-related events, while 35.4% reported poor preparedness. Additionally, 71.95% of households are not exposed to warning systems. Regarding education, 71.95% of respondents do not have formal education. Most of them are male, at around 62.86%. Despite these obstacles, it is encouraging to see that 67.89% have noticed improvements in health and infrastructure. However, a concerning number, 55.71%, claim a lack of support from the government. Access to communication networks is low, at about 7.35%.

Table 2. Descriptive statistics of the study sample.

Variable	Percentage (%)
Perceived climate change preparedness	
Poor	35.40
Satisfactory	50.68
Good	13.93
Early warnings	
No exposure	71.95
Exposure	28.05
Age of respondent	
18–29	19.15
30–39	18.76
40–49	26.31
50–59	19.73
60+	16.06
Level of Education	
No formal education	71.95
Primary	18.57
Secondary	8.32
Tertiary	1.16
Gender of respondent	
Male	62.86
Female	37.14
Gender of household headship	
Male	88.59
Female	11.41
Marital status	
Married	77.37
Single	9.48
Divorced/Widowed	13.15
Religion	
Christian	55.51
Muslim	29.79
African Tradition	14.70
Residency status	
Native	95.94

Table 2. *Cont.*

Variable	Percentage (%)
Non-native	4.06
Years of residing in the locality	
Less than 10	9.67
11–20	17.02
21–30	21.28
31–40	16.83
41–50	14.89
51–60	14.51
61+	5.80
Household size	
1–4	26.89
5–8	43.71
9+	29.40
Household wealth	
Poorest	24.95
Poorer	16.63
Middle	19.92
Richer	17.60
Richest	20.89
Extreme climate events experienced for the past 12 months	
No extreme event was experienced	5.61
Drought	26.31
Flood	33.85
Storm surge	8.12
Erratic rainfall	23.60
Dry Spell	2.51
Community action plan for disaster	
No	79.88
Yes	20.12
Community Climate Action Plan	
No	81.24
Yes	18.76
Improve health and Infrastructure.	
No	32.11
Yes	67.89
Government support systems	
No	55.71
Yes	44.29
Community support and social network system	
No	90.72
Yes	9.28
Extension and knowledge support system on climate	
No	73.69
Yes	26.31
Source of climate information	
Self-experience	2.90
Local community	30.75
External experts	66.34
Household financial safety net	
No Savings	59.77
Formal	4.84
Informal	35.40
Improved communication network	
No	92.65
Yes	7.35

4.2. Bivariate Analysis

Our finding on bivariate analysis is presented in Table 3. We found that exposure to early warnings significantly enhanced households' preparedness to handle weather and climate-related extremes in the past 12 months (OR = 2.995; $p < 0.001$) compared to those without. Furthermore, the age group of 40–49 (OR = 1.656; $p < 0.01$) demonstrated higher preparedness compared to the reference category of those aged 18–29. Socioeconomic status also played a substantial role, with the richest households exhibiting twice the preparedness compared to their poorest counterparts (OR = 2.134; $p < 0.001$). Past experiences with extreme climate events, including droughts (OR = 5.037; $p < 0.001$), floods (OR = 5.877; $p < 0.001$), storm surge (OR = 4.501; $p < 0.001$), erratic rainfall (OR = 3.181; $p < 0.001$), and dry spells (OR = 6.251; $p < 0.001$) were associated with significantly heightened preparedness. Households with a government support system (OR = 1.798; $p < 0.001$) and extension/knowledge support services (OR = 1.695; $p < 0.001$) also improved preparedness levels. We also found that households with informal savings as safety nets demonstrated reduced preparedness (OR = 0.651; $p < 0.01$).

Table 3. Ordered logistic regression analysis predicting good climate preparedness at the bivariate level.

Variable	Bivariate Regression OR (SE)	[95% CI]
Early warnings (Ref: No exposure)		
Exposure	2.995 (0.596) ***	2.027–4.425
Age of respondents (Ref: 18–29 years)		
30–39	1.104 (0.301)	0.646–1.885
40–49	1.656 (0.423) **	1.004–2.733
50–59	1.302 (0.356)	0.761–2.228
60+	1.501 (0.434)	0.852–2.646
Level of education (Ref: No formal education)		
Primary	0.803 (0.177)	0.521–1.239
Secondary	0.991 (0.405)	0.444–2.210
Tertiary	1.833 (0.685)	0.881–3.815
Gender of the respondent (Ref: Male)		
Female	0.927 (0.162)	0.658–1.307
Gender of household headship (Ref: Male)		
Female	0.910 (0.243)	0.539–1.537
Marital status (Ref: Married)		
Single	1.133 (0.330)	0.639–2.008
Divorced/Widowed	1.181 (0.304)	0.712–1.959
Religion (Ref: Christian)		
Muslim	1.291 (0.247)	0.886–1.880
African Tradition	0.660 (0.165)	0.403–1.080
Residency status (Ref: Native)		
Non-native	1.423 (0.609)	0.614–3.294
Years of residing in location (Ref: 10 or less)		
11–20	0.808 (0.279)	0.411–1.590
21–30	0.711 (0.234)	0.372–1.358
31–40	0.953 (0.326)	0.487–1.863
41–50	0.805 (0.281)	0.406–1.596
51–60	0.811 (0.285)	0.407–1.617
61+	1.750 (0.649)	0.741–4.135
Household size (Ref: 1–4)		
5–8	1.500 (0.313)	0.996–2.258
9+	1.120 (0.251)	0.722–1.738
Household wealth (Ref: Poorest)		
Poorer	1.514 (0.402)	0.900–2.549

Table 3. *Cont.*

Variable	Bivariate Regression OR (SE)	[95% CI]
Middle	1.384 (0.352)	0.840–2.280
Richer	1.648 (0.433)	0.984–2.760
Richest	2.134 (0.541) ***	1.298–3.508
Extreme climate events experience (Ref: No event experience)		
Drought	5.037 (2.157) ***	2.175–11.663
Flood	5.877 (2.497) ***	2.555–13.516
Storm surge	4.501 (2.210) ***	1.719–11.787
Erratic rainfall	3.181 (1.380) ***	1.359–7.446
Dry Spell	6.251 (4.402) ***	1.572–24.852
Community action plan for disaster (Ref: No)		
Yes	0.731 (0.148)	0.491–1.089
Community has climate action plan (Ref: No)		
Yes	0.754 (0.157)	0.501–1.135
Improve health and Infrastructure (Ref: No)		
Yes	1.102 (0.196)	0.777–1.563
Government support systems (Ref: No)		
Yes	1.798 (0.309) ***	1.283–2.519
Community support and social network system (Ref: No)		
Yes	1.190 (0.358)	0.659–2.147
Extension/knowledge support system on climate (Ref: No)		
Yes	1.695 (0.332) ***	1.155–2.489
Source of Climate information (Ref: Self-experience)		
Local community	0.737 (0.412)	0.246–2.204
External experts	1.276 (0.699)	0.435–3.736
Household financial safety net (Ref: No Savings)		
Formal	1.048 (0.399)	0.496–2.214
Informal	0.651 (0.116) **	0.459–0.925
Improved communication network (Ref: No)		
Yes	1.318 (0.415)	0.710–2.446

$p < 0.1$, ** $p < 0.01$, *** $p < 0.001$: OR (Odds ratio), SE (standard error), CI (confidence interval).

4.3. Multivariate Analysis

In the multivariate analysis presented in Table 4, households exposed to early warning were 23% more likely to be prepared to handle weather- and climate-related extreme events in the past 12 months than households that were not exposed (OR = 2.238; $p < 0.001$). Regarding age, households with primary farmers within the age bracket of 40–49 years were 26% more likely (OR = 2.265; $p < 0.01$) to report good preparedness compared to households with primary farmers within the age bracket of 18–29 years. Also, single individuals' households were 62% more likely (OR = 2.623; $p < 0.01$) to report more preparedness, and those who reported being divorced or widowed were 90% more likely to report good preparedness (OR = 2.906; $p < 0.001$) compared to married individuals. Households with 5–8 members were 68% more likely to be prepared (OR = 1.684, $p < 0.01$) than households with 1–4 members. Regarding household wealth, the richest were 91% more likely to handle extreme weather and climate-related events in the past 12 months than the poorest households (OR = 2.910; $p < 0.001$). The prior influence of experiencing extreme events (past 12 months) remained significant, notwithstanding a notable increase in effects across all events: drought (OR = 9.252; $p < 0.001$), floods (OR = 6.608; $p < 0.001$), storm surge (OR = 7.915; $p < 0.001$), erratic rain (OR = 4.411; $p < 0.001$) and dry spell (OR = 6.235; $p < 0.01$). Interestingly, households that reported and trusted that their community had a disaster action plan were inversely related to preparedness levels (OR = 0.454; $p < 0.01$). Also, households that reported they received extension/knowledge support service on climate change strengthened their preparedness (OR = 1.675; $p < 0.01$) compared to households that did not. Lastly, households with informal savings as a safety net were less likely to report good preparedness (OR = 0.634; $p < 0.01$).

Table 4. Ordered logistic regression analysis predicting good climate preparedness at a multivariate level.

Variable	**Multivariate Regression OR (SE)**	**[95% CI]**
Early warnings (Ref: No exposure)		
Exposure	2.238 (0.566) ***	1.363–3.675
Age of respondents (Ref: 18–29 years)		
30–39	1.007 (0.365)	0.495–2.049
40–49	2.265 (0.810) **	1.124–4.565
50–59	1.904 (0.761)	0.869–4.171
60+	1.191 (0.514)	0.511–2.777
Level of education (Ref: No formal education)		
Primary	0.869 (0.241)	0.504–1.498
Secondary	1.136 (0.571)	0.424–3.043
Tertiary	1.917 (0.855)	0.799–4.596
Gender of the respondent (Ref: Male)		
Female	1.096 (0.250)	0.700–1.715
Gender of household headship (Ref: Male)		
Female	0.448 (0.187)	0.197–1.019
Marital status (Ref: Married)		
Single	2.623 (1.059) **	1.188–5.791
Divorced/Widowed	2.906 (1.189) ***	1.303–6.482
Religion (Ref: Christian)		
Muslim	1.188 (0.267)	0.765–1.846
African Tradition	0.902 (0.269)	0.502–1.620
Residency status (Ref: Native)		
Non-native	1.717 (0.902)	0.613–4.807
Years of residing in location (Ref: 10 or less)		
11–20	0.764 (0.290)	0.362–1.609
21–30	0.616 (0.228)	0.298–1.273
31–40	1.061 (0.419)	0.489–2.303
41–50	0.643 (0.273)	0.279–1.480
51–60	0.994 (0.442)	0.415–2.380
61+	2.369 (1.338)	0.782–7.170
Household size (Ref: 1–4)		
5–8	1.684 (0.417) **	1.036–2.738
9+	1.096 (0.308)	0.631–1.904
Household wealth (Ref: Poorest)		
Poorer	1.760 (0.523)	0.982–3.153
Middle	1.448 (0.429)	0.810–2.589
Richer	1.852 (0.584)	0.998–3.437
Richest	2.910 (0.944) ***	1.540–5.499
Extreme climate events experience (Ref: No event experience)		
Drought	8.877 (4.428) ***	3.340–23.597
Flood	6.608 (3.297) ***	2.485–17.572
Storm surge	7.915 (4.661) ***	2.495–25.104
Erratic rainfall	4.411 (2.330) ***	1.566–12.424

Table 4. *Cont.*

Variable	Multivariate Regression OR (SE)	[95% CI]
Dry Spell	6.235 (5.003) **	1.293–30.051
Community action plan for disaster (Ref: No)		
Yes	0.454 (0.162) **	0.225–0.915
Community has climate action plan (Ref: No)		
Yes	1.032 (0.382)	0.499–2.134
Improve health and Infrastructure (Ref: No)		
Yes	0.772 (0.166)	0.505–1.179
Government support systems (Ref: No)		
Yes	1.538 (0.334)	1.004–2.354
Community support and social network system (Ref: No)		
Yes	1.086 (0.374)	0.553–2.135
Extension/knowledge support system on climate (Ref: No)		
Yes	1.675 (0.390) **	1.061–2.645
Source of Climate information (Ref: Self-experience)		
Local community	1.404 (0.923)	0.386–5.096
External experts	2.226 (1.454)	0.618–8.012
Household financial safety net (Ref: No Savings)		
Formal	0.571 (0.255)	0.237–1.374
Informal	0.634 (0.140) **	0.411–0.977
Improved communication network (Ref: No)		
Yes	0.719 (0.274)	0.340–1.520
Observations	515	
LR chi2 (43)	125.06	
Pseudo R2	0.1235	
Log-likelihood	−443.579	

$p < 0.1$, ** $p < 0.01$, *** $p < 0.001$: OR (Odds ratio), SE (standard error), CI (confidence interval).

It is crucial to acknowledge that various factors are closely linked to preparedness levels, including access to early warning, the presence of primary farmers aged 40–49 in the household, marital status, household size, income level, prior experience with extreme events, and access to knowledge support services. It is worth noting that households with a disaster action plan in their community and those with informal savings as a safety net displayed lower levels of preparedness, which set the tone for our discussion.

5. Discussion

The rapidly changing climate and the ever-growing threats of extreme weather events and climate-related disasters, both in scope and intensity, have triggered a new discourse beyond current efforts at climate adaptation. Inspired by socio-ecologic resiliency theory, this study examined the relationship between exposure to early warning systems and climate preparedness among smallholder farmers in UWR. Commensurate with our hypothesis, we found a positive association between access to early warning systems and climate preparedness. This result aligns with the work of [7] in the Upper East Region (UER) of Ghana, who reported that smallholder farmers adjust their cropping calendar as an adaptation strategy influenced by climate information on extreme climate and weather events. Beyond Ghana, our finding is consistent with evidence from Baudoin et al. [49] and Cools et al. [50] studies in Egypt and Mali, highlighting the immense utility of EWSs in minimizing the worst damage from climate events, saving lives, and exponentially enhancing resiliency [51]. Indeed, estimates suggest that EWSs can yield a tenfold benefit [19,51].

The UWR is recognized as a climate vulnerability hotspot in the West African subregion [33]. As such, the adverse effects are inevitable and are only projected to worsen.

However, the preparedness to manage such hazards can significantly determine the impact of climate and shape lived experiences and whether these risks become disasters in the long run [52]. Unfortunately, prior research identified smallholders' lack of access to these vital resources due to unavailability or inability to invest in such avenues to facilitate climate preparedness [10]. Another layer of complexity in protracting climate vulnerability in the UWR involves inaccessibility and potential misuse of resources partly stemming from the area's high illiteracy rates [53]. Unsurprisingly, most coping and resilience-building efforts are usually reactive and post facto.

In addition to access to EWSs, several factors have also emerged with a significant relationship with climate preparedness. For instance, households with respondents aged between 40 and 49 were more likely to be climate-prepared when compared to younger farmers. This difference can be explained by rural farmers' general risk aversion, which leads to limited resource commitment and the adoption of vital input [54]. Furthermore, risk aversion may be more prevalent among younger farmers without effective coping and adaptive strategies to withstand the rapidly changing environment. For older farmers, however, assets may also be a proxy for their experience in the farming sector, enabling them to devise better coping and adaptive strategies [55]. Indeed, Hansen et al. [54] have opined that the difference between the selection of crops and the integration of innovative technologies may be linked to the experience of farmers.

We also found that respondents who were single and divorced/widowed were more likely to be climate-prepared than their married counterparts. While this result seems contradictory to those reported in Uganda and Malawi [56,57], this result may be a function of differentiated vulnerabilities and timeliness in decision making. In the marriage setting—especially with the rapid emergence of joint decision making—decision making toward climate preparedness may be slower as input is gathered from all relevant stakeholders to produce well-weighted adaptative strategies [42]. However, the decision-making process is comparatively more straightforward for single or divorced farmers since fewer people are involved. Furthermore, single or divorced people, especially women, may also trigger a proactive edge to seeking solutions since they may already be very conscious of their vulnerability and limited resource access [58]. Earlier evidence from Tanzania also reports that widows and divorced women are more likely to pursue livelihood diversification strategies to improve their livelihood outcomes [59].

The emergence of household size and climate preparedness is consistent with findings from Mohammed et al. [60], who highlighted that while larger households may increase the dependency burden and stress on household resources in the short term, more numbers can be more utilitarian for long-term preparedness, especially considering the stringent labor demands in rural agrarian systems [60]. Research in East Africa also reveals several benefits of relatively larger households that may better equip them for climate preparedness. These include higher levels of diversification, a broad spectrum of climatic knowledge, and experience to inform decisions that can be collectively implemented and executed [61].

Households with prior experiences with extreme climate events such as drought, dry spells, floods, storm surges, and erratic rainfall were more likely to be climate-prepared than those with no experiences. This result is consistent with one of the central tenets of resiliency, which states that resilience transcends simply resisting the change to and conservation of existing structures or persistence to change while maintaining the same function but also constitutes the capacity to learn, combine experience and knowledge, adjust responses to changing external drivers and internal processes, and continue operating [62,63]. Post-shock resilience has been widely acknowledged in diverse fields ranging from environmental change to psychology [62,63]. Past adversities can be critical trigger points for victims to seek new information and expand their resource base to avoid them in the future.

Although the source of climate information was not significant at the multivariate level, the significance of extension services warrants some discussion. Farming households with access to extension services were also more likely to be climate-prepared than their counterparts without access. Despite the reports that extension services perform sub-optimally from being under-resourced in rural sub-Saharan Africa [33,64], they still constitute one of the efficient conduits for propelling climate preparedness, adaptation, and resilience [65]. Extension services offer various information and capacity-building services through cultivation training and demonstration, which help farmers understand and undertake agroforestry, soil and moisture conservation strategies, crop rotation, and the rescheduling of planting dates [66]. In Ghana and elsewhere, there is evidence that farm schools associated with extension services for the demonstrations of climate-smart agricultural practices incentivize and better equip farmers to adopt practices such as switching to drought-resistant seeds [67].

Over-reliance on the community has influenced farmers' preparedness. We were surprised to uncover that farmers who reported that their communities had an action plan for disaster management were less prepared for climate-related risk. The possible attributes of this effect include that these communities often need more resources, like technology, workforce, and funding, to implement disaster plans effectively. Community members may need more awareness and understanding of the existing plan, which reduces its effectiveness. Moreover, climate risks can be complex and unpredictable, sometimes surpassing the scenarios the plans were designed to handle. Cultural factors also come into play; traditional beliefs and attitudes may make people less inclined to rely on disaster-management techniques. Additionally, some plans might not align with these communities' climate-related challenges. Lastly, there could be a skills gap where residents lack training to implement the plan effectively. Consistent with the findings of Breton [68], having a disaster management plan is not the final solution; it must be implemented well, understood by all community members, and adapted to local circumstances to enhance preparedness at a community level [69].

The high poverty rate is widely acknowledged in the literature on environmental change and resilience [70] as one essential characteristic of the UWR that has historically contributed to most farmers' vulnerabilities, mainly through limited farming investments [35]. Farmers in the highest wealth rank may have the necessary resource base and purchasing power to acquire vital inputs, including improved seeds, good storage systems, and mechanized technologies, which are critical in shaping agricultural productivity and livelihood sustenance in the short, medium, and long terms [71].

Given the meaningful influence of wealth, it was no surprise that households dependent on informal financial safety measures tended to have lower levels of preparedness for climate events. Earlier work on credit sources and smallholder resilience in the region highlighted some positive attributes of informal financial avenues that can better position farmers, including accessibility and dependability [33]. Notwithstanding, these informal financial systems still significantly lack absolute income generation potential compared to their formal counterparts [72]. Thus, it follows that households with access to credit from formal sources will have a relatively more robust purchasing power for meaningful agricultural investments. Evidence attests that farmers who receive credit from public banks, private banks, and cooperative societies are better equipped to adopt climate-resilient practices [65].

Despite these relevant findings, there are some noteworthy limitations. This study is based on a cross-sectional design, which, unfortunately, only limits our results to associations. Thus, to deeply understand the nuances in the challenges in access and temporal dynamics of EWSs, some longitudinal and qualitative studies should be conducted. Further, the responses in this survey may not accurately represent their households' status quo since different household members may have different conceptualizations of climate preparedness. Also, further stages of smallholder farmer resilience should be studied with objective indicators of preparedness.

6. Conclusions

Besides these limitations, our study provides crucial pointers on the influence of EWSs in the context of poverty, high illiteracy rates, and worsening climate vulnerability, among other vital markers. Consistent with the evidence around the globe, our findings suggest that households with access to EWSs were more likely to be prepared for extreme climate and weather events. This emphasizes that EWSs are a crucial conduit for proactive risk management as climate change is widespread, including long-term shifts in the climate and extreme weather events. Nevertheless, the effectiveness of warning systems relies on households taking the warnings seriously and acting upon them. However, some factors can influence how people respond, such as how credible they perceive the information. If households have experienced false early warnings, they may be less liable to react. Furthermore, unclear communication or understanding can hinder the desire of farmers to respond. Cultural and social factors also come into play when making decisions, including norms and economic limitations (like crop failure and income loss from evacuations).

Yet we make several policy recommendations based on the current and potential benefits of EWSs for smallholder farmers and rural development. First, the upper limits of EWSs in facilitating climate preparedness in the study context can be increased if the current systems can be expanded, entirely digitized, and complemented with remote sensing technologies to enhance the precision of predictions and patterns. In addition, developers of EWSs should also make room for receiving user feedback. This approach is crucial for tailoring technology that adapts to the needs of farmers as opposed to the usual scenarios of farmers adapting to technologies.

Expanding the EWSs to cover the entire region and beyond is crucial. Promoting localized delivery systems such as community broadcast and information centers close to the communities, particularly those with limited access to technology, is suggested to ensure adequate system delivery. The messaging delivery system and context should be designed to cater to illiterate farmers so that they can understand the procedure.

Furthermore, the government, NGOs, and community leaders should provide support for the delivery of EWSs and encourage the formulation and effective use of community disaster and climate action plans toward community resilience. To keep farmers updated with new skills on climate events, the frequency of farmer field schools/day, training, and extension services should be increased in rural and isolated areas.

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