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FACTORS INFLUENCING RESILIENCE TO CLIMATE VARIABILITY AMONG SMALLHOLDER LOWLAND RICE FARMING HOUSEHOLDS IN NORTHERN GHANA

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Abstract
The ability of smallholder farmers to adapt to changing climatic conditions is crucial in achieving domestic and global food security. The study analysed the resilience of smallholder lowland rice farmers to climate variability and the factors influencing the resilience of smallholder rice systems in the Savelugu municipality of the northern region of Ghana. The data was obtained using a cross-sectional questionnaire administered to 241 households and focus group discussions. A multi-dimensional Climate resilience index (CRI) was calculated for household resilience and used to determine relevant factors influencing household resilience through multiple regression analysis. Overall household CRI averaged 0.49, with transformative capacity, a major contributor with an index of 0.69, while adaptive and absorptive capacities were 0.45 and 0.33, respectively. The resilience analysis shows that income and food access, regular access to health, reliable access to improved water, agroecological conditions, resource governance and access to basic services are essential to household resilience against climate variability. The regression analysis results suggest that farmers' age, cropping diversity, households' primary income, plot position, soil quality, flooding, market access and FBO membership influence household resilience to climate variability. To be effective, policies to improve smallholder farmer resilience to climate variability must include diverse strategies allowing farmers the flexibility of selecting a combination of strategies that suits their socioeconomic and contextual situations; depart from farm-specific and technology-centric interventions to include other value chain dimensions and must address the climatic and non-climatic stressors confronting farmers concurrently to achieve the desired impact.

Keywords: Climate Change and Variability, Rice, Resilience, Smallholder Agriculture, Ghana

Introduction

Climate change is deepening smallholder farmers' already precarious food insecurity, and their ability to adapt to changing climatic conditions is crucial in achieving global food security (Alhassan et al., 2017; Al-Hassan & Poulton, 2009). Ray et al. (2015) attribute up to a third of yield variability to climate variability. The concept of resilience has gained attention in social research as social scientists search for a more responsive way of explaining the increasing and complex dynamics resulting from the rising incidence of man-made and natural shocks, including climate change. From its origins in material science,

resilience thinking has been employed in social science research to understand complex adaptive systems and undertake interdisciplinary and transdisciplinary research, emphasising social-ecological systems (SES) (Folke, 2016). Adopting the concept of resilience makes it possible to identify and examine the factors and related processes that affect actors' vulnerability and their capacity to moderate the effects of climate change. The concept of resilience provides an interesting and insightful nexus between social and ecological dynamics in situations where vulnerability issues are concerned (Issaka et al., 2016). In particular, 'the concept provides an analytical lens to address already observed impacts and the underlying non-climatic causes of vulnerability by shifting the focus to the characteristic features of the SES and how these features interplay to shape vulnerability' (Chinwe, 2010). Thus, resilience describes the ability of social systems to deal with and withstand external shocks to their organisation and infrastructure caused by environmental, economic, or political crises (Adger, 2006). Particularly noteworthy is the position espoused by Gunderson and Holling (2002) and Nykvist and von Heland (2014), as captured in Folke (2016, p. 2), that 'resilience provides sources of memory, flexibility, options and innovations for transformation'. Contemporary resilience thinking is conceptualised as a measure of persistence (defined by the ability of a system to resist change within a specified limit), adaptability (defined by human actions taken to sustain the existing system), transformability (human actions taken to create or enable a fundamentally new system) and the dynamic interplay between them in response to changing environments. Frankenberger et al. (2013) and Béné et al. (2016) describe these as absorptive, adaptive, and transformative capacities. The utility of the resilience concept is, thus, its focus on the variables that impact the ability of social-ecological systems to provide ecosystem services while mitigating the effects of negative externalities in the form of disturbances, uncertainties and change (Chinwe, 2010). For the purpose of this study, resilience is defined as the ability of a system to respond to transitory adverse events (shocks) such as climate variability or long-term adverse trends (stressors) such as climate change through its ability to absorb, adapt and even undergo transformation.

Materials and Methods

Conceptual framework

In this study, a rainfed lowland rice production system refers to an agricultural system defined within a specific institutional, social, cultural and economic context. By this conception, the lowland rainfed rice production system is characterised by a complex interaction of internal and external factors determining their ability to remain resilient to climate variability. The capacity of a system to create, manage and use technology to mitigate the effects of climate change is critical to its resilience. A fundamental assumption in this regard is that a household's propensity to adopt appropriate productivity-enhancing technologies, such as sustainable intensification practices, or adapt existing technologies and strategies in the face of climate-related constraints such as climate variability determines its resilience.

The study analyses the rainfed smallholder rice production system's resilience to climate variability from the social-ecological system (SES) and Social-Ecological Resilience (SER) perspective. Gallopin (1991) defines SES as comprising social (human) and ecological (biophysical) sub-systems and their interactions. The social sub-system constitutes societal rules and institutions that, together, mediate human use of resources and the system of knowledge, worldviews and ethics that govern human relations (Berks et al., 2003; Adger, 2006). On the other hand, the ecological sub-system consists of "self-regulating communities of organisms interacting with one another and with their environment" (Berkes et al., 2003). Thus, the conception of SES 'reflects the idea that human action and social structures are part of nature; hence distinguishing between them does not reflect reality (Adger, 2006). On the other hand, the concept of Social-Ecological Resilience (SER) SER represents the capacity of an SES 'to absorb disturbances (for example, climate variability) while retaining the same basic structure and functioning, the capacity for self-organisation, and the capacity to adapt to stress' (Chinwe, 2010). SER therefore, embodies the concept of SES's absorptive, adaptive and transformative capacities, as illustrated in Fig. 1. The exposure of the rainfed lowland rice farming system to climate variability (shock) is expressed in annual variations in key climate parameters such as rainfall, drought, floods, temperature, pests and diseases that affect farm productivity and, eventually, household livelihoods.

Consequently, the effect of climate variability on a household requires addressing the following critical questions regarding the capacity of a system to remain resilient in the face of shocks:

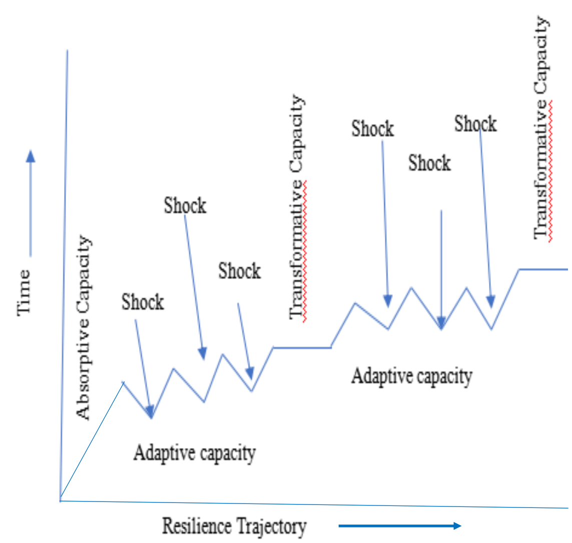

Fig. 1: Resilience framework (Author's construction)

Absorptive capacity: to what extent can the system undergo change and retain the same structure, function, identity and feedback on process and structure? The ability of a household to withstand short-term shocks and sustain its production from year to year without any noticeable change in how it organises its activities or within its inherent ability to manage such shocks denotes its absorptive phase.

Adaptive capacity: to what extent is the system capable of building and increasing the capacity for learning and adaptation? The ability of farm households to withstand short-term shocks by adopting other measures to augment their internal capacity in the short to medium term keeps them within critical thresholds allowing them to sustain their livelihoods, denotes its adaptation phase.

Transformative capacity: to what extent is the system capable of self-organisation? In the long-term, farm households may find themselves unable to sustain their livelihoods and, therefore, may seek livelihood options outside their current livelihood systems, which denotes its transformation phase.

Analytical Framework
The study adapts the analytical framework of Alinovi et al. (2009) to analyse the factors affecting household resilience against climate variability (fig. 2).

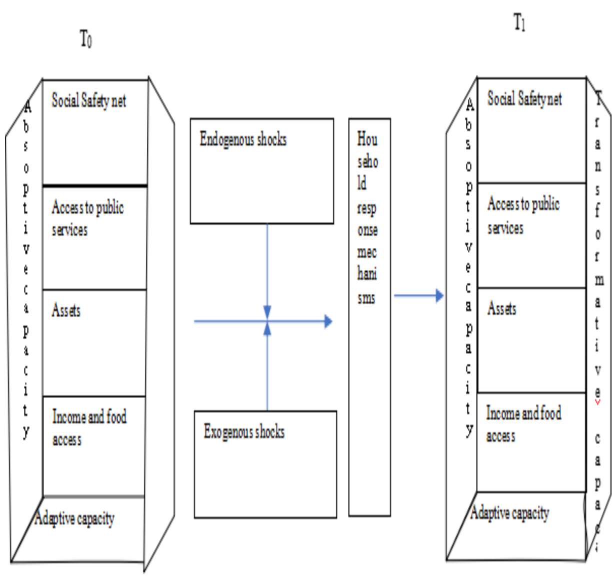

Fig. 2: Analytical Framework (Adapted from Alinovi et al. (2009)

The household is considered the centre of activity of the smallholder rainfed rice production system, where it organises productive activities and takes decisions on production. It is assumed that the resilience of a given household at time T_0 depends primarily on the livelihood options available to it, such as social safety net, access to public services, assets, and income and food access. The ability of a household to respond to a given risk, such as climate variability, depends on these options. However, when facing a shock, a household's choices are mediated by endogenous and exogenous factors, both localised and of broader dimensions. Therefore, the ability and extent to which a household responds to risks and retains its functions depend on its adaptive, absorptive and transformative capacities.
Table 1 provides details of the major resilience components and their hypothesised relationships with the resilience capacities.

The study area
The Savelugu municipality is located in the northern part of the Northern Region of Ghana. It shares boundaries with the West Mamprusi district to the North, the Karaga district to the East, the Kumbungu district to the West and the Tamale Metropolis to the South. The municipality has a total land area of about 2,022.6 sq. km. and a population density of 68.9 persons per sq. km. The Municipality comprises mainly rural communities, with sparse large swaths of arable land. The average household size throughout the municipality is 5.8 (roughly 25.6% lower than the regional average of 7.81), with a total population of approximately 116,300 people. People in this district typically engage in agriculture as their main source of income, with the primary crops being yam, rice, groundnut and cassava. The municipality has a poverty prevalence of 6.3%, with an average daily per capita expenditure of USD 4.55.

Fig. 3: Map of Study Area

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Table 1: Resilience Capacities, Components and Indicators (Adapted from Asmamaw et al., 2019)

Resilient capacities	Major component	Indicators	Hypothesised relationship: relatively resilient if:	Variables	Measurement
Absorptive capacity	Natural disaster and climatic variability	Early warning system, disaster preparedness, climatic shock events during the last 10 years, the ability to cope with disaster	The household has access to an early warning system, gets prepared to shock impacts, experienced a low incidence of climatic shock and has relied on internal resources to mitigate climatic shocks	HH has access to information on impending disaster	No. of times a HH has received early warning information on climate-related disasters in the past 10 years
				HH is prepared for disaster	Dummy: Yes/No
				No. of climatic shocks experienced in the past 10 years by HH	Count of no. of events in the past 10 years
				HH relies on internal resources to mitigate climatic shocks	Dummy: Yes/No
	Stability	Landscape position, soil fertility, SIPs adopted	the majority of households' farmland is on gentle slope, with good soil quality, and most of them have adopted SIPs	HH rice plot position	Dummy: Steep/gentle slope
				Soil quality of HH rice plot	Dummy: good/bad
				No. of SIPs Adopted	No. of SIP currently practices on rice field
	Social capital	Sharing of resources and technology and membership in community-based organisations	there exist experiences of resources and technology sharing and getting involved in a Farmer-based organisation	HH borrowed seed from other HHs during the last 10 years	No. of times HH borrowed seed borrowed in the past 10 years
				HH has regular access to input credit	Dummy: Yes/no
				HH members belong to an FBO	No. of HH members belonging to FBO
Adaptive capacity	Income and food access	Income, food insecurity and dietary diversity	Most households have high annual per capita income, a high dietary diversity score, a low hunger score, and are self-sufficient in food.	Ave. HH per capita annual income	Total HH annual income/No. of HH members
				HH dietary diversity score	Number
				HH Hunger score	Number
				Forced to reduce no. of meals – Adjust Food	Dummy: Yes/No
	Health	Illness score, improved toilet, and health insurance	households experience low child mortality, have access to a toilet, and all members have access to health insurance.	Child mortality	No. of children who have died in the past 10 years
				HH access to toilet	Dummy: Yes/No
				All members of HH have access to health insurance	Dummy: Yes/No
	Water	Access to improved water, water sufficiency and water conflict	Households have access to clean drinking water that can be accessed easily, water sufficiency during the last 12 months and no conflict over water	Source of HH drinking water	Dummy: Improved (Pipe borne or borehole) / Unimproved (Dugout or stream)
				Distance to the nearest source of water	Distance in Km
				Year-round adequacy of HH water source (Water scarcity)	No. of times HH has considered water-scarce during the past 10 years
				Conflicts over water	Dummy: yes/no
	Socio-demographic status	Education and dependency and education	Household head (HHH) is literate with a lower dependency ratio	HH dependency ratio	Number
				HHH level of formal education	No. of years of formal education of HHH
	Assets	Asset and livestock holding, ownership of communication devices and saving	households have considerable assets and livestock holding, access to saving and communication devices	No. of livestock owned by HH	Number
				HH access to phones (At least one household member owns a telephone)	No. of HH members who own a phone
				At least one member of HH belongs to a VSLA	Number
				At least one member of HH owns a motorcycle/ tricycle	Number
	Livelihood strategy	Livelihood diversity, social support score, number of coping strategies and technology utilisation (SIPs)	households have multiple income sources, higher social support scores, utilise technology and apply varieties of coping strategies	Main source of HH income	Dummy: Farm/ Off-farm
				HH has regular access to subsidy	Dummy: Yes/No
				HH coping strategy	No. of HH members who undertake seasonal migration
				HH coping strategy	No. of HH members who sell labour
				HH receives remittances	Dummy: Yes/No
Transformative capacity	Social capital	Conflict management	household experience less conflict in accessing resources	No. of times a member of the HH has been involved in conflict over farmland	No. of conflicts in the past 10 years
	Access to basic services	Access to basic public services, such as market, health services and basic school	households have secure access to land, markets, extension, education and health care	Access to extension	No. of extension visits in the past season
				Access to education	Distance to the nearest school (km)
				Market access	Distance to the nearest market
				Access to health	Distance to the nearest health centre
				Regular access to market information	Dummy: Yes/No

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The area receives an average annual rainfall of 600mm, enough for a single farming season. The annual rainfall pattern is erratic at the beginning of the rainy season, starting in April and intensifying as the season advances, raising the average from 600mm to 1000mm. The municipality is characterised by high temperatures with an average of 34°C, ranging between 16°C to 42°C. The low temperatures are experienced from December to late February, during which the North-East Trade winds (harmattan) greatly influence the weather in the Municipality.

Methods of Data Collection and Analysis

The study adopts a mixed-method approach. A mixed-method approach combines "quantitative and qualitative methods in a single study" (Tashakkori & Creswell, 2007, p. 4). The advantage is that a mixed methods research design allows for more thorough and synergistic data utilisation than the individual quantitative and qualitative methods. The qualitative part of the study sought to provide further insight into the findings from the quantitative study. The mixed-methods approach also provides methodological flexibility because it is adaptable to many study designs and enriches the results based on participant experiences (Wisdom and Creswell, 2013).

Sampling

The study targeted rainfed lowland rice farmers. Therefore, three lowland rice production hubs were purposively selected for the study. These are Nankpanzoo, Yipalsi and Diare. Targeted respondents were smallholder farmers with farm sizes of up to 2.5 ha. Eighty respondents were selected in each community through simple random sampling. Subsequently, a total of 240 respondents were involved in the study. It is common for rice farmers to own more than one rice plot, in which case the questions focused on the main rice plot.

***Focus Group Discussions (FGD)**:*

One FGD each was carried out in Diare, Yipalsi and Nakpanzoo in 2019 to obtain preliminary data on the perception of farmers on climate variability, related shocks, mitigation, adaptation and coping strategies adopted by farmers. A second set of FGDs was carried out in 2020 to explore in detail the type of sustainable intensification practices adopted by farmers and the related constraints, strategies aimed at mitigating the effects of climate variability, the kind of shocks encountered by farmers and to ascertain information obtained from the quantitative data. Each FGD comprised ten (10) smallholder rain-fed rice farmers on average. Information was obtained with the help of a checklist. During the discussion, field assistants recorded information using notebooks and audio recorders. Data obtained were later transcribed, summarised and analysed by the entire team after the field visit.

Key Informant Interviews (KII)

KIIs were held with major stakeholders with the help of a checklist. Key informants included staff of the Meteorological Service, the Department of Agriculture, farmers and researchers from the University for Development Studies to obtain background information on previous and ongoing interventions in the study area.

Questionnaire Administration

Quantitative data were collected utilising a detailed questionnaire and targeted smallholder rice farmers in the study locations. One team of enumerators was deployed to collect data in all the communities to ensure consistency.

Estimation Procedure

Following Asmamaw et al. (2019), the study adopts a two-step approach to calculate a composite climate resilience index. As a first step, a resilience index is calculated for each household. The second step involves analysing the determinants of household resilience to climate variability through a multiple linear regression with the resilience index, calculated in the first step, as a dependent variable.

Resilience Index

The CRI was calculated based on a combination of quantitative and qualitative metrics presented in Table 1. Each variable was scored on a defined scale and aggregated to obtain scores for the sub-components. Subcomponent scores were aggregated to obtain standardised values for the three major resilience components, and a composite resilience index obtained by calculating a weighted average of the resilience components. The values for each of the indicators of the three major resilient components were standardised as follows:

A: Indicators that have a direct but positive relationship with CRI

$$I_a = \frac{S_r - S_{min}}{S_{max} - S_{min}}$$

B: Indicators that have a direct but negative relationship with CRI

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$$I_a = \frac{S_{max} - S_r}{S_{max} - S_{min}}$$

Where I_a represents the standardised value for the indicator, a, S_r are the value for the indicator a for household r, *min* and *max* represent the minimum and maximum values for the indicator across all households. The average value of each component is calculated as follows:

$$M_r = \frac{\sum I_{ai}}{N}$$

Where M_r is one of the sub-components of the CRI, I_{ai} represent the standardised value of an indicator within a component, and N is the number of indicators within each component.
The CRI is calculated as:

$$CRI = \frac{\sum_{P=1}^{n} WM_i M_{ri}}{\sum_{p=1}^{n} WM_{ri}}$$

Where M_{ri} is the number of indicators for a major component and WM_i is the weight of a major component. The CRI is calculated assuming that the major components have equal impact and, therefore, equal weights are assigned to all components. However, indicators are weighted within each component according to the number of indicators within the component.

Multiple Regression

Theoretically, climate change resilience of a household is a function of household characteristics (HHC), plot characteristics (PC), climate-related vulnerability (CV), institutional (INS) factors and household resource endowment (RE).

$$CRI_i = f(HHC, PC, CV, INS, CV)$$

Thus,

$$CRI_i = \beta_{0i} + \beta_{i1}x_{i1} + \beta_{i2}x_{i2} + \dots + \beta_{in}x_{in}$$

Where CRI is the climate resilience index for household i, x is an explanatory variable, and β is a parameter to be estimated.

The variables are explained in Table 2.

Table 2: Explanatory Variables

Variable	Definition	Measurement	*A priori expectations*
	Household characteristics		
Age	Age of a farmer	No. of years	+ve
Gender	Sex of farmer	Male= 1, Female =0	+ve
Household size	No. of persons in the household members	Count of no. of persons	+ve
Crop diversity	No. of Crops Cultivated by a Household	Count of no. of crops	+ve
Experience	Experience in rice farming	No. of years of rice farming	+ve
Income source	HH's primary source of income	1 if farming, 2 otherwise	+ve
Seasonal migration	Farmer migrates	1 = Yes, 2 = No	+ve
Off-farm employment	Farmer is employed off-farm	1= Yes, 2 = No	+ve
	Plot characteristics		
Rice plot position	Nature of slope of rice plot	1 = Gentle, 2 = Steep	+ve
Soil quality	Soil quality of rice plot	1 = Good, 2 = Poor	+ve
SIPs Adopted	No. of sustainable intensification practices adopted	Count of individual SIPs	+ve
	Climate-related Vulnerability		
Drought	No. of droughts in the past 10 years	Count of no. of droughts	+ve/-ve
Flooding	No. of floods in the past 10 years	Count of no. of floods	+ve/-ve
Pests/Disease	No. of pests and diseases in the last 10 years	Count of no. of pest and disease attacks	+ve/-ve
Rains	No. of late rains in the past 10 years	1 = Timely, 2 = Delayed	+ve
	Institutional factors		
FBO	Farmer belongs to a Farmer-based Organisation	1 = Yes, 2 = No	+ve
Market information	Regular access to Market Information is adequate	1 = Yes, 2 = No	+ve
Market access	Distance to the nearest market	Distance kilometres	-ve
Access to health	Distance to Nearest Health Centre	Distance in Kilometres	-ve
Safety net	HH relies on its internal resources to mitigate climatic shock	1 = Yes, 2 =otherwise	+ve
	Household endowment		
Seed	Households self-sufficient in seed	1 = Yes, 2 = No	-ve
Land	Ownership of rice plot	1 = owns, 2 = Otherwise	+ve
Livestock	Total household livestock holding	Count of no. of livestock	+ve

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Results and Discussion

Descriptive statistics

The number of SIPs adopted by a farmer is 5, ranging from one (1) to twelve (12) out of 17 SIPs identified by farmers. This finding supports the notion that farmers are selective in adopting technology packages and often combine technologies that best serve their needs. Most farmers are within the economically active age group, with the age of a farmer ranging between 20 and 69 years and an average of 41 years. Rice cultivation is male-dominated as 84% of the farmers are male. However, it is important to note that some female farmers rely on male household members to cultivate their rice fields. Thus, female participation in rice cultivation could be higher. The average household size is nine and ranges from one to thirty. Farm and rural households in Northern Ghana are usually large and may consist of one or more families. The average experience in rice cultivation is 10 years and ranges between 5 to 50 years. About 93% of farmers in the study area did not belong to an FBO at the time of the study. In the study area, farmers join FBOs mainly to access external support. Thus, FBOs only last as long as such support exists. Distance to the nearest market indicates market access and facilitates access to input and output markets. On average, communities in the study area can access markets without difficulty as a farmer travels 2.9 km to obtain inputs or sell their produce.

Table 3: Descriptive Statistics of Variables

Variable	Min.	Max.	Mean	Std. Deviation
No. of SIPs adopted	1	12	5.32	4.34
Age of Farmer	20	69	41.32	11.497
Household size	1	30	8.93	5.393
No. of Crops Cultivated by a Household	1	5	1.60	0.567
Farming experience	5	50	10.44	8.091
Distance to the nearest market	0	11	2.88	4.247
No. of Livestock owned	0	117	19.57	23.029
Variable	**Measurement**	**%**	**Measurement**	**%**
Gender	Female	16.2	Male	83.8
Primary HH income source	Rice	87.1	Other	12.9
Rice plot position	Gentle	69.29	Steep	30.71
Perception of Soil quality	Good		Bad	
Ownership of Rice Plot	Owner	91.23	Other	8. 87
FBO membership	Yes	6.6	No	93.4
Off-farm Employment	Yes	30.7	No	69.3
Migration of HH members	Yes	10	No	90.0
Regular access to market information	Yes	17.84	No	82.15
Reliance on own resources	Yes	81.33	No	18.67
Household Borrows Seed	Yes	96.68	No	3.32
Dry spells	Yes	70.54	No	29.46
Late rain onset	Yes	44.39	No	55.60
Pests/Diseases	Yes	17.01	No	82.99
Floods	Yes	73.86	No	26.14

The average number of livestock owned by a household in the study area is 20 and ranges between 0 to 117. In principle, livestock ownership is an important source of household income and indicates wealth. Migration among household members is low, with only 10% of household members migrating. Migration, seasonal or otherwise, offers additional income for farm households and a risk-mitigating strategy. Remittance from migrated household members usually supports farming activities during the farming season. Rice cultivation constitutes an important source of income for farm households in the study area, as 87% of farmers indicated that it is a significant source of household income. This result is not surprising since the rural communities derive their livelihood mainly from agriculture. Common natural disasters encountered in the study area are floods, dry spells, late onset of rains, pests and diseases. During the past 10 years, 70.5%, 44.4%, 17.0% and 73.9% of farmers have encountered dry spells, late onset of rains, pests and diseases and floods, respectively. The mean incidence of flooding, dry spells, late rains, pests, and diseases are 2.6, 1.7, 1.5 and 1.3, respectively. Only 31% of households in the study area had at least one (1) member engaged in off-farm employment, confirming that farming is a significant source of income for households. Over 91% of rice plots belong to the households cultivating them.

Types of Climate Shocks and Impact

Over the past 10 years, households in the study area have frequently experienced four major types of climatic shocks. Among these, flooding is the most frequent, with an average of three (3) occurrences. Dry spells and late rains have occurred two (2) times on average over the period. The least shock is pest and disease incidence averaging once (Figure 4). Food insecurity and loss of livelihood are the most significant losses incurred by households as a result of climatic shocks. Loss of livelihood and food insecurity was reported by 95% and 90%, respectively, while conflicts over land and water account for 15% and 2% of climate variability, respectively (Figure 5).

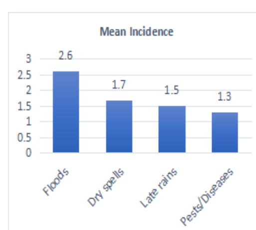

Fig. 4: Incidence of Climatic Shocks

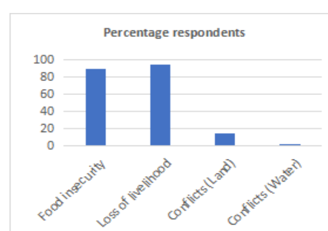

Fig. 5: Impact of Climatic Shocks

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Resilience Components

The average household CRI is 0.49, meaning smallholder farmer rice households in the study area are generally resilient. Transformative capacity contributed the most to household resilience. It averaged 0.69, meaning the ability of rice-farming households to self-organise in the long term to seek livelihood alternatives outside rice lowland rain-fed rice cultivation is high. Absorptive and Adaptive capacity averaged 0.33 and 0.45, respectively. This means that while rice farming households in the study area have a relatively low ability to withstand climatic shock in the short term, they can retain their livelihoods within acceptable thresholds in the short to medium term by improving their internal capacity to withstand climatic variability (Fig. 6).

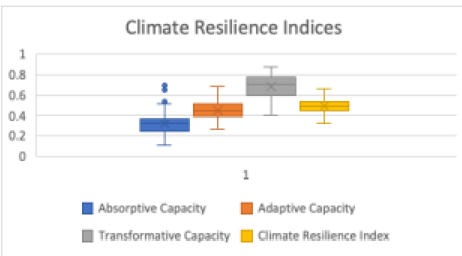

Fig. 6: Distribution of Climate Resilience Index

It is important to note that there are wide variations in household resilience capacities with transformative capacity, absorptive capacity and adaptive capacity ranging from 0.41 to 0.87, 0.11 to 0.64 and 0.27 to 0.67, respectively (fig. 7). Thus, household climate resilience is influenced by individual household attributes.

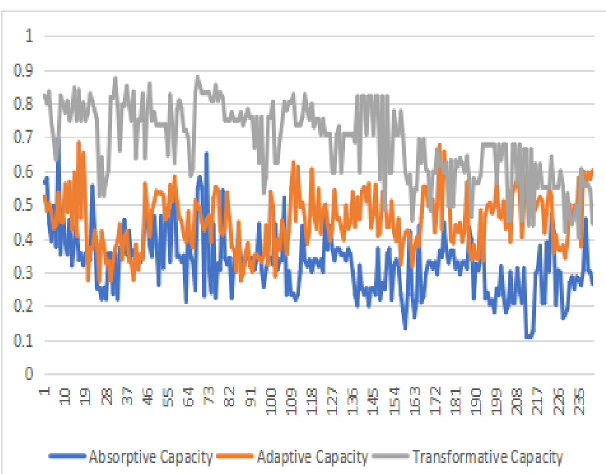

Fig. 7: Distribution of Resilience Capacities

Sub-components of the Resilience Index

Naturally, households in the same geographical location are exposed equally to climate shocks. However, the response to such shocks depends on the individual household attributes (Table 4). Supportive agroecological conditions for rice production contributed the most while social capital contributed the least to absorptive capacity. Income and food access, regular access to health and access to reliable water sources were the major determinants of the adaptive capacity index accounting for 0.57, 0.63 and 0.60, respectively. Other determinants of the adaptive capacity index include household socio-demographic conditions, livelihood and wealth attributes which accounted for 0.32, 0.32 and 0.25 of the adaptive capacity index, respectively. Regarding transformative capacity, effective resource governance and regular access to basic services accounted for 0.93 and 0.63, respectively, while access to alternative livelihood options accounted for 0.25. It is, therefore, evident that income and food access, regular access to health, reliable access to improved water, agroecological conditions, resource governance and access to basic services are essential to household resilience against climate variability.

Table 4: Descriptive Statistics of Variables

Resilience component	Sub-component	Score
Absorptive capacity	Household readiness to respond to climatic shocks	0.39
	Supportive agroecological conditions	0.52
	Social capital	0.05
	Pooled	**0.33**
Adaptive capacity	Income and food access	0.57
	Regular access to health care	0.63
	Regular access to improved water	0.60
	Socio-demographic conditions	0.32
	Wealth status	0.25
	Livelihood strategies	0.31
	Pooled	**0.42**
Transformative capacity	Livelihood options	0.21
	Effective management of resource conflicts	0.93
	Regular access to basic services	0.63
	Pooled	**0.69**

Determinants of Climate Change Resilience

Twenty-three independent variables assumed to affect household climate change resilience were considered in the study. These variables were categorised into five main components: household characteristics, plot characteristics, vulnerability context, institutional factors and resources. Nine variables showed significant effects on household resilience to climate variability. Together these nine variables explain 60.6% of the variance in household resilience against climate variability. The low variance inflation factors (VIF) indicate that the prob-

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lem of multicollinearity is minimal (Table 4).

Household Characteristics

Household characteristics are important determinants of household climate change adaptation (Okunola & Bako, 2021). In the case of this study, the age of a farmer, cropping diversity and a farmer's primary income source (farmer or otherwise) positively affected household resilience to climate variability (Table 4). While the effect of the age of a farmer is significant at the 5% significant level, the effects of cropping diversity and households' primary income source were significant at the 1% significant level.

The result meets our *a priori* expectation that more experienced farmers tend to adopt better strategies to mitigate climate variability, implying that the older a farmer, the more resilient the household is (Okunola & Bako, 2021). Again, the results suggest that older rice growers are less likely to substitute rice growing for other livelihood strategies. They are, therefore, more inclined to adopt climate change mitigation strategies to sustain their livelihood.

Crop diversification is recognised as a common strategy to mitigate the effects of climate change through its ability to suppress pests and disease transmission and act as a buffer against the effects of climate variability (Brenda, 2011). The number of crops cultivated by a household positively and significantly affected household resilience against climate variability, which meets our a priori expectations. It is evident from the study that crop diversification is a common strategy adopted by households to mitigate climate variability in the study area. Generally, households cultivate several small plots of different crops to minimise their losses from climate-related shocks. Diversification of income sources has been positively associated with climate resilience (D'Errico & Giuseppe, 2017; Boka, 2017; Tesso et al., 2012).

The present study hypothesised that rice farmers are less likely to diversify their income sources in the short to medium term due to climate variability since they lack the resources and the opportunities to do so. Therefore, rice-growing households in the study area are more likely to adopt climate change mitigation strategies to protect their primary source of livelihood, farming, than to diversify their livelihood sources. True to our expectations, farming as a primary source of income has a significant and positive effect on household resilience against climate variability.

Table 5: The Determinants of Household Climate Change Resilience

Variable	B	Std. Error	t	Sig.	VIF
Age of a farmer	0.001**	0.000	2.166	0.031	1.828
Gender of farmer	-0.011	0.007	-1.524	0.129	1.140
Household Size	0.001	0.001	0.970	0.333	1.510
Crop diversity	0.021***	0.004	5.159	0.000	1.629
Farming experience	-0.001	0.000	-1.300	0.195	1.591
Primary Income Source	0.027***	0.010	2.654	0.009	2.031
Migration	-0.001	0.009	-0.065	0.948	1.303
Off-farm Employment	0.002	0.007	0.226	0.821	1.975
Rice plot position	-0.025***	0.006	-4.186	0.000	1.260
Soil Quality	-0.039***	0.008	-4.804	0.000	1.931
No. of SI Adopted	0.004	0.002	1.587	0.114	1.414
Incidence of Flooding	-0.005***	0.002	-3.483	0.001	1.646
Incidence of Dry Spells	-0.003	0.002	-1.597	0.112	1.435
Late on-set of rain	0.001	0.002	0.316	0.753	1.622
Incidence of Pest/diseases	-0.003	0.002	-1.488	0.138	1.262
Access to Market Information	-0.008	0.010	-0.806	0.421	1.090
Distance to Nearest Market	-0.003***	0.001	-3.292	0.001	2.117
Distance to Nearest Health Post	0.002	0.001	1.260	0.209	1.711
FBO Membership	0.069***	0.010	6.639	0.000	1.151
Reliance on Own Resources	0.019*	0.011	1.801	0.073	2.980
HH Borrows Seed	0.010	0.010	0.917	0.360	1.088
Ownership of Rice Plot	-0.012	0.010	-1.247	0.214	1.913
No. of Livestock Owned by HH	0.000	0.000	1.516	0.131	1.457

Plot Characteristics

Rice plot position and soil quality have significant but negative effects on household resilience at the 1% significant level. Good soil management has improved agroecosystem resilience and yield stability under climate extremes, while steep slopes have been associated with accelerated erosion and, consequently, loss of agricultural productivity (Nouri et al., 2021; Gao et al., 2020; Asmamaw, 2019). The focus group discussion revealed that flooding is recurrent and causes severe damage to rice. At the same time, soils are generally poor due to farmers' inability to sustain crop production based on increased input use.

Exposure to Climate-Related Vulnerabilities

A system's sensitivity to climate-related vulnerabilities is essential to how effectively people affected act to reduce the adverse effects of climate change (Ludena et al., 2015). Exposure to specific climate change-related hazards such as floods have posed a significant threat to household resilience to climate change (Birkmann,

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2022). In this study, the incidence of flooding is negative and significantly associated with household resilience to climate change at the 1% significance level. Flooding is more frequent than other natural contextual vulnerabilities in the study area, as farmers have experienced flooding every two years.

Institutional factors

The contribution of institutions and institutional arrangements to climate change adaptation has been recognised in climate change resilience discourse (Mubaya & Mafongoya, 2017; Ampaire et al., 2017; Agrawal et al., 2008). Under such circumstances, formal and informal institutional mechanisms to support household recovery from climatic shocks are critical to ensuring household resilience against climate variability. Institutions and institutional arrangements facilitate access to essential resources, innovations and knowledge towards enhancing local resilience to climatic shocks. In this study, market access, proxied by distance to the nearest market and membership of FBOs, were associated significantly with household resilience to climate change at the 1% significance level. However, market access negatively affected household climate change resilience. Other studies revealed a positive relationship between market access and climate change resilience (Boka, 2017; Asmamaw et al., 2019). The result obtained, however, is understandable within the context of the study.

The focus group discussions showed that although distant markets tend to be more profitable, the cost of accessing them is high due to high information and transportation costs. Therefore, farmers are constrained to selling farm produce at the farm gate and to intermediaries who offer lower prices. Participation in FBOs affected climate change resilience positively. This is similar to results obtained by Adzawla et al. (2020). The effect of households' reliance on their internal resources to mitigate the effects of climatic shocks significantly and positively affected household resilience against climate variability at the 10% significant level. Households which are financially and technically least equipped are more likely to be affected more adversely by climate change (Seaman et al., 2014). Thus, households must find the resources to support their recovery in times of climatic shocks in the absence of reliable social and public support.

Conclusion

Smallholder farmers' ability to adapt to changing climatic conditions is crucial in achieving domestic and global food security. This study examined the resilience of smallholder rice farming households to climate variability in the Savelugu municipality of the northern region of Ghana. Cross-sectional data were obtained through a questionnaire involving 241 households and focus group discussions. Of the 17 sustainable intensification practices identified in the study area, farmers adopt 5 of them regularly to mitigate the effects of climate variability. A multi-dimensional household CRI was calculated for household resilience and used to determine factors influencing household resilience to climate variability through multiple regression analysis. The study revealed that floods, dry spells, late rains, pests and diseases are the common climatic shocks experienced by farmers. Household CRI is 0.49. Transformative capacity contributed the most to Household CRI with an index of 0.69, while adaptive and absorptive capacities contributed 0.45 and 0.33, respectively. The relatively low absorptive and high transformative capacity of smallholder rice farming households in the study area suggests that the nature and function of the rainfed smallholder rice production system are changing, and farmers are likely to substitute rain-fed rice cultivation for other sources of livelihood. The regression analysis results suggest that nine variables comprising household characteristics, plot characteristics, vulnerability context, institutional factors and resources influence household climate resilience, explaining 60.6% of the variance in household resilience against climate variability. These include farmers' age, cropping diversity, household's primary income, plot position, soil quality, flooding, market access and FBO membership. On the other hand, the resilience analysis revealed that income and food access, regular access to health, reliable access to improved water, agroecological conditions, resource governance and access to basic services are essential for smallholder household climate resilience. The high transformative capacity index indicates that, in the long term, households have the ability to seek livelihood options outside smallholder rice production. In contrast, the comparatively low absorptive capacity means a household's weak capacity to contain climatic shocks. The following recommendations are made towards improving the impact of interventions aimed at improving smallholder household resilience to climate variability:

Farm and off-farm related factors determine smallholder farmer household vulnerability to climate change. To be effective, policies aimed at improving smallholder farmer-household climate resilience must address the climatic and non-climatic stressors confronting farmers concurrently.

Adaptation plans to improve smallholder farmer households' climate resilience must include diverse strategies allowing farmers the flexibility of selecting a combination of strategies that suits their socioeconomic and contextual situations.

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Consequently, policies to address smallholder farmer households' climate resilience must depart from farm-specific and technology-centred interventions to include other value chain dimensions to achieve the required impact.

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Appendix

Resilience component	Sub-component	Score	Sub-component	Score
			Early warning	**0.01**
	Climatic Shocks	**0.39**	Disaster Preparedness	**0.06**
			Self-reliance	**0.81**
			No. of shocks	**0.67**
Absorptive Capacity			Plot positino	**0.69**
	Stability	**0.52**	Soil quality	**0.22**
			No. of SIPs	**0.65**
			Access to input credit	**0.06**
	Social Capital	**0.05**	FBO membership	**0.07**
			Borrow seed	**0.03**
			Per capita income	**0.12**
	Income and Food Access	**0.57**	Dietary diversity score	**0.48**
			Hunger score	**0.85**
			Reduced daily meals	**0.85**
			Child mortality	**0.95**
	Health	**0.63**	Access to health insurance	**0.85**
			Access to improved toilets	**0.08**
			Improved water source	**0.54**
	Water	**0.60**	Access to water (Distance to water source)	**0.74**
			Water scarcity (year-round access to water)	**0.49**
			Absence of water conflict	**0.61**
Adaptive Capacity			Sex of household head	**0.84**
	Socio-demographic status	**0.32**	Dependancy ratio	**0.48**
			Educational level of household head	**0.17**
			Livestock ownership	**0.17**
			Savings (VSLA membership)	**0.15**
	Wealth Status	**0.25**	Means of transport (motorbike)	**0.47**
			Communication (mobile phone)	**0.13**
			Roofing sheet	**0.34**
			Migration	**0.22**
			Sale of labour	**0.11**
	Livelihood strategies	**0.31**	Access to subsidy	**0.83**
			Remittances	**0.26**
			Ability to affort inputs (non-subsidised)	**0.13**
	Alternative Livelihoods	**0.21**	Crop diversity	**0.30**
			Crop-Livestock conflict	**0.88**
	Conflict Management	**0.93**	Land tenure security	**0.98**
			Conflict over land	**0.89**
Transformative Capacity			Regular access to market information	**0.91**
			Regular access to agricultural extension	**0.36**
	Access to Basic Services	**0.63**	Access to education	**0.79**
			Access to education	**0.74**
			Access to regular health care	**0.35**