ISSN: 2338-1345 e ISSN 2808-8948 – Vol. 13 (1) 20-35 https://ojs.bakrie.ac.id/index.php/APJSAFE/about

Asia Pacific Journal of Sustainable Agriculture Food and Energy (APJSAFE)

Assessing the climate change and its impact on livelihoods of smallholder farmers in Karaga district of Ghana

Alhassan Bawa*

Department of Sustainable Agriculture, Faculty of Agriculture and Natural Resource, Tamale Technical University, Tamale, Ghana
**Corresponding author's E-mail address: abawa@tatu.edu.gh*

Received: 1st May 2025 | Revised: 13th Jun 2025 | Accepted: 18th Jun 2025

Abstract—Agricultural production and food security among smallholder farmers has been threatened as a results of the effect of the changing climate. This study sought to analyse the changing climate and its impact on livelihoods among smallholder rural farmers in the Karaga district of Ghana. The research adopted a mixed-method approach where both quantitative and qualitative data were used. Primary data was obtained from 272 households through interviews, focus group discussions, field observation, and key informant interviews. The findings show that majority of farmers recognize the negative effects of climate change on their livelihoods. Farmers also perceive potential benefits from new technologies such as high-yielding varieties and irrigation that can enhance their well-being. Smallholders also confirmed that the adaptation and mitigation strategies were through indigenous weather forecasting, and bio-insecticides innovations. In the years of crop failure because of climate hazards, smallholder farmers resort to trading, firewood harvesting for sale and charcoal burning as a coping livelihood strategy. The research also reveals that there is no significant differences between gender and adaptation response to the changing climate. The study further reveals that women and children are the most vulnerable during climate-related displacements. In conclusion, the ancient traditional practices of smallholder farmers, such as the use of 'rain callers', the use of forest reserves as shrines, indigenous weather forecasting, and the use of bio-insecticide innovation, are still very relevant in adapting to climate variability. The research recommends the promotion of indigenous weather information systems and sustainable agricultural practices to build rural smallholders' capacity to adapt.

***Keywords*—smallholder farmers, livelihoods, climate change, adaptation, mitigation, greenhouse gases**

INTRODUCTION

Climate change is a systematic change in the long-term state of the atmosphere over multiple decades or longer. A change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land use (IPCC, 2019). The Intergovernmental Panel on Climate Change (IPCC) defines climate change as any change in climate over time, whether due to natural variability or as a result of human activity (IPCC, 2021; IPCC, 2007). The United Nations Framework Convention on Climate Change defines Climate Change as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.

Ghana's climate is tropical and strongly influenced by the West Africa monsoon winds. The climate is generally warm with variable temperatures masked by seasons and elevation. The northern part of the country typically records one rainy season, which begins in May and lasts until September/October. Southern Ghana records two rainy seasons; the major season from April to July and the minor from September to November. Several climate models have confirmed that air temperature has increased by 1.0 ^{0}C between 1960 and 2003, at an average rate of 0.21 ^{0}C per decade (NC4, 2020). The rate of increase has generally been more rapid in the northern parts than in the southern parts. Rainfall is highly variable on inter-annual and inter-decadal timescales suggesting that long-term trends would be both difficult to identify and manage their associated consequences.

Sensitivity is the degree to which a given community or ecosystem is affected by climatic stresses. The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change (IPCC, 2021). For instance, a community dependent on rain-fed agriculture is much more sensitive to changing rainfall patterns than one where mining is the dominant livelihoods. Likewise, a fragile, arid or semi-arid ecosystem will be more sensitive than a tropical one to a decrease in rainfall, due to the subsequent impact on water flows.

Adaptive capacity is defined as the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC, 2001). Adaptation to climate change is defined as the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2019). Resilience can be defined as the ability of a community to resist, absorb, and recover from the effects of hazards in a timely and efficient manner, preserving or restoring its essential basic structures, functions and identity (IPCC, 2019). A hazard is defined as a dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage (UNISDR, 2009).

Food security exists when households have physical, social and economic access to sufficient, safe and nutritious food at all times that meets their dietary needs and food preferences for an active and healthy life (Achaempong *et al*., 2022).

The greenhouse effect is due to a set of chemicals present in Earth's atmosphere known as greenhouse gases that trap heat close to the planet's surface. As the Sun's rays travel through the atmosphere, they are in the form of ultraviolet (UV) rays and visible light that warms the Earth's surface. The warm surface then emits heat that travels from the surface back toward space as infrared (IR) waves and some of it makes its way back to outer space. The rest of it is trapped by greenhouse gases such as water vapour, carbon dioxide, methane, ozone, chlorofluorocarbons, and a few other chemicals and is re-radiated by these chemicals back to the Earth's surface. This keeps the lower part of the atmosphere warm enough for humans to survive. If the greenhouse gases increase in the atmosphere, more of this heat is trapped and the Earth warms; if the greenhouse gases diminish in the atmosphere, less of this heat is trapped and the Earth cools (Farmer & Cook, 2013).

Ghana's total greenhouse emissions were estimated at 42.2 million tonnes of carbon dioxide ($MtCO_2e$) in 2016, representing more than 7.1% of the 2012 levels (Table 1). When the Forestry and Other Land Uses (FOLU) emissions are excluded from the national total, emissions stood at 29.28 $MtCO_2e$. Mathematically, the contributions of Forestry and Other Land Uses such as settlements and commercial uses, land-use change (e.g. conversion of forest into agricultural lands), and forestry activities accounts for 12.87 $MtCO_2e$ in 2016 largely due to anthropogenic causes as a result of population increase and limited efforts of afforestation and reforestation activities to remove carbon from the atmosphere. Similarly, Agriculture, Forestry and Other Land Use alone contributes 22.92 Mt CO_2e representing 54.38 percent of the National Emissions. The major sources of greenhouse gas contribution by agriculture are from livestock, and croplands particularly due to the implementation of the Government flagship programme 'Planting for Food and Jobs' which promoted fertiliser use through subsidy and subsequent 'Rearing for Food and Jobs' with free distribution of animal and bird varieties to farmers in 2016.

Table 1. Trends of greenhouse gas emission by sectors in Ghana

IPCC Sector/Categories	Total Emission ($MtCO_2e$)					Percentage Change (%)			
	1990	2000	2010	2012	2016	1990-2016	2000-2016	2010-2016	2012-2016
National emission with FOLU	25.34	27.26	35.23	39.35	42.15	66.3	54.60	19.60	7.10
National emission without FOLU	3.72	14.53	22.5	26.39	29.28	158.70	101.50	30.10	10.90
Agriculture, Forest and Other Land Use (AFOLU)	20.10	19.47	21.49	22.05	22.92	14.00	17.70	6.70	4.00
Waste	1.02	1.48	2.53	2.71	3.17	210.80	114.20	25.30	17.00
Energy	3.73	5.96	10.11	13.07	15.02	302.70	152.00	48.60	14.90
Industrial processes and product use	0.49	0.36	1.09	1.52	1.04	112.20	118.90	-4.60	-31.30

Source: NC4 2020

Though the emissions from waste and energy are low compared to AFOLU, there is a worrying trend of gradual growth as indicated in the percentage increase of 17% and 15% respectively from 2012 to 2016. The economic expansion of the economy has led to an increase in carbon emissions from road transport, thermal electricity generation, biomass utilisation for cooking, deforestation and disposal of domestic liquid waste. The crucial need to eradicate poverty hinges on the expansion of the economy, which goes along with an increase in greenhouse gas emissions. Consequently, Ghana expects the national emissions to grow as we develop, but will plateau and then decrease over time as she implements the National Determined Contributions (NDC).

Climate impacts such as increasingly intense and frequent extreme weather events, affect people in developing countries disproportionately, threatening lives and livelihoods, human security, and sustainable development (World Economic Forum, 2021; Codjoe & Atiglo, 2020). Human activities have explicitly influenced and are still influencing a wider range of climate variability including weather and climate extremes. Widespread and rapid changes in the atmosphere, ocean, cryosphere, and biosphere have occurred due to the release of greenhouse gases including Carbon Dioxide (CO_2), Methane (CH_4), and Nitrous Oxide (N_2O) leading to higher temperature rises and increased precipitation (IPCC, 2021). Human-induced climate change has contributed to increases in agricultural and ecological droughts in some regions due to increased land evapotranspiration (IPCC, 2021; Odonkor et al., 2020). Climate variability and change largely due to these greenhouse gases are already seriously disrupting rainfall patterns, increasing drought frequency, storms, and floods.

This affects rain-fed agriculture which represents significant risks to livelihoods and food security through reducing crop and livestock yields, particularly of the most vulnerable populations in the least developed parts of the world (FAO, 2020). According to IPCC (2021), greenhouse gas emissions are most likely to double from the current 410 ppm of carbon dioxide (CO_2), 1866 ppb of methane (CH_4), and 332 ppb of nitrous oxide (N_2O) in 2019 by the year 2100 and temperatures expected to increase between 1.8 ^{0}C and 4.4 ^{0}C by the year 2100 with a corresponding rise in sea level's glaciers melt which will further exacerbate the changing climate's impact globally.

In Africa, climate change impact is a major challenge and a threat to food security and livelihoods for millions of rural dwellers who depend largely on natural resources. According to the World Economic Forum (2021), Africa is the continent that is mostly affected by the impacts of climate change and extreme weather events due to its vulnerability to the damaging effects of these hazards and its low coping capacities to recover from them. In sub-Saharan Africa where Ghana belongs, the changing climate's impact is even more critical as it threatens to erode the development gains made in the past and hampers the ability to accomplish the sustainable development aspirations envisaged according to the Fourth National Communication to the UNFCCC (NC4, 2020). It further indicates that, vulnerability due to dependence on agriculture adversely impacts livelihoods, with increasing severity from the coast to the Northern savannah and worsen in communities in the Northern dry savannah zone where the study area is found using agriculture-livelihood sensitivity analysis. The five Northern regions of Ghana are prone to the greatest desertification threats in the country on an area of about 78,718 km^2 (NC4, 2020).

In recognition of the threat of climate change, governments globally were tasked to develop, implement and evaluate action plans towards the reduction of greenhouse gas emissions by 15% and hold planetary warming below 2 °C (3.6 °F) of preindustrial levels by 2030 in the Conference of Parties (COP21) in December 2015 (UNFCCC, 2016). In line with the global climate agreement, Ghana has designed and implemented policies in the northern ecological zones in response to climate change mitigation and adaptation relating to agriculture as in the National Food and Agriculture Sector Development Policy (FASDEP II), Community-Supported Agriculture and Food Security Action Plan (CSAFSAP), Tree Crop Policy and Gender with the focus on women's livelihood diversification as in the National Gender Policy (2015), Social Protection Policy (2015), and Child and Family Welfare Policy (2015). Despite policy ambitions of Ghana, the country still faces the adverse effects of changing climate in the areas of water resources, energy supplies, crop production, and food security with its Northern regions being the most vulnerable to the increased extreme weather conditions with higher incidences and more prolonged periods of flooding and droughts (MFA, 2019). Having a better understanding of the causes of climate variability will trigger behavioural actions among the Ghanaian populace to reduce human activities that contribute to climate change (Odonkor *et al*., 2020). This study sought to analyse the changing climate and its impact on livelihoods among smallholder rural farmers in the Karaga district of Ghana.

Climate variability has a wide range of impacts on the rural economy including agricultural productivity, revenues of the farm household, and asset values, and it also affects the agricultural infrastructure through the change in water sources available for agriculture. According to Kim *et al*. (2010), the impact of climate change can be classified into two namely; positive impacts and negative impacts as shown in Figure 1. The positive impacts of climate change resulting from global warming include the increase in crop productivity due to the fertilization effect caused by the increase in carbon dioxide and nitrous oxide concentrations in the atmosphere, expansion of the areas available for the production of tropical and/or subtropical crops, and the emergence of new crop varieties produced. Negative impacts of climate change from global warming include reduced crop quantity and quality due to the reduced growth period following high levels of temperature rise; reduced sugar content, bad coloration, and reduced storage stability in fruits; the increase of weeds, blights, and harmful insects in agricultural crops; reduced land fertility due to the accelerated decomposition of organic substances; and increased soil erosion due the increased rainfall.

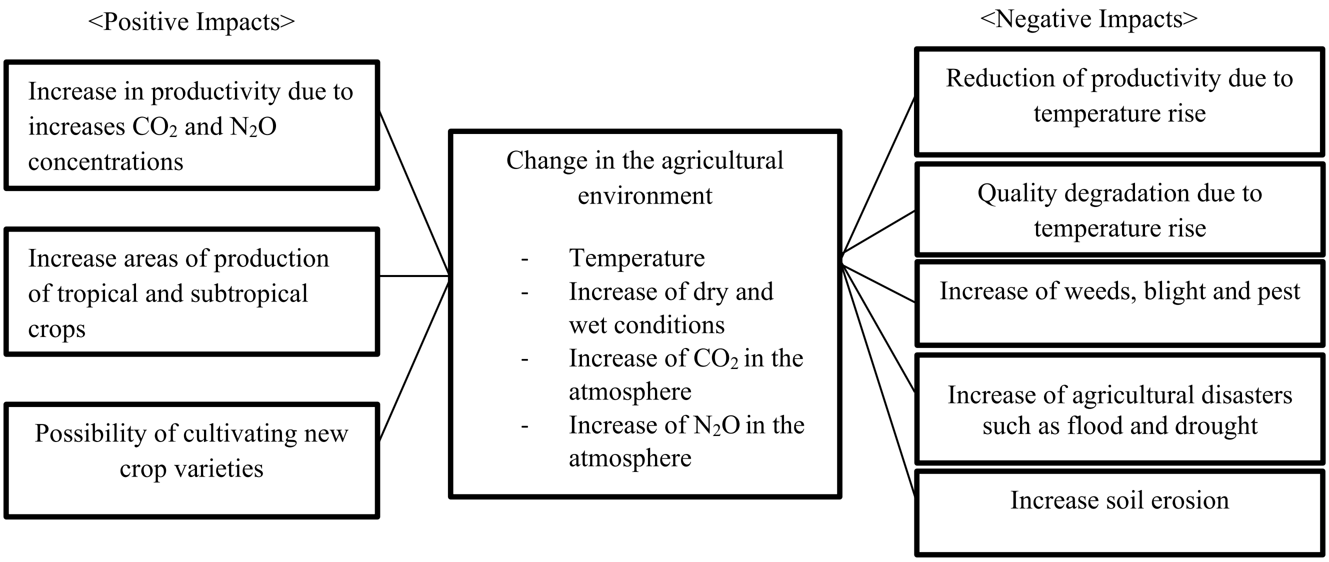

Figure 1. The two major impacts of climate change on agriculture productivity

Source: Adapted from Kim et al. 2010

METHODOLGY

Study Area

The study was carried out in Karaga district of the Northern region of Ghana. The Karaga district is located in the north-eastern portion of the Northern region between latitudes 9^o30^o North and longitudes 0^o and 45^o West (PHC, 2021). The district capital is about 89.6 km north-east of Tamale, the regional capital. The approximate land area of Karaga district is 5,796 km^2 with a population of 114,225; consisting of 55,677 males and 58,548 females (PHC, 2021). Female-headed households are made up of 11.8% in the district, with an average household size of 9.6 members. About 30% of the population resides in settlements that can be classified as town. This means that about 70% of the population is rural.

The vegetation is a typical Guinea-Savannah type, characterized by tall grasses interspersed with drought resistance trees such as Shea and Dawadawa. The climate reflects a typical continental climate experienced in Northern Ghana. There is only one rainy season, which builds up gradually from little rains in April to a maximum in August-September, and then declines sharply to a complete halt in October when the dry season sets in. Rainfalls are very torrential and range between 85 mm and 1150 mm per annum with irregular dry spells occurring in June - July. Temperatures are high throughout the year with the highest of 36 ^oC or above in March and April. Low temperatures are experienced between November and February (the harmattan period) (PHC, 2021). The only opportunity opened to the Karaga district is in the area of agriculture. The district is endowed with vast productive agricultural land with a potential for the production of cereal crops, root and tuber, legumes, industrial crops and also rearing of livestock. The district exports grains and yams to other regions, especially Upper East. Cultivation of non-traditional export crops such as cashew is also gaining currency. Cotton is also produced on a large scale in the district. The district also has a large concentration of economic trees such as Shea and Dawadawa. Cattle, sheep and goats are reared on a large scale in the district. On the average, almost every household in the district rears some animals of a kind (PHC, 2021).

There is no established industry in the district. However, there are over one hundred groups engaged in various income generating activities. Income generating activities include sheabutter extraction by women groups and smock weaving by men. Low agricultural productivity and lack of ready markets for produce from income generating activities are some of the root causes of poverty in the district, although it is endowed with a strong renewable resources base that offer potentials for enhanced agricultural productivity.

Conceptual Framework

From Figure 2, climate variability and climate change which is scientifically proven to be caused by the release of greenhouse gasses such as Carbon Dioxide (CO_2), Methane (CH_4), and Nitrous Oxide (N_2O) into the atmosphere (IPCC, 2021), leading to rising average and extreme temperatures, which intend causes changes in precipitation. Consequently, these result in extreme weather events such as floods, drought, storms and emergence of strange pests and diseases. The extreme weather events leads to land and biodiversity degradation, resulting in reduction in agricultural production and food security, and this eventually reduces rural livelihoods.

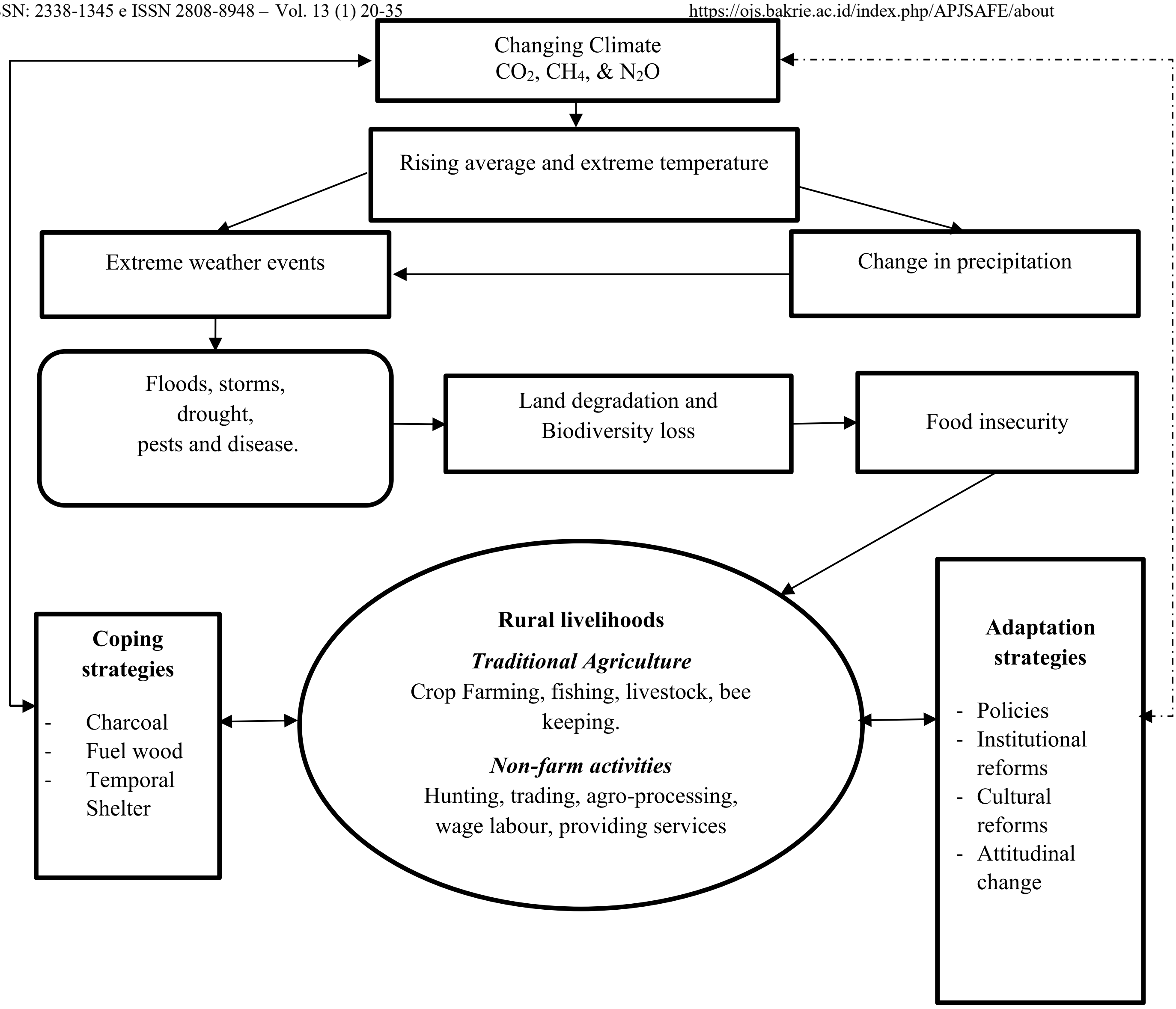

Figure 2. Conceptual framework

Research Design

The research design is the overall plan for collecting data in order to answer the research questions (Bell, 1993). It also includes the specific data analysis technique or methods that the researcher intends to use. The research design used for the study was the mixed methods. That is, it combines quantitative and qualitative methods in data collection and analysis. The instruments that were used for data collection were questionnaires, interview guide and checklist for focus group discussion. The study was exploratory in nature as it investigated the views of smallholder farmers and duty bearers on climate variability and change to livelihoods with a particular focus on agricultural production and food security. The study used a survey to examine the experiences of rural people whose livelihoods are largely dependent on natural resources often impacted by climate variability and how they adapt to these changes. This then informed the collection of necessary qualitative data to further provide clarification and explanations to the quantitative data. The study also identified similarities and differences in the adaptive strategies of communities, households, and gender to ascertain the vulnerability groups in this district. The different data sets both qualitative, and quantitative have been analysed simultaneously. The single-phase timing of this design is the reason it has also been referred to as the "concurrent triangulation design" (Creswell *et al*., 2003).

Population and Sampling Method

The population for the study consisted of smallholder household farmers in the Karaga district. The simple random sampling technique was used to select the Karaga district, out of sixteen districts in the Northern region of Ghana, for the study. The simple random sampling technique was again used to select four communities (out of thirteen communities), which normally benefit from NGOs developmental interventions in the Karaga district, for the study. The communities selected for the study include: Tong, Nyong-Nayili, Bagurugu, and Yamo-Karaga. A simple random sampling method was used to select 272 households from a total households of 849 from four selected communities in the study area. The sample size calculation was done following the formula proposed by Yamane (1967) as stated below:

$$n = \frac{N}{1 + N(e)^2}$$

Where 'n' is the sample size, 'N' is the population size in this research taken to be the total number of households in the study communities, and 'e' is the level of precision.

The level of precision also sometimes known as sampling error, is the range estimated to be the true value of the population. In this research, the sampling margin of error is estimated to be five percent (5%).

$$\mathrm{n} = \frac{849}{1 + 849(0.05)^2}$$
$$\mathrm{n} = \frac{849}{3.1225}$$
$$\mathrm{n} = 271.8975$$
$$\mathrm{n} = 272$$

Simple random sampling is the type of sampling method that gives each independent same-size sample in the population an equal chance of getting selected or being subjects (Yamane, 1967).

There were also four (4) interviews conducted with the Department of Agricultural Extension Agents using purposive sampling techniques to understand the climate action implementations, and challenges at the community level within the districts.

Furthermore, Focus Group Discussions (FGD) were conducted to give insightful community-level opinions on the effects of climate variability on their agricultural activities and livelihoods in each community. This tool helped to identify the community's indigenous strategies in coping with climate hazards and served as a validation of information gathered from the interviews and the questionnaire.

Design of Questionnaire

The questionnaires for the study were designed and administered using the Kobo toolbox for data collection. The questionnaires were structured based on the objectives of the study with some bio-data of the respondents being captured. The questions were closed-ended in nature to obtain quantitative data regarding the respondents' experiences relating to the topic. The questionnaire was translated into the local language (Dagbanli) for the household respondents by the trained research assistant. Research Assistants were trained to help in administering questionnaires and gathering data by writing, audio recording, observing, and pictorially capturing data.

Qualitative data was collected using semi-structured interviews, and observation by the researcher to elicit information on the sustainability of varied coping and adaptation strategies and their implications on rural livelihood. These semi-structured interviews were conducted by contacting key informants with the needed knowledge and experience on the effects of changes in climate on agricultural-related livelihoods in the communities. The semi-structured interview guide was developed from the main topics of the survey that needed clarity. A total of 4 interviews were conducted with Agricultural Extension Agents (AEAs) of the Department of Agriculture working at the communities. Focus group discussion method was used to gather qualitative data regarding changing trends of climate events and how they impact agro-related livelihoods of smallholder households. The selection process was based on the purposive sampling technique and a total of four (4) FGDs was conducted with a membership of between 5 to 10 (1 FGD in each of the study communities).

Data Collection and Analysis

Both quantitative and qualitative data were collected from primary source for the study. Secondary data sources were also collected. The primary data was collected from farm households. This data was disaggregated by gender to help understand the gender dimension of climate variability and change effects. Data was also collected from the District Department of Agriculture on specific climate action plan implementations and challenges using interviews. Some historic data were generated from the Department of Agricultural and the District Assemblies in connection to climate information such as rains, drought, and floods events. The quantitative data gathered from the survey through the Kobo toolbox was generated into a Microsoft Excel document which also was imported into IBM SPSS statistic 22 for analysis. The use of the Kobo toolbox for data collection made the analysis much easier because the questionnaires were pre-coded and automatically generated in the format of SPSS which helped to reduce errors. The data was edited by making follow-ups to correct omissions, and non-responses to ensure that there was consistency in the responses. Qualitative data was analysed using text analysis by slicing and dicing unstructured data from the interviews and focus group discussions into easy forms to interpret.

Prior to the analysis, the data was coded. Analysis was done using the Statistical Package for Social Sciences (SPSS). Descriptive statistics, such as frequencies, percentages and means were computed. Cross tabulations of variables were also computed and the chi-square tests used to establish relationships. Summaries of findings were presented in graphs and tables.

RESULTS AND DISCUSSIONS

Socio-Demographic Characteristics of Respondents

Gender of Respondents

Gender is a term used by most cultures as a binary that describes an individual's social identity related to an individual's biological sex and personality or behavioural tendencies as masculine or feminine (Maddux & Winstead, 2019). The roles played by each category of gender help understand how climate variability and change affect their livelihoods differently. It is therefore important to disaggregate the data using gender composition. Table 2 indicates the dominance of males which can largely be attributed to the customary practice of males being the household heads. Agricultural activities are the main livelihoods of these rural communities, and these activities are dominated (59.9%) by male respondents, while females constitute only 40.1%. The findings consequently show that, males produce more of the household food in these rural communities. This finding is contrary to the observations made by FAO (2015) who reported that women produce 60% to 70% of food in developing countries.

Table 2. Gender distribution of respondents

Community	Male		Female		Total (%)	
	Respondents	Percent (%)	Respondents	Percent (%)	Respondents	Percent (%)
Bagurugu	16	5.9	52	19.1	68	25.0
Nyong-Nayili	45	16.5	23	8.5	68	25.0
Tong	45	16.5	23	8.5	68	25.0
Yamo-Karaga	57	21.0	11	4.0	68	25.0
Total	163	59.9	109	40.1	272	100

Source: Field survey 2024

Household Size

From the study, Nyong-Nayili recorded the highest average household size of 10.48 whilst Yamo-Karaga recorded the lowest average household size of 6.05 (Table 3). The average household size for the four selected communities is 7.38 people, which is far beyond the national average of 4.2 people (GSS, 2021). The household size is regarded as the essential social and economic unit of society. Changes in the household size, therefore impact positively or negatively at the aggregate levels of a community. An increasing number of households, means more food and other resources are needed to cater for the growing needs. A large household size when not well managed could result in poor welfare, lower income, poor health status, and pressure on natural resources thereby having the likelihood of affecting adaptation responses to climate variability and change.

Table 3. Household size and age of respondents

Community	Household Size	Age of respondents	Frequency	Percent (%)
Bagurugu	**6.67**	**18-35**	**98**	**35.9**
Nyong-Nayili	**10.48**	**36-60**	**138**	**50.9**
Tong	**6.31**	**60 and above**	**36**	**13.2**
Yamo-Karaga	**6.05**			
Total	**29.51**	**Total**	**272**	**100.0**
Average house size	**7.38**			

Source: Field survey 2024

Age of Respondents

Climate variability and change issues are best understood with prolonged experiences of climate events over some period of time. To this effect, the research has categorized the ages of the respondent into three to help understand their insight and perceptions of climate issues. The study also used age characteristics to appreciate the different kinds of livelihoods for different age groups. Form Table 3, majority of the respondents (50.9%) are within the age range of 36-60 years and are more involved in livelihood activities in rural areas, particularly agricultural livelihood, while 35.9% are within the youthful ages of 18-35 years and marginally engage in rural livelihood activities. Respondents above 60 years who constitute the aged group were 13.2%, and this group are the least involved in livelihood activities.

Educational Status of Respondents

The results from Table 4 indicate that majority of respondents had no formal education (52.21%), 20.59% of respondents had primary education, whilst 0% of the respondents had tertiary education. Education is an important component of climate adaptation because it encourages people to change their attitudes and behaviour in order to make informed decisions. Education empowers the young by motivating them to take actions that engender their development by helping them understand and address the impacts of the climate crisis through knowledge, skills, values, and attitudes acquisition. Education level influences positively the households' livelihood diversification (Gecho, 2017). This research thus assessed the educational levels of the rural dwellers in relation to their livelihoods and how they are coping or adapting to climate variability and change. Climate adaptation measures are quite technical and need some level of education to understand and interpret the technologies that are being introduced.

Table 4. Level of education of respondents

Educational Level	Respondents	Percent (%)
No formal education	**142**	**52.21**
Primary	**56**	**20.59**
JHS/JSS/Middle School	**42**	**15.44**
SHS/SSS	**32**	**11.76**
Tertiary	**00**	**0.00**
Total	**272**	**100.00**

Source: Field survey 2024

Occupation of Respondents

Wet/Rainy Season Occupation

Rural livelihood mostly revolves around farming activities predominantly crop farming and livestock production (Dube & Phiri, 2013). From Table 5, farming is the occupation of majority of respondents (96.32%), minority of respondents are involved in studying (1.84%) and teaching (1.84%) in the Karaga district. This finding is similar to the findings of Davis *et al*. (2010a, b). It is by far not surprising that 1.84% had teaching as their main occupation in the District since their highest educational levels reaches the SHS. It is important to note that farming in most of these communities are largely rain-fed and any negative change in the rainfall patterns negatively impact on their livelihoods.

Table 5. Wet Season occupation of respondents

Occupation	Respondents	Percent (%)
Farmer	262	96.32
Student	5	1.84
Teacher	5	1.84
Trader	0	0.00
Total	272	100.00

Source: Field Survey 2024

Dry Season Occupation

The dry season is usually confronted with limited employment opportunities for rural dwellers whose main livelihood is dependent on rain-fed agriculture especially subsistent farmers, leading to migration to other areas. From the results in Table 6, Yamo-Karaga community has 22% of the respondents engaging in dry season farming due to the availability of a dam and a number of privately owned mechanised boreholes for irrigational purposes. Also, 10% of the respondents in Nyong-Nayili are also engaged in dry season beans farming using the Libga dam as source of water. Livelihood diversification strategies differ from one community to the other based on the resource available to them. This according to the study, help communities to develop different levels of resilience to the impacts of climate variability and change. However, the Tong community recorded the highest number of 10% of households that were unemployed during the dry season, making them more vulnerable than the other communities during the dry season. Farmers in Sub-Saharan Africa participate in livelihood diversification activities to increase households' income accumulation and to maintain livelihoods facing increasing climatic and economic risks (Echebiri et al., 2017; Prowse, 2015).

Table 6. Dry season occupation of respondents

Community	Respondent household occupation in the dry season					
	Percentage responses (%)					
	Farm labourer	Artisan	Farmer	Others	Trader	Unemployed
Bagurugu	0	0	0	13	12	0
Nyong-Nayili	0	1	10	4	9	2
Tong	1	3	4	2	6	10
Yamo-Karaga	0	0	22	1	2	0

Source: Field survey 2024

Rainfall Patterns and Community Perception

Both Focus Group Participants and Respondents of the household questionnaire were unanimous in their observations that rainfall patterns have changed in the district. They observed that the patterns had become more unpredictable with a shorter duration and skewed distribution. From the household survey, 96.4% of the respondents observed a change in the rainfall pattern with fewer occurrences and more frequent in the month of August while 3.6% of respondents reported no change in the rainfall patterns (Table 7).

Table 7. Rainfall pattern and community perception in the district

Rainfall pattern in the community	Respondents	Percent (%)
Rainfall pattern changes	262	96.4
No change in rainfall pattern	10	3.6
Perceived effect of changing rainfall pattern on livelihood		
Changes in rainfall pattern have negative effect on livelihood	223	82
Changes in rainfall pattern have positive effect on livelihood	49	18
Adaptive strategies to changing rainfall pattern		
Relying on radio/TV	149	54.8
Relying on past season's weather experience	84	30.7
Relying on expert opinions from Ghana meteorological agency	9	3.2
Rely on a combination of either of the three sources to predict the rainfall patterns	30	11.3

Source: Field survey 2024

From the Focus Group Discussions, a male farmer said the seasons have changed with drier season months more than rainy season months. One of them said;

> *"Some 30 years ago, in the month of March there were early heavy rains where rivers were full to capacity signifying the onset of the rainy season for land preparation. Planting of early maize or cowpea mostly in April and will continue until early November before cessation."*

The general sentiment from the discussions revealed that precipitation levels had drastically reduced affecting the livelihood of the people. For instance, one of the participants in FGD said;

> *"… early maize/cowpea which was a hunger gap bridging for farmers due to its high yields and short gestation characteristics, is now gradually becoming extinct due to delayed rains observed in recent years thereby affecting its production*."

82% of the respondent believe the changes in rainfall pattern has negatively affected their livelihoods while 18% disagree with the notion that, it has negatively affected their livelihoods since it has encouraged dry season production and the introduction of improved varieties which are more high-yielding. In a quest to adapt to the changing patterns of rainfall, the household survey revealed that, 54.8% rely on radio/television, 30.7% on past season's weather experience, 3.2% use expert opinions from Ghana Meteorological Agency and 11.3% use the combination of either of the three sources to predict the rainfall patterns for subsequent years in order to reduce the effect of the changing patterns (Table 7).

In a focus group discussion, a male farmer from Tong community said that;

> *"Farmers are able to use indigenous methods to predict the onset of rains such as the gathering of a certain type of cloud particularly in the morning, movement of birds, like the great egret, in groups from east to west, shedding of leaves of Feidherbia Albida tree and the fruiting of wild plum. These are used in determining the appropriate time for planting to avoid the adverse effect of the changing patterns of rain. Moreover, the experience of intense heat after heavy downpours in the month of September or October, coupled with the growth of leaves of the Feidherbia Albida tree, and the movement of great egret birds in groups from west to east also signifies the cessation of rains thus prompting farmers to harvest their produce on time to reduce post-harvest losses. When ants are seen transporting their eggs, and the flooding of earthworms on a sunny day among others also signifying that there will be rainfall within the day while Bombardier Beetle is seen everywhere during early rains signifies a favourable season"*.

One of the participants of the focus group discussion at Bagurugu said;

> *'… as for me, I will not advise any person to plant any crop after the 15th of July because of my experience of the rainfall patterns unless the person wants to plant Sesame (Zinzam in Dagbanli)'*.

Adaptive Strategies to the Changing Climate

Smallholders have adopted diversified ways of coping with the changing climate as they gradually shifted from practices such as single continuous cropping with no fallow periods (18.0%) and shifting cultivation (4.1%), to mixed cropping (33.1 %), crop rotation (25. 7%) and a combination of mixed cropping and crop rotation (19.1%) as in Table 8. This shift in practice helps reduce the risk of total loss from adverse weather conditions since one of the multiple crops could perform, improve the soil fertility, and serve as food sovereignty for them.

Table 8. Farming practice of smallholders

Farming practice	Respondents	Percent (%)
Continuous cropping with no fallow periods	49	18
Shifting cultivation	11	4.1
Mixed cropping	90	33.1
Crop rotation	70	25.7
Crop rotation and mixed cropping	52	19.1
Total	272	100.0

Source: Field survey 2024

Precipitation and Temperature Changes

From the results of the household survey, 49.1% of the respondents indicated that temperatures had increased drastically over the years. 39.4% of the respondents believe that there has been a drastic decrease in precipitation over the years, making temperatures hotter and warmer than had been in the past. However, 11.5% of the respondents were of the view that the decreased precipitation is due to increased temperature. The increased temperature had probably resulted in decreased precipitation levels making the agricultural lands drier (Table 9). A woman in a Focus Group Discussion at Tong said that: '*it looks like the sun is now closer to the earth than in the olden days with regards to the increased temperatures*'.

Table 9. Perception of precipitation and temperature changes

Precipitation and temperature changes	Respondents	Percent (%)
Increased temperature	134	49.1
Decreased precipitation	107	39.4
Decreased precipitation is due to increased temperature	31	11.5
Total	272	100.0

Source: Field survey 2024

Crop Fertilization and Weed Control

The research revealed that, 41% of smallholder farmers rely solely on chemical/inorganic fertilizers for crop production, 36% use only organic fertilizer, and 23% rely on both organic inorganic fertilizers as presented in Figure 3. The use of inorganic fertilizers to some extend are good in increasing yields and ensuring food security for smallholders, but when greater attention is laid on the use of inorganic fertilizers by smallholders as shown by the data which are not produced locally, it will not be sustainable for these smallholders to be self-sufficient. This goes to confirm the posit of Mari et al. (2008) who said, fertilizer overuse gradually results in soil compaction which has the potential of causing problems such as excessive soil strength, root growth restriction, poor aeration, poor drainage, runoff, erosion, and deterioration of the soil, with the potential of causing food insecurity in the future.

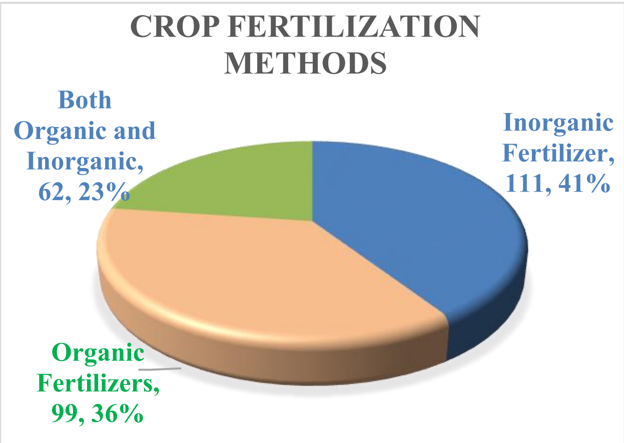

Figure 3. Fertilizer usage by smallholder farmers
Source: Field survey 2024

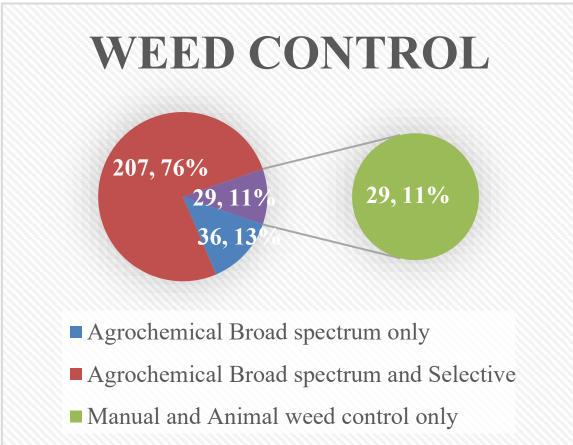

Figure 4. Weed control methods by smallholder farmers

Also in Figure 5, 76% of the respondents use agrochemicals (broad spectrum and selective) for weed control in their fields while only 11% use manual and animals for controlling weeds (Figure 4). These show highly unsustainable practices in crop production which could worsen smallholders' efforts to adapt to the changing climate in addressing rural livelihoods when not checked. This confirms the reports of Bisht & Chauhan (2020) which states that chemical fertilisers above the threshold levels pollute the atmosphere and contributes to the effects of climate variability and change though they help to improve food security.

Adaptive Strategies to High Temperatures

The research revealed that 65.8% of the households resort to drinking more water and sleeping outside their rooms in the open compounds during the night in order to cope with the uncomfortable condition of the increasing temperatures. 33.5 % of the respondents say they do nothing but just bear with the prevailing condition while 0.7% use air-conditioning as a coping strategy (Figure 5).

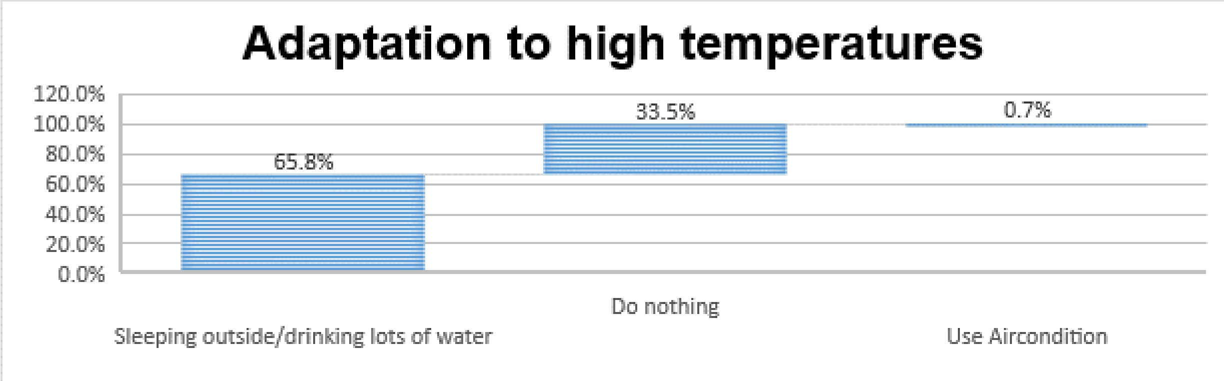

Figure. 5. Adaptation response of smallholders to high temperatures

Source: Field survey 2024

In conclusion, there is evidence of increased temperatures over the years. Farming practices such as the over-dependence on the use of agrochemicals in agricultural production have exacerbated these conditions which in turn affect the health and productivity of rural households. There is therefore, the need to adopt sustainable practices (such as bio-fertilizers, manual weed control, and bio-pesticides among others) that help the land.

Coping Livelihood Responses to Climate Hazards

In years of severe climate hazards, smallholder farmers relied on diverse economic activities to cushion their financial burden that arose from production losses or poor yields. Table 10 shows that, majority of smallholders in Yamo-Karaga engaged in fuel wood harvesting for sale (16%) and charcoal burning (10%) which rather exacerbates the effects of climate change in the long run. A good number of smallholder households engaged in petty trading activities (42%), a livelihood diversification strategy that helps in their sustenance until the next farming season. Migration (7%) plays an important role in the lives of people of Nyong-Nayili particularly in the years of crop failure. For instance, a key informant indicated that, the people of Nyong-Nayili migrate to Ejura in the Ashanti region to work on maize farms and usually come back with many bags of maize for their family's upkeep. Also interesting to note is the support from neighbours (3.7%) in the communities and remittances (4.8%) from family members and friends living outside the communities.

The study also revealed through key informant interviews that, the initiatives of smallholders to engage in livestock production, grain banking, and belongingness to 'Susu' groups, equally played a crucial role in reducing the negative impacts of climate variability and change in seasons of crop failures.

Table 10. Coping livelihood activities in years of crop failure from climate hazards

Livelihood Activities	Yamo-Karaga	Nyong-Nayili	Grand Total
Charcoal burning	28 (10.3%)	13 (4.8%)	41 (15.0%)
Depend on neighbours	5 (1.8%)	5 (1.8%)	10 (3.7%)
Fuelwood harvesting and sales	44 (16.2%)	0 (0%)	44 (16.2%)
Gathering and picking	8 (2.9%)	3 (1.2%)	11 (4.0%)
Hunting	10 (3.7%)	8 (2.9%)	18 (6.6%)
Migrate to other places	1 (0.4%)	19 (7.0%)	20 (7.4%)
Rely on remittances	1 (0.4%)	12 (4.4%)	13 (4.8%)
Trading	39 (14.3%)	76(27.9%)	115(42.3%)
Total	136 (50%)	136 (50%)	272 (100)

Source: Field survey 2024

Flood and Storm Disaster Risk Perception

Flood events posed significant threats to agricultural production and rural livelihoods. According to the household survey presented in Table 11, 35.3% and 21% of the respondents migrate to nearby schools/churches and neighbours respectively as a coping strategy in times of flood, while 33.4% reconstruct temporal wooden structures as shelter and to safeguard their properties. This confirms that, floods sweep away crops, livestock, and homes which further leads to injuries and casualties (Yiran and Stringer, 2016; Fiasorgbor et al., 2018). In general, the low-lying nature of the lands in the study communities in the Karaga district makes them more liable to flooding in years of copious rains (mostly between July and September).

Table 11. Coping strategies among communities on floods and storms

Coping Strategy	Yamo-Karaga	Nyong-Nayili	Total
Construct temporal huts	75	16	91 (33.4%)
Migrate to nearby schools	38	58	96 (35.3%)
Others	2	16	18 (6.6%)
Rely on NADMO	10	0	10 (3.7%)
Rely on Neighbours	13	44	57 (21.0%)

Source: Field survey 2024

Only 3.7% of the respondents say they get support from the National Disaster Management Organisation (NADMO). The coping strategies differ from district to district dependent on their proximity to some of the facilities available to them. These coping mechanisms further contribute to the depletion of forest resources which in the future could contribute to increased climate variability.

Adaptation to Drought

Drought is one of the climate hazards that pose severe damage to crop production as a major livelihood of rural communities. Frequent drought hardens the topsoil, preventing the use of rudimentary tools such as hoes and cutlasses inhibiting crop and animal health (Fagariba et al., 2018). According to the FGD in Nyong-Nayili, a man said;

> *'… in the past, we were not experiencing dry spells like this time except in 1983 but now it is like a routine happening every year. This is because of the way we cut trees unceasingly without planting some couple with other sinful acts like stealing and immoral sexual behaviours that make the gods angry at us'.*

According to this man, drought is caused by human activities and supernatural forces that are influenced by an act of man.

Strategies to Drought Adoption

Households and communities naturally react to changes in the environment that affect their livelihood by employing their own immediate solutions to solve them. Despite this tendency to cope with changing trends, others do nothing (2.4% from Yamo-Karaga, and 18.56% from Nyong-Nayili) in time of the occurrence of drought to cope or adapt to it (Table 12).

From Table 10, the coping and adaptation strategies by households showed that, many of them resort to replanting of their crops (50.30% for both communities). This means that, they are aware of the occurrence of drought and thus make provisions every year by reserving seeds to be used for replanting in years of severe drought making them resilient to its effects. Also, the use of composting which is an indigenous practice with local materials, irrigation in some areas where they are available, and use of drought tolerant varieties are good adaptation strategies for reducing the effects of drought by communities and households.

Table 12. Drought adoption strategies of respondents

Drought adoption strategies	Community household responses (%)		Total (%)
	Yamo-Karaga	Nyong-Nayili	
Do nothing	2.40	18.56	20.96
Irrigation	0.00	17.37	17.37
Mulching/Composting	2.40	2.40	4.80
Replanting	28.14	22.16	50.30
Resistant varieties	4.19	2.40	6.59

Source: Field survey 2024

One interesting finding is the use of sacrifice as a coping mechanism by both the Yamo-Karaga and Nyong-Nayili communities. A man in the FGD at Yamo-Karaga said;

> "*In the past when we experienced prolonged drought, the community members would drag the 'Bugulana' (Earth priest) to the shrine with local pito and a fowl to be used to pour libation on the shrine enchanting that because there is no water they are making a sacrifice with pito. The team that went there will not get home before the rain will fall, but today because of Christianity and Islam, we have stopped the practice".* In another FGD in Nyong-Nayili, a woman recounted a similar situation by stating categorically that, "*selected elders of the land would approach the'Saa Buguli ' (Shrine Lord or Rain caller) with a plea for rains with pito and a fowl which would be used to make sacrifices on the shrine and immediately the rains will fall".*

Gender Linkages to Agro-resilience Building in Climate Variability and Change

Social Assessment of Gender Agro-resilience

The study assessed the relationship between gender and social factors that influence agro-resilience to climate change in the study area using chi-square test statistics at a 95% level of confidence. The study revealed that, regardless of ones gender, access to productive lands (x^2=2.073, p=0.355), cultural norms (x^2=0.117, p=0.733), legal (x^2=1.347, p=0.246), and power (x^2=1.400, p=0.237) did not significant influence agro-livelihood resilience building (Table 13). This means that, regardless of one's gender, smallholder farmers' access to productive lands, cultural norms of their communities, legal stratum, and power had no impact on their agro-livelihood resilience building and did not also have impact on their adaptation strategies to the changing climate. However, smallholder farmers' control of natural resources such as land, access to timely climate information, adoption of climate information, and non-farm income significantly influenced their agro-resilience building. For instance, the occurrence of floods and storms that result in displacement poses a serious health threat, and safety challenges to women and girls compared to their male counterparts.

"… problem of women is even worse when support items are given because men are mostly those who benefit from them" (FGD in Tong). A similar result was obtained in the findings of Kaunza-nu-dem et al. (2021) that, support items were mostly registered and delivered in the name of the males than women. This confirms the male control of resources, resulting from cultural and social systems that subjugate women to a lower status (Pranab et al., 2022). Also, a man stated during a FGD in Bagurugu that "women attend meetings and listen more to the radio, thus having easy access to climate information and adapt to them than their male counterparts".

Table 13. Chi-square test for independence between social assessment of gender and agro-resilience building

Social strata	Pearson chi-square (x^2)	df	Asymp. sig. P-Value (2-sided)
Control over land	4.187	1	0.041
Access to productive lands	2.073	2	0.355
Food production	15.753	2	0.000
Control over food	6.093	2	0.048
Control over income	8.186	2	0.017
Cultural	0.117	1	0.733
Affluence	4.136	1	0.042
Education/Technology	4.036	1	0.045
Legal	1.347	1	0.246
Power	1.400	1	0.237
Displacement	30.078	2	0.000
Adoption to climate information	14.145	2	0.001
Timely climate information	18.285	3	0.000
Non-farm income	12.217	2	0.002

Source: Field Survey, 2022

Constraints to Gender Agro-resilience Building

The need for each gender to have the ability to build their own resilience towards the effects of the changing climate on their agro-livelihoods is important. Gender inequalities can render women particularly vulnerable to climate hazards and thwart their adaptation process (UNHCR, 2020). The findings revealed that lack of access to productive land as well as the control over land use significantly influence smallholders' agro-resilience (Table 14). However lack of financial resources as well as farm inputs (technology), though important but do not significantly influences smallholder farmers' agro-resilience.

Table 14. Chi-square test for independence between constraints and agro-resilience

Constraints	Pearson chi-square (x^2)	df	Asymp. sig. (2-sided)
Lack of access to Productive land	13.154	1	0.076
Financial	0.076	1	0.782
Control over land	7.031	1	0.008
Lack of farm inputs (Technology)	0.057	1	0.812

Source: Field survey 2024

Access to Climate Information

Access to reliable weather and climate information enables smallholder to prepare in advance against prevalent climatic inconsistencies. This information can help them to plan their livelihood activities with alternative options to reduce climatic shocks. Table 15 shows that, 34.6% (23.9% in Yamo-Karaga and 10.7 in Nyong-Nayili) of respondents receive some form of climate information to help in planning their agro-livelihoods which is statistically significant (x^2=21.068, p<0.001). This climate information is mostly on rainfall data (26.5%) and seasonal outlook (7%) at the start of the season, mostly from agricultural extension officers to help smallholders improve their adaptive capacities which is also statistically significant (x^2=50.611, p<0.001). There is therefore the need for intense education of smallholders on climate adaptation information to enhance their resilience.

Table 15. Climate information details by respondents

Weather information categorization	Yamo-Karaga (%)	Nyong-Nayili (%)	Significance Value
Those who get weather alerts or forecasts	65(23.9)	29(10.7)	x^2=21.068 p= 0.000
Areas of Weather information			x^2=50.611 p= 0.000
High Temperature	3(1.1)	0(0.0)	
Rainfall	50(18.4)	22(8.1)	
Seasonal Outlook	12(4.4)	7(2.6)	
Accuracy of weather information			x^2=21.783 p= 0.000
Fairly Accurate	41(15.1)	18(6.6)	
Highly inaccurate	0(0.0)	2(0.7)	
Inaccurate	7(2.6)	3(1.1)	
Very accurate	14(5.1)	6(2.2)	
Sources of Weather information			x^2=66.212 p= 0.000
Community information centre	2(0.7)	1(0.4)	
GMET/SMS alert	11(4.0)	3(1.1)	
Internet	4(1.5)	7(2.6)	
Other Farmers	12(4.4)	0(0.0)	
Radio/TV	33(12.1)	16(5.9)	
Social media	0(0.0)	2(0.7)	

Source: Field survey 2024

The grading of climate information received by respondents was seen to be fairly accurate (21.7%) in the sense that, the predictions are mostly generalized for regional or district and in some cases not in consonance to realities at the community level (Table 15). 7.3% of the respondents think that the information given are very accurate while 3.7% thinks that they are inaccurate. Though climate information from the study seem to have some discrepancies, they are statistically significant ($p<0.001$) for decision making towards improving smallholders' adaptive capacities and enhanced rural livelihoods. The Ghana Meteorological Agency also needs to work on improving these data needs for reliability. The major source of information delivery concerning climate information from this study is proved to be the use of community radio/TV with 18% of respondents getting education of the weather from such medium. In a FGD at Yamo-Karaga, one woman said;

> *"I like the radio because it gives me information on my farming activities and I also get the chance to call and ask questions though sometimes difficult to get connected because of poor network in this community….".*

5.1% of respondents also get Short Message Service alert (SMS alert) from GMET which is a good measure for adaptation only if the information given is accurate enough to inform decision making. 4.4% get their information from other farmers, 4.1% from the internet, 1.1% from community information centres and 0.7% from social media.

CONCLUSIONS

The following conclusions were drawn from the study:

Ancient traditional practices of smallholder farmers such as the use of forest reserves as shrines, indigenous weather forecasting, and the use of bio-insecticide innovation are some of the adaptive measures for climate variability.

The female is more vulnerable in times of climate related displacement than their male counterparts.

Extension services improve knowledge and skills of smallholders, thereby improving their resilience and building their adaptive capacities to the changing climate.

Timely and accurate climate information from the Ghana Meteorological Agency helps to reduce the impact of climate hazards on livelihoods of smallholder farmers.

Recommendation

Based on the conclusions, the following recommendations are made:

The traditional practices of smallholder farmers such as the use of traditional rain callers, the use of forest reverses as shrines, the indigenous weather forecasting systems as well as the use of bio-insecticide innovations should be maintained.

The training of smallholders on the preparation of bio-insecticides, compost and other sustainable bio-fertilizers will help reduce the effects of agrochemicals, thereby enhancing the adaptive strategies of smallholders to climate change.

Disaster relief items by NADMO and other NGOs should consciously target women and girls' security and safety as they tend to be the most vulnerable in periods of displacement.

Lastly, there is the need for the Ghana Meteorological Agency to improve upon the accuracy of their weather forecast information by the acquisition of modernised gadgets built with up-to-date ICT so that smallholders can rely on their information for planning.

Acknowledgement

I do acknowledge the logistical support of the Millar Institute for Transdisciplinary and Development Studies (MITDS). I also acknowledge the critical comments and scientific inputs made by all researchers of the Millar Institute for Transdisciplinary and Development Studies, Bolgatanga, Ghana.

Author's Contributions

This work was carried out by a single author. The Author designed the study, wrote the protocol, supervised the work, collected data and performed the statistical analysis, managed the literature searches, wrote the first draft of the manuscript, read and approved the final manuscript.

Competing Interests

Author has declared that no competing interests exist.

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