Unveiling Resilience: Exploring the Adaptive Capacities of Ghana's Forest Fringe Communities in the Face of Climate Change

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ABSTRACT

This study employed a comprehensive two-stage sampling method to investigate climate change impacts and adaptation strategies in Ghana, focusing on three distinct ecological zones: Dry Semi Deciduous (DSD), Moist Semi-deciduous (North West) MSDNW, and Savannah (SAV). 600 households from randomly selected communities within each ecozone participated in interviews and questionnaire administration over a two-year data collection period. Data was gathered through questionnaires, interviews, and focus group discussions, utilizing both qualitative and quantitative methods for analysis. Descriptive statistical methods were applied to determine socio-economic factors and social vulnerability levels across the ecological zones. The study revealed significant variations in adaptive capacity among the ecological zones. The Savannah (SAV) zone exhibited higher scores in non-farm income-generating activities, adaptive capacity for changing cropping patterns, and adoption of irrigation in response to climate change. Conversely, the Dry Semi-Deciduous (DSD) zone excelled in forest plantation modules, relocation of farming activities due to climatic factors, and modification in agrochemical use. Access to information on climate change varied significantly among ecological zones, emphasizing the necessity for tailored and context-specific strategies. The study's conclusion underscores the importance of recognizing and addressing diverse challenges and opportunities faced by communities in different ecological zones. To enhance adaptive capacity and resilience to climate change in Ghana, the study recommends targeted information dissemination for improved access, support for economic diversification, and promotion of climate-resilient agricultural practices. Emphasizing the role of economic diversification, adaptive agricultural practices, and forest-related measures, the study highlights their critical contribution to building resilience and adaptive capacity in the face of climate change.

Keywords: Climate Change, Exposure, Sensitivity, Adaptation

1.1. INTRODUCTION

Climate change is an unequivocal reality in Ghana, substantiated by extensive studies revealing substantial shifts in climatic conditions spanning the last four decades. Over this period, Ghana encountered a significant temperature surge of 1°C, accompanied by a notable 20% reduction in rainfall and a 30%

decline in runoff (Agyeman Bonsu et al., 2008; EPA, 2000). Future projections paint a concerning scenario, predicting a potential temperature increase of 1–3°C by 2060 and 1.5–5.28°C by 2090, coupled with expected drastic alterations in seasonality, rising sea levels, and storm surges (World Bank, 2011). The tangible impacts of climate change and variability, including unpredictable rainfall, floods, and heightened extreme weather events, have become palpable in Ghana (EPA and MEST, 2011).

Ghana's ecological zones, pivotal for supporting livelihoods and providing critical natural resources, have not been exempt from the repercussions of climate change. Historical climate data analyzed by the Ghana Meteorological Agency from 1960 to 2000 indicates a consistent upward trend in temperature and a simultaneous decrease in rainfall across all ecological zones (Kuuzegh, 2007; Anim-Kwapong and Frimpong, 2005; EPA, 2000). Future climate change scenarios project alarming declines in mean annual rainfall values, particularly in the Semi-Deciduous Forest and Rain Forest zones. By 2080, both zones are expected to witness significant increases in mean annual temperatures. Additionally, model projections suggest a notable rise in the average minimum temperature in the Sudan and Guinea Savanna zones by 2100. The Guinea Savanna, Forest-Savanna Transition, and Coastal Savanna ecological zones are anticipated to be particularly vulnerable, facing challenges like droughts and shortened farming seasons (Yaro, 2010).

While most climate change studies have predominantly focused on the biophysical and environmental dimensions, often at the national scale, limited attention has been given to the social aspects at the local level, encompassing households, rural communities, and districts. Recognizing the importance of understanding local-level responses to climate change, delving into the social aspects of vulnerability and examining underlying socio-economic factors becomes crucial. This approach ensures a more nuanced understanding and facilitates the development of tailored policy measures, steering away from the common one-size-fits-all solutions prevalent in national-level assessments.

Given the intricate interplay of socio-economic, political, and environmental factors influencing vulnerability, along with the diverse coping and adaptation strategies employed, there is an imperative need to explore dimensions beyond biophysical impacts. Wehbe et al. (2003) emphasized the inadequacy of solely quantifying biophysical impacts to comprehend population vulnerability to climatic conditions. Recognizing the significance of local-level adaptation studies, the IPCC (2007) highlighted how indigenous-based adaptation practices within communities can enhance resilience.

To address these gaps, the study conducts a comprehensive assessment of social vulnerability to climate change across four ecological zones, utilizing a social vulnerability index (SVI). Additionally, it delves into climate change impacts and identifies locally evolved adaptation strategies, underlining the necessity for localized insights to inform effective resilience-building measures.

The SVI serves as an algorithm designed to quantify social vulnerability, offering a valuable tool for understanding and measuring key aspects of climate adaptive capacity. It facilitates the assessment of adaptive capacity variations over temporal and spatial dimensions, providing insights into social dimensions of vulnerability concerning climate change at different scales. The SVI proves beneficial for researchers and decision-makers, aiding in the identification of areas requiring action or intervention. Furthermore, it serves as a tool for testing the potential impact of programs or policies by manipulating indicator values and recalculating the overall vulnerability index. The SVI also can project future vulnerability under different climate change scenarios, offering foresight into potential challenges. Understanding the procedures and diverse measurement methodologies associated with social vulnerability is crucial for planners and emergency managers. This knowledge empowers them to make informed decisions, prioritize actions, and effectively mitigate vulnerability, ultimately minimizing the impacts of disasters.

1.1.1. Research Objective

To determine the social vulnerability of fringe communities and how they have developed adaptive capacities against climate change

1.1.2. Research Hypothesis:

H_0: There is no significant difference in social vulnerability levels among fringe communities, and their adaptive capacities against climate change are uniform.

H_1: Fringe communities exhibit varying levels of social vulnerability to climate change based on demographic, economic, and social factors.

1.1.3. Research Questions:

1 What are the demographic factors contributing to the social vulnerability of fringe communities to climate change?
2 How do economic factors influence the social vulnerability of fringe communities in the face of climate change?
3 What role do social factors play in determining the vulnerability of fringe communities to climate change?
4 To what extent have fringe communities developed adaptive capacities to cope with and mitigate the impacts of climate change?

1.2. Conceptual Framework of Social Vulnerability to Climate Change

1.2.1. Components of vulnerability

The concept of vulnerability is complex and varies among different authors (Cutter 1996; Brooks 2003). Most authors adhere to the classical definition of vulnerability as a combination of exposure, sensitivity, and adaptive capacity McCarthy et al. (2001). Exposure refers to the extent of a system's exposure to significant climatic variations, sensitivity relates to how a system is affected by climate-related stimuli, and adaptive capacity represents a system's ability to adjust to climate change and its consequences. However, authors offer different interpretations of these components. For instance, some view exposure and sensitivity as vectors and adaptive capacity as a scalar Yohe & Tol (2002), while others emphasize the translation of exposure into a hazard and the distinction between biophysical and social vulnerability Vincent (2004). It is important to note that these explanations provide general descriptions and require detailed definition for quantitative assessment. Quantifying social vulnerability to climate change necessitates establishing mathematical relationships among its main components.

1.2.2. Adaptive capacity

Adaptation encompasses adjustments in ecological, social, or economic systems in response to current or anticipated climatic stimuli and their impacts (Smith et al. 2001). It is crucial for coping with unavoidable climate changes and sea level rises resulting from accumulated greenhouse gases (Leary, Adejuwon & Barros 2008). Adaptive capacity to climate change involves various resources and capabilities that societies or communities can utilize to reduce risk and vulnerability, including physical, institutional, social, and economic means, as well as skilled personal and collective attributes such as leadership and management (Brooks 2003). Adaptive capacity is context-specific, varying across countries, communities, social groups, and individuals, as well as over time and among different systems and regions. The determinants of adaptive capacity include technological options for adaptation, resource availability and distribution, institutional structure, human and social capital, access to risk-spreading processes, decision-makers information management, and the public's perception of stress sources and exposure significance (UNISDR 2004). Enhancing adaptive capacity is essential for reducing vulnerability to climate change, especially in situations where opportunities for reducing exposure are limited. Adaptation involves an ongoing process of identifying vulnerabilities and employing adaptive management strategies to address climate risks and other related risks .

1.2.3. Assessments of vulnerability to climate change

Several factors influence the extent of vulnerability to climate change in a region, encompassing aspects such as the magnitude, timing, persistence, and reversibility of impacts, as well as the likelihood and confidence in estimates of uncertainty regarding impacts and vulnerabilities. Additional factors include the potential for adaptation, the distributional aspects of impacts and vulnerabilities, and the significance of the system(s) at risk (IPCC 2007).

Vulnerability assessments to climate change aim to furnish information that can inform the development of policies to mitigate the risks associated with climate change. These assessments come in various types, ranging from quantitative to semi-quantitative, non-adaptive to perfectly adaptive, science-driven to policy-driven, and simplistic to sophisticated (Fussel & Klein 2006). However, two overarching approaches can be identified: impact-led and vulnerability-led. Impact approaches initiate with climate system scenarios and progress through biophysical impacts to socio-economic evaluation, primarily focusing on potential long-term impacts of climate change. Conversely, vulnerability-led approaches commence at the local scale, addressing socio-economic responses to climate change and emphasizing adaptation with stakeholder involvement (Sahin & Mohamed 2010).

1.2.4. Social Vulnerability

Vulnerability can be broadly categorized into physical or biophysical vulnerability and social vulnerability (Brooks 2003). While physical vulnerability is concerned with the ultimate impacts of a hazard event, social vulnerability focuses on the risk of exposure or sensitivity of groups or individuals to stress resulting from the impacts of hazard events (Adger 2003). Social vulnerability encompasses factors such as poverty, inequality, marginalization, food entitlements, access to insurance, housing quality, gender, ethnicity, religion, class, and age. It includes demographic and social characteristics that make certain communities more vulnerable than others, irrespective of the specific hazard type or threat source (Adger & Kelly 1999).

The nature of social vulnerability varies depending on the hazard, and certain hazard-specific factors exist (Cutter 1995). However, generic sensitivity factors like poverty, inequality, health, access to resources, and social status are likely to influence the vulnerability of communities and individuals to a range of hazards. Disaggregating social vulnerability into individual and collective aspects helps clarify the scale and unit of analysis (Cutter & Finch 2008). Individual vulnerability is determined by factors such as access to resources, diversity of income sources, and social status (Brooks 2003). The collective vulnerability of a nation, region, or community is influenced by institutional and market structures, including social security, average income, infrastructure, healthcare facilities, warning systems, and disaster management plans (Adger 1999).

1.2.5. New Concepts for Social Vulnerability Index

The suggested SVI (Social Vulnerability Index) incorporates the primary components of exposure, sensitivity, and adaptive capacity. This framework aligns closely with the definition proposed by McCarthy et al. (2001) as utilized in the Third Assessment Report of the International Panel on Climate Change and subsequently reaffirmed in the Fifth Assessment Report, finalized in November 2014. This approach also aligns with the trend observed in recent studies attempting to construct SVIs, such as those conducted by Shah et al. (2013), Ahsan & Warner (2014), and Morzaria-Luna, Turk-Boyer & Moreno-Baez (2014).

1.2.5.1. Exposure

Exposure is characterized as the degree to which a system experiences substantial climatic variations (McCarthy et al. 2001).In this study, exposure is specifically delineated as the extent to which the population in a designated area is subjected to natural hazardous events. This is quantified by the average percentage of individuals (or households) within defined groups who experience direct impacts from primary natural hazardous events (such as storms, floods, or droughts) about the total population (or households) in the specified area. Each subgroup of individuals (or households) within the exposure component is directly affected by a particular natural hazardous event, thus constituting an exposure factor.

1.2.5.2. Sensitivity

Sensitivity is the extent to which a system is influenced, either adversely or beneficially, by climate-related stimuli (McCarthy et al. 2001). In this study, sensitivity is delineated as the extent to which particular groups of individuals (e.g., females, the young and old, or farmers) in a designated area are vulnerable to natural hazardous events. Population sensitivity is quantified by the average percentage of individuals (or households) in these specific groups concerning the total population (or households) in the specified area. Each distinct group of individuals (or households) thus serves as a sensitivity factor, and sensitivity encompasses sub-components, including demographic and socio-economic groups.

1.2.5.3. Adaptive Capacity

Adaptive capacity encompasses the resources and capabilities that a community can employ to mitigate risk and reduce vulnerability. These include physical, institutional, social, and economic means, as well as skilled personnel, and collective attributes such as leadership and management (UNISDR 2004). In this research, adaptive capacity is quantified by the average percentage of individuals (or households) within specific groups who possess the ability to adapt to natural hazardous events to the total population (or households) in a designated area. Each group of individuals (or households) signifies a distinct capacity, comprising a variety of elements.

1.3. Methodology

1.3.1. Survey Design

The study used qualitative and quantitative sampling procedures in the data collection.The study employed a two-stage sampling method to select communities and households. Initially, households were categorized into three ecological zones (Dry Semi Deciduous (DSD), Moist Semi-deciduous (North West) MSDNW, and Savannah (SAV)) in the first stage. Following this ecological zone stratification, four communities were randomly chosen within each ecozone for the study. In the second stage, purposive sampling was utilized to select households for interviews and questionnaire administration. The criteria for household selection across all ecological zones were that the household head must be at least 25 years old or older. This criterion aimed to include respondents who had experienced long-term climate changes and their corresponding effects. At the community level, fifty households from each ecological zone were selected for interviews and questionnaire administration, totaling 600 households participating in the study. Data collection spanned two years, from 2019 to 2021. The information about household selection in different ecological zones is presented in the Table Error! No text of specified style in document..**1** below.

Table Error! No text of specified style in document..**1: Distribution of Households based on Ecological zones**

Dry Semi Deciduous (DSD)		**Moist Semi-deciduous (North West) MSDNW**		**Savannah (SAV)**	
Location	**Sample Size**	**Location**	**Sample Size**	**Location**	**Sample Size**
Boadwo	50	Goaso	50	Jema	50
Berekum	50	BediakoNo.1	50	Kintampo	50
Sunyani	50	BediakoNo.2	50	Tuobodom	50
Techire	50	Gambia no.1	50	Busunyaa	50
Total	**200**		**200**		**200**
***Total Household Population*	*1,174,830*		*549,089*		*1,184,634*

1.3.2. Sample Size

Teddlie & Tashakkori (2003) present a technique for determining the sample size, taking into account the population size and the desired confidence level for the survey results. In a similar vein, WHO (2005) recommends a sample size calculation method that considers the confidence limits of the survey result, the precision of the research design, and prevalence. This approach was utilized by Hahn, Riederer & Foster (2009) in their survey to compute a livelihood vulnerability index for two districts in Mozambique. The formula for calculating the sample size is expressed by the equation:

$$N = deff * (Z^2 * p * q)/e^2$$

Where:

N: Sample size

Z: corresponds to the confidence limits of the survey result. The value of Z for confidence limits of 95% is 1.96
p and q: correspond to the proportion of the sample in the population who held a specific characteristic (p) or not (q). N will be maximum when a value of 0.5 is assigned to both (p) and (q).
e: corresponds to the precision of the research design, which is usually within 10% of the population mean, and (e) will be assigned a value of 0.10
deff: corresponds to the design effectiveness. With a survey employing cluster sampling, a default value of 1.5 to 2.0 for deff is typically used.

Based on Formula 3.1, the sample size of each commune in this research was calculated:

$$N = 2.0*[(1.96)^2*0.5*0.5]/(0.1)^2 = 192$$

As a result, a survey was conducted with the selection of 200 households from each ecological zone, leading to a total sample size of 600 households across the three ecological zones. The choice of 200 households aimed to accommodate non-responsive households.

1.4. Data Collection

Understanding the intricate dynamics of social vulnerability within a community necessitates a comprehensive research approach that combines qualitative and quantitative methods. This dual-method strategy serves to capture the nuanced narratives and statistical insights essential for a holistic assessment. In this study, qualitative data collection focused on delving into the lived experiences and perspectives of key community stakeholders, while quantitative data collection aimed at quantifying and analyzing key indicators related to social vulnerability.

1.4.1. Qualitative Data Collection

The qualitative phase of the study employed two primary methods - in-depth interviews and focus group discussions. These methods provided a platform for engaging with diverse perspectives within the community.

1.4.1.1. In-Depth Interviews

Key figures, including Chief farmers, Opinion Leaders, Assemblymen, and Unit committee members, were strategically chosen for their profound understanding of community dynamics and social vulnerabilities. The interviews delved into detailed explanations of factors of exposure and sensitivity components, offering insights into the past occurrences, causes, and impacts of these factors. Additionally, the temporal dimension was explored, providing a nuanced understanding of the historical context and future projections according to the informants.

1.4.1.2. Focus Group Discussions

Engaging participants from various sectors, such as farmers, fisherfolk, Non-Timber Forest Products (NTFPs) collectors, plantation workers, and traders, ensured a diverse representation. Focus group discussions became a forum for expert opinions on community vulnerability and adaptive capacities. Participants shared their unique experiences, concerns, and insights, fostering a collective exploration of resilience strategies within the community.

1.4.1.3. Quantitative Data Collection

Complementing the qualitative insights, the research utilized questionnaires featuring open-ended, close-ended, and Likert scale questions. The questionnaire survey targeted key informants and focus groups, specifically focusing on climate change impacts and adaptation strategies. By posing questions related to changes in resource demands, participation in non-farm income activities, and demographic and socio-economic factors, the study sought to quantify and analyze essential indicators contributing to social vulnerability in different ecological zones.

This integrated approach, combining rich qualitative narratives with quantitative rigor, forms the foundation for a robust assessment of social vulnerability within the studied community.

1.4.2. Data Analysis

1.4.3. Descriptive Statistics

In social research, analyzing respondents' descriptive information is crucial for understanding demographics and questionnaire responses. This study utilized the Statistical Package for the Social Sciences (SPSS) for a nuanced exploration of participant characteristics. The analysis began with an examination of demographic variables like age, gender, education, and occupation through frequency analysis, revealing the diverse sample composition. Moving beyond demographics, SPSS facilitated a multifaceted analysis of key questionnaire responses, employing measures such as frequencies, mean values, standard deviations, and minimum and maximum values. Frequencies highlighted the occurrence of specific responses, offering a clear depiction of distribution within categories like age groups and educational backgrounds.

Mean values gauged the average response to questions with numerical scales, providing insight into the typical level of agreement or disagreement. Standard deviations measured response variability, indicating diversity or consensus among participants. Delving into minimum and maximum values revealed the range of responses, essential for understanding the spectrum of opinions within the participant pool. SPSS went beyond numerical tables, creating visually appealing tables and figures for effective communication. These graphical representations served as powerful tools for intuitively interpreting patterns, trends, and outliers within the data, enhancing the study's depth and clarity.

1.4.4. Estimating Social Vulnerability Index

To assess the social vulnerability of forest fringe communities in the chosen ecological zones, indicators were chosen to represent the demographic, economic, and social elements influencing a system's vulnerability to climate change. The primary components identified were sensitivity, exposure, and adaptation, each comprising sub-components delineating various factors influencing community vulnerability. Demographic factors were assessed through indicators like household size and literacy. Economic factors were represented by indicators such as diversified sources of income and engagement in climate-sensitive occupations, while social factors were measured through indicators like access to climate change information and reliance on forest resources. For each indicator within the demographic, economic, and social factors (the major components of social vulnerability), measured in different units, standardization was performed to create an index using Eq.1, following the approach outlined by Hahn et al. (2009).

$$Index_{Sv} = \frac{S_v - S_{min}}{S_{max} - S_{min}} \qquad \text{eqn. 1}$$

where, $Index_{sv}$ = index value of each indicator, S_V = actual value of each indicator for the respective factors (major components) of vulnerability, S_{max} and S_{min} = the maximum and minimum values respectively of each indicator for the respective factors (major component) of vulnerability. To create one vulnerability index for each factor (major components) of social vulnerability for each ecological zone, the index values of the indicators for each factor of social vulnerability were summed up and the average was determined. This was done using Eq.2:

$$M_v = \frac{\sum_{i=1}^{6} Index_{sv}}{n} \quad \text{eqn. 2}$$

where, M_v = the averaged index value of one of the factors (major components) of social vulnerability, $Index_{sv}$ = index value of each indicator for the respective factors (major components) of social vulnerability, and n = the number of indicators for each factor (major components) of social vulnerability. The social vulnerability of the rural communities for each ecological zone was determined by substituting the index values of all the factors in Eq. (1) resulting in Eq. 3 as follows:

$$SV = f.\left[\frac{1}{n}(M_{SF} + M_{EF} + M_{HC} + M_{SM})\right] \quad \text{Eqn 3.}$$

where, M_{SF} = the index values of the social factors, M_{EF} = the index values of the economic factors, M_{HC} = the index values of the historical and cultural factors, M_{SM} = the index values of social mobility factors, and n = the number of factors (major components) of social vulnerability.

1.4.5. Determination of factors influencing Social Vulnerability

In the exploration of factors influencing social vulnerability, a structured approach was adopted through the utilization of a five-point Likert scale. This scale served as a valuable tool to gauge respondents' perceptions and opinions regarding various factors. The Likert scale, ranging from strongly disagree to strongly agree, allowed participants to express their sentiments on each factor in a graded manner. To distill meaningful insights from the Likert scale responses, the mean values were employed as a statistical metric. Mean values offer a quantitative representation of the central tendency of a dataset and were instrumental in discerning the average sentiment or perception of the respondents regarding each influencing factor.

Determining the mean values involved summing up all individual responses for a specific factor and then dividing this cumulative sum by the total number of respondents. Mathematically, this is expressed as:

$$Mean\ Value = \frac{Sum\ of\ Individual\ Responses}{Number\ of\ Respondents}$$

This approach provided a consolidated measure that captured the overall sentiment of the surveyed population regarding the degree to which each factor influenced social vulnerability. This methodological rigor not only facilitated a quantitative analysis but also enabled a more comprehensive understanding of the factors at play within the social fabric under investigation.

1.5. Results

1.5.1. The Age of the Respondents

The age breakdown reveals varying proportions within the surveyed population. Specifically, the 20-25 age group constitutes 8% of the total sample, encompassing 48 participants. This group represents a relatively smaller segment of the overall study population. In comparison, participants aged 25-30 make up 8.5% of the total sample, totaling 51 individuals. This age category demonstrates a slight increase in representation compared to the 20-25 group. Moving into the 30-35 age range, 56 individuals fall into this category, accounting for 9.3% of the total participants. The percentage continues to rise, indicating a gradual increase in the proportion of older participants.

Table Error! No text of specified style in document.**.2: Age of Respondents**

Age	Frequency	Percent
20-25	48	8
25-30	51	8.5
30-35	56	9.3
35-40	81	13.5
40-45	78	13
45-50	79	13.2
50-55	70	11.7
55-60	56	9.3
60-65	50	8.3
Above 65	31	5.2
Total	600	100

The most highly represented age group is those aged 35-40, comprising 81 participants and making up 13.5% of the total sample. This suggests a significant concentration of individuals within this age range in the surveyed population. Following closely behind, the 40-45 age group represents 13% of the total sample, with 78 participants, contributing substantially to the overall distribution. Similarly, participants aged 45-50 make up 13.2% of the total sample, totaling 79 individuals. This age range is well-represented in the surveyed population. The 50-55 age group accounts for 11.7% of the total sample, with 70 individuals, maintaining a relatively high representation.
As age increases, there is a gradual decrease in the percentage of participants. The 55-60 age range represents 9.3% of the total sample, with 56 participants. Participants aged 60-65 constitute 8.3% of the total sample, with 50 individuals, following the overall decreasing trend. The category of participants above 65 years old comprises the smallest proportion of the surveyed population, representing 5.2% of the total sample, with 31 individuals.

1.5.2. Educational Background of Respondents

According to Table Error*! No text of specified style in document.***.3**, 154 respondents representing 25.7% of the sampled population have no formal education. The data in the table highlights that the largest segment of respondents, accounting for 40.7% or 244 individuals, have successfully finished primary education. Additionally, a noteworthy but comparatively smaller group, constituting 15.2% of the total sample, possesses a Junior High School Certificate, signifying progression beyond primary education but not yet reaching senior high school completion. Participants with senior high school education make up 12.5% of the total sample, indicating a significant yet relatively smaller portion of individuals who have concluded their secondary education.

Table Error! No text of specified style in document.**.3: Educational background of Respondents**

Educational Background	Frequency	Percent
No Formal Education	154	25.7

Primary Education	244	40.7
Junior High School Certificate	91	15.2
Senior High School	75	12.5
Tertiary	36	6
Total	**600**	**100**

The group with tertiary education is the least numerous, representing 6% of the total sample. This subgroup has pursued higher education, showcasing a segment of the population with advanced academic backgrounds.

1.5.3. Household Size of Respondents

A modest yet noteworthy 4.3% of participants dwell in single-member households, indicative of individuals living independently. The most prevalent household size, accounting for 27.5% of the total sample, consists of two members. This prevalence hints at a substantial presence of nuclear families or shared living arrangements characterized by a minimal number of members.

Table Error! No text of specified style in document.**.4: Household size of Respondents**

Household Size	Frequency	Percent
1	26	4.3
2	165	27.5
3	172	28.7
4+	237	39.5
Total	**600**	**100**

Constituting 28.7% of the total sample, participants residing in households with three members represent a significant portion of the population. This household size category may encompass diverse family structures, such as couples with a child or single-parent families. The largest demographic segment, comprising 39.5%, pertains to households with four or more members. This category suggests a considerable prevalence of larger families or extended households, potentially accommodating multiple generations living together.

1.5.4. Dependence of Households on Forest Resources

The mean score for respondents relying on fuelwood as their primary energy source is 4.58, with a relatively low standard deviation of 0.708, indicating a higher reliance on the forest resource to offset their vulnerability to climate change. This suggests that participants commonly view fuelwood as a vital source of energy, particularly significant for households relying on it for cooking and heating. In the case of timber dependence, participants provide a slightly higher mean rating of 4.66. The standard deviation of 0.843 suggests variability in perceptions, indicating that while generally positive, opinions on timber dependency may differ among respondents. Factors such as construction needs may influence reliance on timber, contributing to the observed variability.

Table Error! No text of specified style in document.**.5: Dependence of Households on Forest Resources**

Forest Resources	Frequency	Mean	Std. Deviation	Minimum	Maximum
Fuelwood	600	4.58	0.708	1	5
Timber	600	4.66	0.843	1	5
Non-Timber Forest product	600	5	0	5	5
Livelihood activities	600	4.63	0.878	1	5

Non-timber forest products receive a unanimous maximum rating of 5, signifying a consistent and high dependence on these resources. This suggests a robust reliance on non-timber forest products for various purposes, including medicinal plants, fruits, and handicraft materials. The lack of variability in perceptions underscores a unanimous acknowledgment of the critical importance of these resources in participants' lives. Livelihood activities associated with forest resources receive an average rating of 4.63, with a standard deviation of 0.878. This indicates a generally positive perception, albeit with some variability in respondents' assessments. Dependence on these forest-related livelihood activities may be influenced by factors such as income generation through the sale of forest products or engagement in agroforestry practices, contributing to the observed variability in perceptions. The findings suggest that the utilization of fuelwood, timber and various Non-Timber Forest Products (NTFPs), alongside engagement in diverse livelihood activities, plays a pivotal role in bolstering adaptive capacity. This, in turn, mitigates the vulnerability and lessens the impact of climate change on livelihoods.

1.5.5. Factors influencing Social Vulnerability to Climate change

The Table 17 shows the sensitivity component and adaptive capacity component of social vulnerability, as well as the primary component index and sub-component index for each ecological zone. The sensitivity component includes social, economic, and historical/cultural factors that make a community more vulnerable to the impacts of climate change.

Table Error! No text of specified style in document.**.6: Indexed Primary components, Sub-components, and total social vulnerability index of the three ecological zones.**

Social vulnerability factors	Indicators	Sub-Component Index			Primary Component Index		
(Primary Component)	(Sub-Component)	Ecological zone					
		MSD	DSD	SAV	MSD	DSD	SAV
SENSITIVITY COMPONENT							
Social	Household Size	0.64	0.43	0.55	0.21	0.14	0.18
	Household Security Status	0.61	0.62	0.43			
	Household relocation within the past 5 years	0.76	0.86	0.61			
Economic	Climate Related Occupation	0.83	0.41	0.41	0.14	0.07	0.07
	Monthly Household Income	0.58	0.52	0.77			
	Disruption in livelihoods due to climate change	0.54	0.64	0.35			

	Household Income below povertyline	0.53	0.31	0.33			
	Agriculture as primary source of income	0.56	0.8	0.44			
	Forest Plantation as primary source of Income	0.57	0.63	0.61			
Historical and Cultural	Years in Current Occupation	0.42	0.54	0.73	0.11	0.14	0.18
	Period Occupation has existed in the area	0.72	0.45	0.81			
	Involvement of previous Generations with current occupation	0.82	0.33	0.77			
	My Family has identity/Culture with occuaption	0.51	0.47	0.68			
Social Mobility	Occupation of Parents	0.77	0.38	0.38	0.15	0.08	0.08
	Parents educational status	0.81	0.81	0.56			
	Parents ownership of their own house	0.41	0.67	0.46			
	Parents ownership of their own farm	0.32	0.39	0.43			
	Financially better than parents	0.45	0.56	0.6			
Sub-total					0.61	0.42	0.51
Overall social vulnerability index					**0.153**	**0.106**	**0.128**

MSD: Moist Semi Deciduous, DSD: Dry Semi Deciduous, SAV: Savannah

The primary component index is the weighted average of the sub-component indices, while the sub-component index is the weighted average of the indicators within each sub-component. The table shows that the total social vulnerability index is highest in the Dry Semi-Deciduous (DSD) ecological zone, with a value of 0.51, followed by the Moist Semi-Deciduous (MSD) ecological zone with a value of 0.42, and the Savannah (SAV) ecological zone with a value of 0.51. The sensitivity component index is highest in the DSD ecological zone, with a value of 0.61, followed by the SAV ecological zone with a value of 0.51, and the MSD ecological zone with a value of 0.42. This suggests that the DSD ecological zone is more vulnerable to the impacts of climate change due to its higher sensitivity to social, economic, and historical/cultural factors.

1.5.6. Climate Change Exposure Factors in the Three Ecological Zones

Table Error*! No text of specified style in document.***.7** offers a comprehensive view of exposure components related to climate change across three distinct ecological zones: Moist Semi-Deciduous (MSD), Dry Semi-Deciduous (DSD), and Savannah (SAV). Each ecological zone is evaluated based on four key exposure components, shedding light on the population's familiarity with the concept of climate change, access to information about climate change, experiences of any changes in climate and its variability, and perceptions of changes in the health and vitality of nearby forests.

In terms of familiarity with the concept of climate change, the Savannah (SAV) zone stands out with the highest proportion, scoring 0.68. This indicates that 68% of individuals in SAV are familiar with the concept. Moist Semi-Deciduous (MSD) follows closely with a familiarity score of 0.57, while the Dry Semi-Deciduous (DSD) zone shows the lowest familiarity at 0.44.

Table Error! No text of specified style in document.**.7: Exposure Components in the three Ecological zones**

Exposure Components	Ecological Zone		
	MSD	**DSD**	**SAV**
Familiar with the concept of climate change	0.57	0.44	0.68
Access to information about climate change	0.66	0.33	0.49
Experienced any change in the climate and its variability	0.53	0.53	0.68
Changes in the health and vitality of nearby forests	0.76	0.68	0.39

MSD: Moist Semi Deciduous, DSD: Dry Semi Deciduous, SAV: Savannah

Access to information about climate change reveals significant disparities among the ecological zones. Moist Semi-Deciduous (MSD) takes the lead with a score of 0.66, indicating a higher level of access to information. Savannah (SAV) follows with a score of 0.49, suggesting relatively less access. In contrast, the Dry Semi-Deciduous (DSD) zone records the lowest access score of 0.33, indicating limited access to information about climate change.

The experiences of any change in the climate and its variability exhibit similarities between Moist Semi-Deciduous (MSD) and Dry Semi-Deciduous (DSD), both registering a score of 0.53. On the other hand, Savannah (SAV) surpasses with a score of 0.68, indicating a higher percentage of individuals in SAV who have experienced climate change.

Perceptions of changes in the health and vitality of nearby forests showcase varying degrees across the ecological zones. Moist Semi-Deciduous (MSD) has the highest perception score of 0.76, suggesting a strong acknowledgment of changes in forest health. Dry Semi-Deciduous (DSD) follows with a score of 0.68, indicating a substantial perception of changes. In contrast, Savannah (SAV) records the lowest perception score at 0.39, indicating a lower awareness or perception of changes in forest health.

1.5.7. Climate Change Impact on Three Ecological Zone

The Table Error*! No text of specified style in document.**.8*** under scrutiny provides a comprehensive exploration of the perceived impacts of climate change across three distinct ecological zones: Moist Semi-Deciduous (MSD), Dry Semi-Deciduous (DSD), and Savannah (SAV). Through a nuanced evaluation of various climate change-related factors, the table sheds light on the diverse ways in which these ecological zones are affected, as perceived by the population residing in each.

Table Error! No text of specified style in document.**.8: Climate change Impact on Three Ecological zone**

Climate Change Impact	Ecological Zone		
	MSD	**DSD**	**SAV**
Erosion	0.62	0.51	0.51
Storms	0.43	0.59	0.63
Floods	0.56	0.80	0.62
prolonged Droughts	0.41	0.74	0.71
Unpredicted Rainfall Patterns	0.36	0.44	0.46

High Temperatures	0.75	0.53	0.80
Drying of water bodies	0.33	0.75	0.82
Shift in the cropping season	0.36	0.64	0.53
Reduction in crop yield	0.48	0.40	0.68

MSD: Moist Semi Deciduous, DSD: Dry Semi Deciduous, SAV: Savannah

Beginning with the impact of erosion, the Moist Semi-Deciduous (MSD) zone is perceived to experience a moderate impact (0.62), followed closely by the Dry Semi-Deciduous (DSD) and Savannah (SAV) zones, both registering a score of 0.51. This suggests that erosion is a notable concern across all three ecological zones, albeit with slight variations in perceived severity.

Moving on to storms, the Savannah (SAV) zone stands out with the highest perceived impact at 0.63, followed by the Dry Semi-Deciduous (DSD) zone with a score of 0.59. Moist Semi-Deciduous (MSD) records the lowest perceived impact at 0.43. This discrepancy indicates that storms are perceived to have a more pronounced impact in Savannah and Dry Semi-Deciduous zones compared to the Moist Semi-Deciduous zone.

In terms of floods, the Dry Semi-Deciduous (DSD) zone is perceived to be highly susceptible, registering the highest impact score at 0.80. Savannah (SAV) follows closely with a score of 0.62, while Moist Semi-Deciduous (MSD) has a lower perceived impact at 0.56. This implies that floods are considered a significant concern, particularly in the Dry Semi-Deciduous zone.

The perceived impact of prolonged droughts reveals a similar trend, with Dry Semi-Deciduous (DSD) again exhibiting the highest susceptibility at 0.74, followed by Savannah (SAV) at 0.71. Moist Semi-Deciduous (MSD) has the lowest perceived impact at 0.41, suggesting a relatively lower concern for prolonged droughts in this zone.

Unpredictable rainfall patterns are perceived to have a lower impact across all three ecological zones, with Moist Semi-Deciduous (MSD) registering the lowest at 0.36, followed by Dry Semi-Deciduous (DSD) at 0.44, and Savannah (SAV) at 0.46. This indicates a general perception of relatively stable rainfall patterns, albeit with some variation.

High temperatures are perceived to have a substantial impact, especially in the Savannah (SAV) zone, which records the highest score at 0.80. Moist Semi-Deciduous (MSD) follows closely with a score of 0.75, while Dry Semi-Deciduous (DSD) has the lowest perceived impact at 0.53. This suggests that high temperatures are a major concern, particularly in the Savannah and Moist Semi-Deciduous zones.

Drying of water bodies is perceived to have a significant impact in both the Dry Semi-Deciduous (DSD) and Savannah (SAV) zones, with scores of 0.75 and 0.82, respectively. Moist Semi-Deciduous (MSD) has the lowest perceived impact at 0.33. This implies a heightened concern for the drying of water bodies in the Dry Semi-Deciduous and Savannah zones.

A shift in the cropping season is perceived to have a relatively lower impact, with Moist Semi-Deciduous (MSD) recording the lowest at 0.36, followed by Savannah (SAV) at 0.53, and Dry Semi-Deciduous (DSD) at 0.64. This indicates a general perception of resilience or adaptability to shifts in cropping seasons, with some variation across the ecological zones.

The perceived reduction in crop yield varies across the ecological zones, with Savannah (SAV) exhibiting the highest impact at 0.68, followed by Moist Semi-Deciduous (MSD) at 0.48, and Dry Semi-Deciduous (DSD) at 0.40. This suggests that the reduction in crop yield is considered a significant concern, particularly in the Savannah zone.

1.5.8. Adaptive Capacity of Communities to Climate Change

The examination of adaptive capacity across three distinct ecological zones—Moist Semi-Deciduous (MSD), Dry Semi-Deciduous (DSD), and Savannah (SAV)—reveals a nuanced landscape of community responses to the impacts of climate change. This analysis encompasses a spectrum of factors indicative of each community's ability to adapt, reflecting both shared and unique challenges within each ecological zone.

Table Error! No text of specified style in document.**.9: Adaptive Capacity of Communities to Climate Change**

Adaptive Capacity	Ecological Zone		
	MSD	DSD	SAV
Engagement in non-farm income generating activities	0.53	0.42	0.63
Change in cropping Patterns in response to climate change	0.57	0.67	0.76
Engagement of Forest plantation modules	0.45	0.57	0.29
Relocattion of farming activities due to climatic factors	0.60	0.88	0.75
Adoption of Irrigation due to Climate change	0.51	0.21	0.84
Modification in use of agro-chemicals due to climate change	0.58	0.57	0.72
More than half of Household members have health insuarance cards	0.59	0.12	0.31
Household members employed as Government workers	0.38	0.47	0.27
Having income from various sources	0.27	0.80	0.46
Having access to financial loan	0.38	0.22	0.22
Effectiveness of strategies in responding to climate change impacts	0.63	0.89	0.57

MSD: Moist Semi Deciduous, DSD: Dry Semi Deciduous, SAV: Savannah

Within the realm of engaging in non-farm income-generating activities, the Savannah (SAV) stands out with the highest score of 0.63, followed by Moist Semi-Deciduous (MSD) at 0.53, and Dry Semi-Deciduous (DSD) at 0.42. This suggests a higher propensity for economic diversification in the Savannah zone, potentially enhancing resilience against climate-related challenges.

Adaptive responses related to changing cropping patterns exhibit a noteworthy trend, with Savannah (SAV) showcasing the highest adaptive capacity at 0.76, followed by Dry Semi-Deciduous (DSD) at 0.67, and Moist Semi-Deciduous (MSD) at 0.57. This implies a heightened flexibility in agricultural practices, particularly in the Savannah zone.

Assessing the engagement of forest plantation modules as an adaptive strategy, Dry Semi-Deciduous (DSD) leads with a score of 0.57, followed by Moist Semi-Deciduous (MSD) at 0.45, while Savannah (SAV) records the lowest score at 0.29. This variation suggests a more pronounced reliance on forest-related adaptive measures in the Dry Semi-Deciduous zone.

Relocation of farming activities due to climatic factors emerges as a critical adaptive strategy, with Dry Semi-Deciduous (DSD) exhibiting the highest score at 0.88, followed by Savannah (SAV) at 0.75, and

Moist Semi-Deciduous (MSD) at 0.60. This highlights the significance of spatial adjustments in response to changing climate conditions, particularly in the Dry Semi-Deciduous zone.

The adoption of irrigation due to climate change portrays a distinctive pattern, with Savannah (SAV) leading at 0.84, followed by Moist Semi-Deciduous (MSD) at 0.51, and Dry Semi-Deciduous (DSD) at 0.21. This underscores the critical role of irrigation as an adaptive measure, particularly in the Savannah zone.

Modification in the use of agro-chemicals due to climate change demonstrates a varied adaptive capacity, with Savannah (SAV) exhibiting the highest score at 0.72, followed by Moist Semi-Deciduous (MSD) at 0.58, and Dry Semi-Deciduous (DSD) at 0.57. This indicates a nuanced approach to agricultural practices tailored to specific ecological conditions.

The availability of health insurance coverage as an adaptive measure reveals divergent patterns, with Moist Semi-Deciduous (MSD) leading at 0.59, followed by Savannah (SAV) at 0.31, and Dry Semi-Deciduous (DSD) at 0.12. This emphasizes the importance of health-related adaptive strategies, albeit with notable variations.

In terms of employment in government positions as an adaptive factor, Dry Semi-Deciduous (DSD) leads with a score of 0.47, followed by Moist Semi-Deciduous (MSD) at 0.38, and Savannah (SAV) at 0.27. This suggests the role of stable government employment as a potential resilience-building factor, particularly in the Dry Semi-Deciduous zone.

The diversity of income sources as an adaptive strategy exhibits considerable variation, with Dry Semi-Deciduous (DSD) leading at 0.80, followed by Savannah (SAV) at 0.46, and Moist Semi-Deciduous (MSD) at 0.27. This highlights the importance of income diversification in enhancing adaptive capacity, particularly in the Dry Semi-Deciduous zone.

Access to financial loans as an adaptive measure shows a similar pattern, with Moist Semi Deciduous (MSD) leading at 0.38, followed by Dry Semi-Deciduous (DSD) and Savannah (SAV) at 0.22. This underscores the role of financial resources in building adaptive capacity, albeit with some variations.

Finally, the perceived effectiveness of strategies in responding to climate change impacts presents noteworthy insights. Dry Semi-Deciduous (DSD) leads with the highest score at 0.89, followed by Moist Semi-Deciduous (MSD) at 0.63, and Savannah (SAV) at 0.57. This sheds light on the efficacy of implemented strategies in addressing the unique challenges posed by climate change, with the Dry Semi-Deciduous zone exhibiting the highest perceived effectiveness.

1.6. Discussion

1.6.1. Dependence of Households Dependence on Forest Resources

The mean scores and standard deviations offer a nuanced understanding of the perceptions and variability among respondents regarding their dependence on these resources. The mean score for reliance on fuelwood as the primary energy source is 4.58, indicating a substantial dependence on fuelwood for cooking and heating purposes. The relatively low standard deviation of 0.708 suggests a consistent perception among participants regarding the importance of fuelwood in their daily lives. This aligns with existing literature highlighting the significant role of fuelwood in meeting energy needs in many rural and forest-dependent communities (Cooke et al., 2008a, 2008b; Paudel, 2018). Furthermore, the mean rating of 4.66 for timber dependence underscores the importance of timber for various purposes such as construction. The slightly higher standard deviation of 0.843 indicates some variability in perceptions, reflecting differing views among respondents regarding their reliance on timber. This variability may be influenced by factors such as the availability of alternative construction materials and cultural practices related to timber use (Boampong et al., 2015; Du et al., 2021; Ramage et al., 2017; Ratnasingam et al., 2018; Švajlenka & Kozlovská, 2021).

The unanimous maximum rating of 5 for non-timber forest products signifies a consistent and high dependence on these resources for various purposes, including medicinal plants, fruits, and handicraft materials (Arnold & Pérez, 2001; Gouwakinnou et al., 2019; Kar & Jacobson, 2012; Mariki, 2013; Wale et al., 2022). This underscores the critical importance of non-timber forest products in the livelihoods of the surveyed households. The lack of variability in perceptions suggests a unanimous acknowledgment of the significance of these resources in supporting household activities and well-being (Arnold & Pérez, 2001; Gouwakinnou et al., 2019; Kar & Jacobson, 2012; Mariki, 2013; Wale et al., 2022). The average rating of 4.63 for livelihood activities associated with forest resources and a standard deviation of 0.878 indicates a generally positive perception with some variability in respondents' assessments. This variability may stem from diverse livelihood strategies and individual experiences related to engaging in forest-based activities for income generation and sustenance (Du et al., 2021; Gouwakinnou et al., 2019).

In summary, the data on household dependence on forest resources and livelihood activities provides valuable insights into the multifaceted role of forests in supporting the daily lives and well-being of the surveyed communities. The variability in perceptions reflects the complex interplay of cultural, economic, and environmental factors shaping household reliance on forest resources and underscores the need for context-specific approaches to sustainable forest management and livelihood development. These findings align with broader discussions on the significance of forest resources for rural livelihoods, emphasizing the need for sustainable management practices that consider local dependencies and promote resilience in the face of environmental and socio-economic changes. Overall, the data presented contributes to a deeper understanding of the intricate relationships between forest ecosystems and human well-being, highlighting the importance of incorporating local perspectives and experiences in conservation and development initiatives.

1.6.2. Social Vulnerability to Climate Change

The sensitivity component index, which includes factors such as household size, economic status, and occupation, is highest in the Dry Semi-Deciduous (DSD) ecological zone, with a value of 0.61, followed by the Savannah (SAV) ecological zone with a value of 0.51, and the Moist Semi-Deciduous (MSD) ecological zone with a value of 0.42. This suggests that households in the DSD ecological zone are more vulnerable to the impacts of climate change due to their higher sensitivity to social, economic, and historical/cultural factors. The assertion aligns with the existing body of knowledge emphasizing that vulnerability to climate change is multifaceted, encompassing social, economic, and historical/cultural dimensions. Similar studies done by (Ford et al., 2008; Ford & Smit, 2004; Thomas et al., 2019; T. Wang & Sun, 2023) highlight the differential vulnerability of communities, regions, and countries, attributing it to a combination of these factors. Understanding the sensitivity of households in the DSD ecological zone to such influences provides valuable insights into crafting targeted adaptation and mitigation strategies (Ford et al., 2008; Ford & Smit, 2004; Thomas et al., 2019; T. Wang & Sun, 2023).

The primary component index, which is the weighted average of the sub-component indices, is highest in the DSD ecological zone, with a value of 0.51, followed by the MSD ecological zone with a value of 0.42, and the SAV ecological zone with a value of 0.51. This suggests that households in the DSD ecological zone may be more vulnerable to the impacts of climate change due to their higher sensitivity and lower adaptive capacity. The statement aligns with existing research on vulnerability assessments, indicating that ecological zones play a crucial role in determining susceptibility to climate change impacts. Studies such (Awuni et al., 2023; Balogun & Onokerhoraye, 2022; Ford & Smit, 2004; Malik et al., 2012) emphasize the significance of exposure and adaptive capacity in assessing vulnerability.

The sub-component indices provide further insights into the specific factors contributing to social vulnerability to climate change. For example, the economic sub-component index includes indicators such as disruption in livelihoods due to climate change, household income below the poverty line, and agriculture as the primary source of income. The data shows that households in the DSD ecological zone have the highest economic sub-component index, with a value of 0.41, followed by the MSD ecological zone with a value of 0.52, and the SAV ecological zone with a value of 0.77. This suggests that households in the DSD ecological zone may be more vulnerable to the economic impacts of climate change, such as loss of income and livelihoods. The statement aligns with the findings of (Awuni et al., 2023), emphasizing the economic impacts of climate change on households in the DSD ecozone. The research highlights that climate change can lead to chronic water shortages, rising sea levels, flooding, and damage to infrastructure, all of which contribute to economic challenges, including loss of income and livelihoods. The economic consequences mentioned in the statement resonate with the broader discourse on climate change vulnerability and its adverse effects on the financial well-being of communities.

1.6.3. Climate Change Exposure Factors in the Three Ecological Zones

One of the exposure components evaluated is the population's familiarity with the concept of climate change. The data shows that the Savannah (SAV) zone has the highest proportion of individuals familiar with the concept, with a familiarity score of 0.68. This is followed closely by the Moist Semi-Deciduous (MSD) zone with a familiarity score of 0.57, while the Dry Semi-Deciduous (DSD) zone shows the lowest familiarity at 0.44. This result is consistent with the findings in the research of (Awuni et al., 2023; Balogun & Onokerhoraye, 2022).

Another exposure component evaluated is access to information about climate change. The data reveals significant disparities among the ecological zones, with the MSD zone taking the lead with a score of 0.66, indicating a higher level of access to information. Savannah (SAV) follows with a score of 0.49, suggesting relatively less access. In contrast, the Dry Semi-Deciduous (DSD) zone records the lowest access score of 0.33, indicating limited access to information about climate change.

The experiences of any change in the climate and its variability exhibit similarities between Moist Semi-Deciduous (MSD) and Dry Semi-Deciduous (DSD), both registering a score of 0.53. On the other hand, Savannah (SAV) surpasses with a score of 0.68, indicating a higher percentage of individuals in SAV who have experienced climate change. Perceptions of changes in the health and vitality of nearby forests showcase varying degrees across the ecological zones. Moist Semi-Deciduous (MSD) has the highest perception score of 0.76, suggesting a strong acknowledgment of changes in forest health. Dry Semi-Deciduous (DSD) follows with a score of 0.68, indicating a substantial perception of changes. In contrast, Savannah (SAV) records the lowest perception score at 0.39, indicating a lower awareness or perception of changes in forest health. This result is consistent with the findings in the research of (Awuni et al., 2023; Balogun & Onokerhoraye, 2022).

1.6.4. Climate Change Impact on Three Ecological Zones

The data shows that the perceived impact of erosion is moderate in the Moist Semi-Deciduous (MSD) zone, with a score of 0.62, followed closely by the Dry Semi-Deciduous (DSD) and Savannah (SAV) zones, both registering a score of 0.51. This suggests that erosion is a notable concern across all three ecological zones, albeit with slight variations in perceived severity. In terms of storms, the Savannah (SAV) zone stands out with the highest perceived impact at 0.63, followed by the Dry Semi-Deciduous (DSD) zone with a score of 0.59. Moist Semi-Deciduous (MSD) records the lowest perceived impact at 0.43. This discrepancy indicates that storms are perceived to have a more pronounced impact in Savannah and Dry Semi-Deciduous zones compared to the Moist Semi-Deciduous zone. The findings of (Awuni et al., 2023) is similar to the findings as provided above.

The data also reveals that the Dry Semi-Deciduous (DSD) zone is perceived to be highly susceptible to floods, registering the highest impact score at 0.80. Savannah (SAV) follows closely with a score of 0.62, while Moist Semi-Deciduous (MSD) has a score of 0.56. This suggests that households in the DSD ecological zone may be more vulnerable to the impacts of floods. The perceived impact of prolonged droughts reveals a similar trend, with Dry Semi-Deciduous (DSD) exhibiting the highest susceptibility at 0.74, followed by Savannah (SAV) at 0.71. Moist Semi-Deciduous (MSD) has the lowest perceived impact at 0.41, suggesting a relatively lower concern for prolonged droughts in this zone. With higher impact scores for floods (0.80) and prolonged droughts (0.74), it aligns with the research of (Armah et al., 2010; Atanga & Tankpa, 2021; Owusu et al., 2021) which assert that ecological zones are more susceptible to specific climate-related hazards. This information supports the assertion that households in the DSD zone are at a higher risk of facing adverse impacts from both floods and prolonged droughts compared to the Savannah (SAV) and Moist Semi-Deciduous (MSD) zones.

High temperatures are perceived to have a substantial impact, especially in the Savannah (SAV) zone, which records the highest score at 0.80. Moist Semi-Deciduous (MSD) follows closely with a score of 0.75, while Dry Semi-Deciduous (DSD) has the lowest perceived impact at 0.53. This suggests that high temperatures are a major concern, particularly in the Savannah and Moist Semi-Deciduous zones. In terms of the reduction in crop yield, the Savannah (SAV) zone exhibits the highest impact at 0.68, followed by Moist Semi-Deciduous (MSD) at 0.48, and Dry Semi-Deciduous (DSD) at 0.40. This suggests that the reduction in crop yield is considered a significant concern, particularly in the Savannah zone (Armah et al., 2010; Atanga & Tankpa, 2021; Awuni et al., 2023; Malik et al., 2012; Owusu et al., 2021).

Climate change is a global phenomenon that has significant impacts on various aspects of human life, including agriculture, health, and the environment. The adaptive capacity of communities to climate change is critical in enhancing resilience and reducing vulnerability to the impacts of climate change. The adaptive capacity of communities varies across different ecological zones, reflecting the unique challenges and opportunities within each zone (Awuni et al., 2023).

One of the key measures of adaptive capacity is engagement in non-farm income-generating activities. The Savannah (SAV) zone exhibits the highest score of 0.63, followed by Moist Semi-Deciduous (MSD) at 0.53, and Dry Semi-Deciduous (DSD) at 0.42. This suggests a higher propensity for economic diversification in the Savannah zone, potentially enhancing resilience against climate-related challenges. Economic diversification is critical in reducing the dependence of communities on a single source of income, which can be vulnerable to climate change impacts such as droughts and floods (Armah et al., 2010; Atanga & Tankpa, 2021; Owusu et al., 2021).

Another critical measure of adaptive capacity is the change in cropping patterns in response to climate change. The Savannah (SAV) zone showcases the highest adaptive capacity at 0.76, followed by Dry Semi-Deciduous (DSD) at 0.67, and Moist Semi-Deciduous (MSD) at 0.57. This implies a heightened flexibility in agricultural practices, particularly in the Savannah zone. Flexibility in agricultural practices is critical in adapting to changing climatic conditions, such as changes in rainfall patterns and temperature (Atanga & Tankpa, 2021; Awuni et al., 2023; Balogun & Onokerhoraye, 2022).

The engagement of forest plantation modules is another measure of adaptive capacity. Dry Semi-Deciduous (DSD) leads with a score of 0.57, followed by Moist Semi-Deciduous (MSD) at 0.45, while Savannah (SAV) records the lowest score at 0.29. This variation suggests a more pronounced reliance on forest-related adaptive measures in the Dry Semi-Deciduous zone. Forest-related adaptive measures, such as forest plantation modules, can enhance the resilience of communities to climate change impacts such as soil erosion and flooding (Atanga & Tankpa, 2021; Awuni et al., 2023; Balogun & Onokerhoraye, 2022)..

Relocation of farming activities due to climatic factors is another critical measure of adaptive capacity. Dry Semi-Deciduous (DSD) exhibits the highest score at 0.88, followed by Savannah (SAV) at 0.75, and Moist Semi-Deciduous (MSD) at 0.60. This highlights the significance of spatial adjustments in response to changing climate conditions, particularly in the Dry Semi-Deciduous zone. Spatial adjustments, such as relocation of farming activities, can enhance the resilience of communities to climate change impacts such as droughts and floods (Atanga & Tankpa, 2021; Awuni et al., 2023; Balogun & Onokerhoraye, 2022)..

The adoption of irrigation due to climate change is another critical measure of adaptive capacity. Savannah (SAV) leads at 0.84, followed by Moist Semi-Deciduous (MSD) at 0.51, and Dry Semi-Deciduous (DSD) at 0.21. This underscores the critical role of irrigation as an adaptive measure, particularly in the Savannah zone. Irrigation can enhance the resilience of communities to climate change impacts such as droughts and changes in rainfall patterns (Atanga & Tankpa, 2021; Awuni et al., 2023; Balogun & Onokerhoraye, 2022)..

Modification in the use of agrochemicals due to climate change is another measure of adaptive capacity. Savannah (SAV) exhibits the highest score at 0.72, followed by Moist Semi-Deciduous (MSD) at 0.58, and Dry Semi-Deciduous (DSD) at 0.57. This indicates a nuanced approach to agricultural practices tailored to specific ecological conditions. A nuanced approach to agricultural practices can enhance the resilience of communities to climate change impacts such as changes in soil fertility and pest infestations (Atanga & Tankpa, 2021; Awuni et al., 2023; Balogun & Onokerhoraye, 2022)..

In conclusion, the adaptive capacity of communities to climate change varies across different ecological zones, reflecting the unique challenges and opportunities within each zone. The differences in adaptive capacity underscore the importance of tailored and context-specific strategies to enhance resilience and adaptation to climate change across different communities and ecological zones. The measures of adaptive capacity discussed above, such as economic diversification, flexibility in agricultural practices, forest-related adaptive measures, spatial adjustments, irrigation, and nuanced approaches to agricultural practices, can enhance the resilience of communities to climate change impacts.

1.6.5. Conclusion

The document provides valuable insights into the adaptive capacity of communities to climate change in Ghana, highlighting the nuanced responses and challenges faced across different ecological zones. The conclusions drawn from the study shed light on critical factors influencing adaptive capacity and offer important implications for policy and practice.

One of the key conclusions is the significant variation in adaptive capacity across ecological zones. The Savannah (SAV) zone stands out with the highest scores in engagement in non-farm income-generating activities, adaptive capacity for changing cropping patterns, and adoption of irrigation due to climate change. On the other hand, the Dry Semi-Deciduous (DSD) zone exhibits the highest scores in the engagement of forest plantation modules, relocation of farming activities due to climatic factors, and modification in the use of agro-chemicals due to climate change. These variations underscore the need for tailored and context-specific strategies to address the diverse challenges and opportunities faced by communities in different ecological zones.

The study also emphasizes the importance of access to information about climate change. Significant disparities in access to information were observed among the ecological zones, with Moist Semi-Deciduous (MSD) exhibiting a higher level of access compared to the Dry Semi-Deciduous (DSD) zone. This highlights the need for targeted efforts to improve access to climate change information, particularly in zones with lower access scores, to empower communities to make informed decisions and adapt to changing environmental conditions.

Furthermore, the conclusions underscore the critical role of economic diversification, adaptive agricultural practices, and forest-related adaptive measures in enhancing resilience and adaptive capacity. The findings suggest that promoting alternative livelihood options, supporting climate-resilient agricultural techniques, and safeguarding forest ecosystems are essential for building adaptive capacity and reducing vulnerability to climate-related challenges.

1.6.6. Recommendations

Based on conclusions, several recommendations are proposed to enhance adaptive capacity and resilience to climate change in Ghana. These include:

1. **Targeted Information Dissemination:** Implement targeted programs to improve access to climate change information, particularly in zones with lower access scores. This can involve the development of educational resources, community engagement initiatives, and the strengthening of communication channels to raise awareness and understanding of climate change impacts and adaptation strategies.
2. **Economic Diversification:** Support the development of non-farm income-generating activities and entrepreneurship, especially in zones where economic diversification scores are relatively low. Providing access to financial resources, skills training programs, and promoting sustainable livelihood options can enhance economic resilience and adaptive capacity.
3. **Climate-Resilient Agriculture:** Promote climate-smart agricultural practices, crop diversification, and sustainable land management techniques to enhance agricultural productivity and food security. This can be achieved through investment in agricultural extension services, provision of improved seeds and technologies, and capacity building for farmers.
4. **Forest Conservation and Management:** Safeguard and sustainably manage forest ecosystems, while supporting community-based forestry initiatives. Strengthening forest-related adaptive measures can contribute to enhancing resilience, ecosystem services, and the livelihoods of communities dependent on forest resources.
5. **Spatial Planning and Infrastructure Development:** Facilitate land-use planning, climate-resilient infrastructure development, and community-led adaptation planning to address the challenges

associated with spatial adjustments. This can help communities adapt to changing environmental conditions and reduce the risks associated with climate change impacts.

By integrating these recommendations into policy formulation, development planning, and community-based initiatives, stakeholders can work towards building adaptive capacity, reducing vulnerability, and fostering sustainable development in the face of climate change. This holistic and context-sensitive approach is essential for addressing the diverse challenges posed by climate change and advancing the well-being of communities in Ghana.

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