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Analysis of farm households' perceived climate change impacts, vulnerability and resilience in Ghana

William Adzawla[a,*], Shaibu Baanni Azumah[b], Paul Yao Anani[c], Samuel A. Donkoh[a]

[a] University for Development Studies, P.O Box TL1882. Tamale, Ghana
[b] Solidaridad Network, West Africa. Okine Street, East Legon, Accra PMB KD 11, Kanda, Accra, Ghana
[c] German Development Cooperation (GIZ). P. O. Box KA 9698. Airport Res. Area, Accra, Ghana

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ABSTRACT

Analysis of climate impacts, vulnerability and resilience is crucial to understand how humans relate with global environmental changes. Against the backdrop of lack of comprehensive information on assessment on these indicators within Ghana's context, this study used cross-sectional data from 300 farmers from two districts of Ghana to analyze climate change through a subjective approach. The data was analysed using ordered probit regression. The result established that, majority of the farm households perceived significantly high impacts of climate change on their livelihoods; low to very low climate vulnerability; and high to very high resilience to climate change. The factors that explained the level of climate impact were age, credit access, number of unemployed households, household per capita expenditure, and number of times of flood a farmer experienced in recent times. The estimated climate vulnerability level of the farmers was significantly influenced by education, credit, membership of farmer based organization (FBO), unemployed household members, non-farm income, environmental warning and droughts. Also, climate resilience of the farmers was significantly influenced by the location, credit access, FBO membership, consumption expenditure, drought and source of domestic water. The result established that a broader consultation and strategy is required to address the consequences of climate change and to improve the resilience of farm households in Ghana.

Introduction

Globally, climate change has become a major developmental challenge, especially for developing economies whose socioeconomic development is largely driven by rainfed agriculture. Evidence show that the four warmest periods are recorded in 2015-2018, with temperature projections showing an upward trend (see Fig. 1) [26]. There is no sign that global increases in temperature would peak soon [24]. Similarly, projections show a decline in seasonal and regional precipitation [22]. These changes in climate have effects on all sectors of the economy and aspects of human life. Basically, climate change and its

* Corresponding author.
E-mail address: adzawlawilliam@gmail.com (W. Adzawla).

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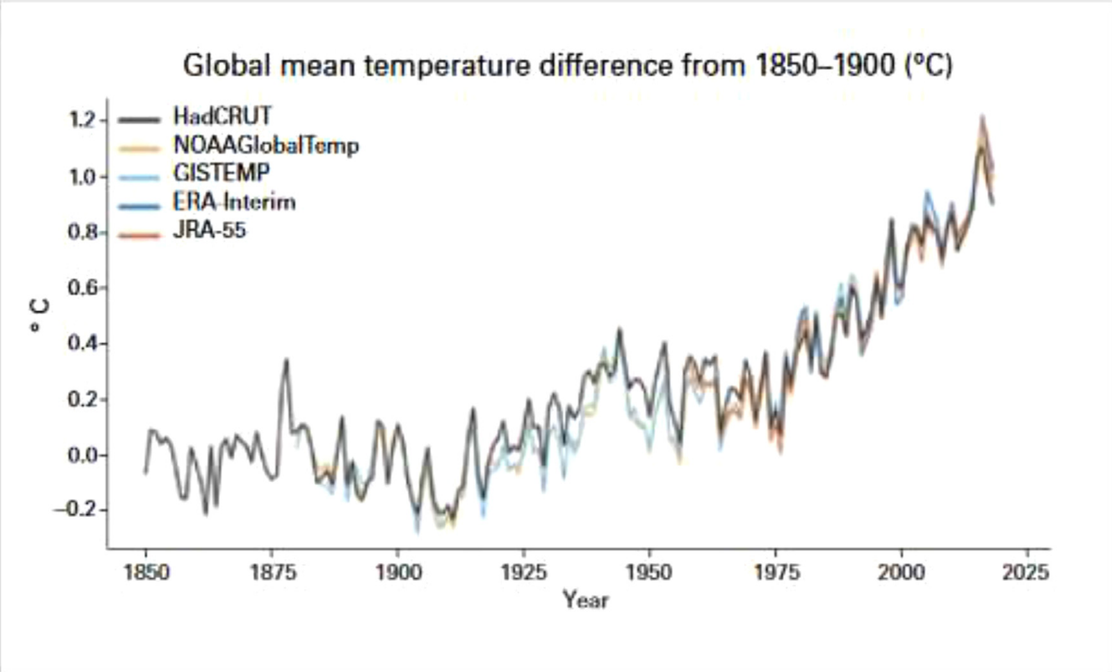

Fig. 1. Global mean temperature trend
Source: **Source:** WMO [26].

stressors affect humans by destabilizing livelihoods, especially for poor households [19]. Achieving sustainable food production and food security is being challenged by climate change as yield of most staple food crops are either stagnant or on the decline [22]. Variability in climate has altered livelihoods, leading to an increasing vulnerability, reducing the possibilities of securing livelihoods and poverty annihilation [4]. Overall, three important aspects of climate change that require more analysis are climate threat and impacts, climate vulnerability, and climate resilience. However, these are location-specific and thus vary from one area to another. Therefore, global analysis of these aspects of climate change cannot be a rule of thumb for policy decision-making. As such, this study analysed these climate aspects within Ghana's context.

Vulnerability is defined as a function of exposure, sensitivity and adaptive capacity. Vulnerability is context specific, and its measurement or assessment is not universal [6]. However, empirical studies have measured it through participatory, simulation or indicator approaches [14]. Among these, the indicator approach has gained wide usage [17]. As is the case of sub-Saharan Africa, Ghana's climate vulnerability is due to its low adaptive capacity and high reliance on climate sensitive sectors such as agriculture. Arndt et al. [7] explained that Ghana's vulnerability to climate change can be explained by high dependence on agriculture; hydropower for electricity supply; and infrastructure deficits. Evidence shows that Ghana's record of temperature is rising while rainfall is reducing and becoming more erratic [23]. Ghana's rainfall is predicted to decline by 1.1% in 2020 to 20.5% by 2080 while temperature will increase by 0.8 °C to 5.4 °C above 1960–2000 average by 2080 [23]. Like other countries in the sub-region, Ghana is and would be experiencing a decline in its crop growing season [21]. Overall, climate change is having negative effects on efforts toward reducing poverty, unemployment and food insecurity in the country. Ojha et al. [16] explained that localized vulnerability analysis is required for effective adaptation planning or programming.

Climate resilience has become a major aspect for climate discussions since it largely determines how climate efforts such as adaptation are yielding results, especially into the future. It involves the ability of a system such as households to draw on its characteristics and opportunities to cope, adapt and develop to the changes in climate shocks before, during and after the shock [20]. This implies that resilience moves beyond just adaptation but also, the time taken to recover or bounce back from a climate shock. The longer the period taken to recover, the less the resilience of the system. Therefore, developing a climate resilient household is an important path to sustainable development.

Climate change has become a major threat to man and the eco-system. A number of developmental indicators are being affected by the changing climate. A stable ecosystem which is a necessary condition for agriculture and food security is challenged by climate change [16]. Simply put, achieving a zero hunger globally can be interrupted by climate change as extreme climate events will intensify into the future [25]. Smith & Gregory [18] explained that one of the major global threat is how to produce food to feed the about ten billion human population in 2050 under the changing climate simultaneously with a reduction in environmental impacts from agriculture. Although climate change have a global impact, the impacts are not universally distributed. Global populations along the coast are not spared of climate impacts as the oceans and atmospheric processes are going to be altered by climate change [10]. Adzawla et al. [2] and Adzawla & Kane [3] demonstrated that climate change have negative implications on inequality, specifically gender inequality, in northern Ghana. These reviews suggests that the impacts of climate change is diverse and deepen the reasons for which climate change is a global threat.

Admittedly, this is not the first study to explore the climate vulnerability, impacts or resilience of households to climate change in Ghana. However, this study addresses two missing gaps. First, previous studies [9,27] have relied on objective measure of various climate aspects, neglecting or overriding the views of the households on their own assessments of these indicators. Recently, climate analysis through subjective approaches are being recommended due to its advantages [11]. This subjective analysis involves the households' cognitive and affective self-assessment of their capabilities and capacities to respond to risks [11]. Secondly, previous studies such as Nyantakyi-Frimpong & Bezner-Kerr [15] focused on a single aspect of climate change analysis in their empirical study. Although these provide a somehow detailed analysis of the climate aspect considered, they do not allow policy makers to trace the various climate aspects among observations. This is addressed in this study by analyzing the climate impact, vulnerability and resilience of farmers. The advantage is that this study provides a more comprehensive and perhaps, apt policy recommendations on how to tackle climate change among farm households in Ghana.

Methodology

Study location

The study was conducted in two districts of Ghana, South Tongu and Zabzugu districts, where MoFA has implemented some climate risk management projects in the past few years. Zabzugu district is located in northern Ghana, specifically in the Northern region. The district covers a land area of 1100.1 sq km and experiences a unimodal rainfall distribution with a mean annual rainfall of 1125 mm. The vegetation of the district is guinea savannah, though some areas in the southern part fall within the transitional zone. About 86% of the district's labor force engages in agriculture, forestry and fishery related occupation. The major food crops produced in the district include yam, maize, millet, rice, cassava and groundnuts. The South Tongu district is located in southern Ghana, specifically in the Volta region of the country. It lies between latitudes 6°10′ and 5°45′ North and longitudes 30°30′and 0°45′ East. The district occupies a total land area of 643.57sq km and located in the coastal savannah vegetation zone. About 56% of the economically active population of the district engage in agriculture, primarily, in the production of crops such as maize, rice and vegetables

Research design, sampling procedure and data collection

The study used a mixed research design by combining both qualitative research design with a quantitative research design. For instance, while the subjective expressions of the respondents were analysed using qualitative procedure, the analysis of the responses were complemented with quantitative (econometric) methods. The use of the mixed research design allowed to cross validate the research findings.

A two-step simple random sampling procedure was used in selecting the respondents for the study. In the first stage, ten communities that benefited from GIZ climate change related projects were selected from South Tongu and Zabzugu districts, by generating random numbers for each community using Microsoft excel program. The communities that recorded the topmost five random numbers in each district were selected. In the second step, 30 beneficiary farmers in each community were selected randomly. Therefore, a total of 300 beneficiary farmers were used for this study; 150 from each district. The data for this study was collected by trained extension officers who understand the local dialects of the people and the agricultural production conditions of the districts. The data for this study was obtained from a broader data collected on the assessment of climate adaptation strategies and the impacts on households' livelihood. This involved questionnaire administration. The questionnaire included both open and closed ended questions, with inputs from staffs of Ministry of Food and Agriculture (MoFA) in the local districts, experts in climate change and socioeconomic researchers. A pre-test on the questionnaire was done and corrections made before the main data collection. The choice of questionnaire in the data gathering was to allow the researcher gather enough data relevant for the study. The final data was processed with Microsoft excel and analysed using STATA software.

Data analysis

The study involved the analyses of climate impact, vulnerability and resilience. These were based on subjective approach where the respondents were asked to provide their own assessment on these aspects without the researcher engaging in any indicator computation. In this study, a five-point Likert scale (very low, low, average, high and very high) was provided to respondents to assess their households. In order to improve the distribution of the result and enhance the quality of the analysis, the five-point scale was re-organized into three-scale as low/very low, average and high/very high. The assignment of values to the scale was based on the aspect of climate analysed. While the climate impact on households' livelihood and vulnerability were ranked as 0 (high/very high), 1 (average) and 2 (low/very low), climate resilience of the farmers was scaled 0 (low/very low), 1 (average) and 2 (high/very high). Considering these meaningful ordering, ordered probit regression was estimated each for climate impact, vulnerability and resilience as follows: Given,

$$y^* = x'\beta + \varepsilon \tag{1}$$

where x is a set of independent variables that are hypothesized to influence y, β are unknown parameters that are to be estimated, ε is a random error term y^* is defined for the climate aspect to be measured.

$y^*$is unobservable, therefore, according to Greene (2003) a set of y distribution is stated as follows:

$$\begin{aligned} &y = 0 \; if \; y^* \le 0 \\ &y = 1 \; if \; 0 < y^* \le \mu_1 \\ &y = 2 \; if \; y^* > \mu_1 \end{aligned} \tag{2}$$

where μ_s are unknown threshold parameters that are estimated with β. These threshold parameters can be interpreted as the intercepts since they determine the estimates for different values of y. ε in Eq. (1) is assumed to be normally distributed. From Eq. (1), the probabilities of prediction can be estimated as:

$$\begin{aligned} &Prob(y = 0|x) = \Phi(-x'\beta) \\ &Prob(y = 1|x) = \Phi(\mu_1 - x'\beta) - \Phi(-x'\beta) \\ &Prob(y = 2|x) = 1 - \Phi(\mu_1 - x'\beta) \end{aligned} \tag{3}$$

Therefore, the corresponding marginal effects of the changes in the predictor variables are given as:

$$\frac{\partial Prob(y = 0|x}{\partial x} = \emptyset(-x'\beta)\beta$$

$$\frac{\partial Prob(y = 1|x}{\partial x} = [\emptyset(-x'\beta) - \emptyset(\mu_1 - x'\beta)]\beta$$

$$\frac{\partial Prob(y = 2|x}{\partial x} = \emptyset(\mu_1 - x'\beta)\beta$$

Empirically, the model estimated is given as:

$$\begin{aligned} climate = {} & \beta_1 District + \beta_2 Age + \beta_3 Sex + \beta_4 Education + \beta_5 Credit + \beta_6 FBO + \beta_7 Unemployed\ HH \\ & + \beta_8 Consumption\ expenditure + \beta_9 Nonfarm\ income + \beta_{10} Water\ source + \beta_{11} Cooking\ energy \\ & + \beta_{12} Environmental\ warning + \beta_{13} Flood + \beta_{14} Drought \end{aligned}$$

where climate was defined separately for climate impact level, climate vulnerability level and climate resilience level. The predictor variables are defined with their expected signs in Table 1.

Results and discussions

Levels of climate threat/impact on households' livelihood

Fig. 2 shows the level of threat of climate change on households' livelihoods. The results show that overall, the majority of the farmers perceived at least a high threat of climate change on their livelihoods. Specifically, 70.7% and 85.3% of the farmers in Zabzugu and South Tongu districts, respectively indicated that climate change had either very high or high threat on their livelihoods. While no farmer in Zabzugu district indicated a low or very low threat of climate change, 4% of farmers in South Tongu district indicated that climate change posed a lower or very low threat to their livelihoods.

Determinants of households' revealed level of climate threat on their livelihoods

Table 2 shows the factors that influenced farmers' subjective indication of the level of threat climate change have on their livelihoods. The result reveal that age, credit access, number of household members without economic activity, household per capita consumption and floods are significantly related to climatic impacts. The estimated Chi-square of the model was significant, though, with a low pseudo R-squared.

Age had its expected negative effect of climate impact on farmers' livelihoods. Thus, the higher the age of the farmer, the higher the perceived impact of climate change on their livelihood. The marginal effect of age moving from very low or low threats from climate change is −0.003 and this is higher than the marginal effect of an average (−0.0004) climate threat .

Table 1
Definition and expected outcome of variables.

Variables	Definition/Measurement	Expected outcome Impact	Vul.	Resilience
District	The location of the farmer. 1 if the farmer is in South Tongu district and 0 if in Zabzugu district	+	+	+/-
Sex	The biological sex status of a farmer. 1 if a male and 0 if a female	+	+	+
Age	The number of years from birth to the time of data collection	-/+	–	-/+
Education	The total number of years of formal education, starting from primary one	+	+	+
Credit	1 if a farmer had accessed credit and 0 if not	+	+	+
FBO	A group of farmers coming together with a common goal and purpose. 1 if the farmer belonged to a group and 0 if not.	+	+	+
Unemployed HH	The total number of economically active household members who are unemployed.	–	–	–
Consumption expenditure	The annual per capita consumption expenditure of a household, in Ghana cedis.	+	+	+
Nonfarm income	The total income from nonfarm economic activities, in Ghana cedis.	+	+	+
Water source	The source from which a farmer obtains its water for domestic purpose. 1 if from pipe water and 0 if borehole/river/rain water	+	+	+
Cooking energy	The primary source of energy for domestic cooking purpose. 1 if a farmer uses gas and 0 if firewood/charcoal.	+	+	+
Flood	The number of times a farmer experienced floods in the past five years.	–	–	–
Drought	The number of times a farmer experienced drought in the past five years.	–	–	–
Environmental warning	Information on the occurrence of a climate shock such as floods. 1 if a farmer received warning signals prior to the occurrence of climate shocks and 0 if not.	+	+	+

Source: Researchers' construct, 2019.

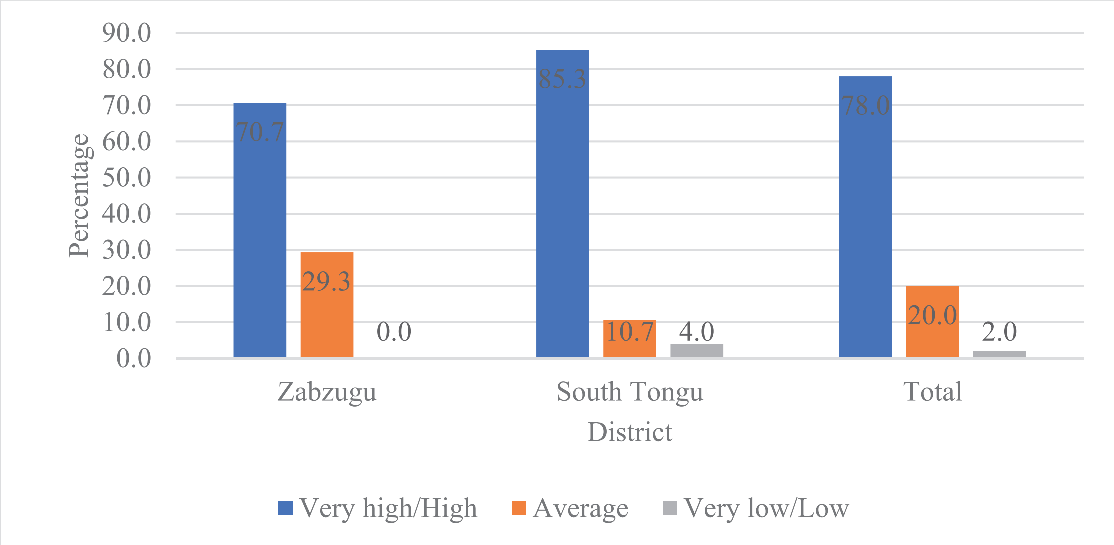

Fig. 2. Level of climate threat to households' livelihood
Source: Source: field data, 2019.

Table 2
Impacts of climate change on households' livelihood.

Variables	Coef.	Std. Err.	$P > z$	Marginal effects Average	Very low/low
District	−0.028	0.285	0.921	−0.007	−0.001
Sex	0.015	0.181	0.934	0.004	0.0005
Age	−0.014*	0.008	0.062	−0.003	−0.0004
Education	0.006	0.021	0.775	0.001	0.0002
Credit	0.492*	0.275	0.074	0.119	0.015
FBO	0.223	0.326	0.495	0.054	0.007
Unemployed HH	0.110***	0.038	0.004	0.027	0.003
Consumption expenditure	0.003**	0.002	0.035	0.001	0.0001
Non-farm income	−0.00001	0.00007	0.906	−0.0000020	−0.0000003
Water source	−0.193	0.242	0.426	−0.046	−0.006
Cooking energy	0.041	0.426	0.923	0.010	0.001
Flood	−1.892*	0.999	0.058	−0.456	−0.058
Drought	−0.316	0.996	0.751	−0.076	−0.010
Environmental warning	0.220	0.201	0.274	0.053	0.007
Cut 1	0.754	0.525			
Cut 2	2.142	0.544			

Source: field data, 2019.
Note: Climate impact is defined as 0 = high/very high, 1 = average, 2 low/very low; Chi-square = 32.74***, Pseudo R^2 = 0.0920; ***, ** and * indicates significance at 10%, 5% and 1%, respectively.

Generally, the elderly engages in agricultural and/or non-agricultural economic activities that are mostly based on indigenous practices while the youths adopt new improved technologies or production strategies. This difference in production technology predisposes the livelihoods of the elderly to more climate threats than the younger farmers who appear more innovative and responsive to climate threats.

The estimated positive effect of credit on the revealed impacts of climate change on farmers' livelihoods was expected. The implication is that farmers who had access to credit had lower threats or impacts of climate change on their livelihoods than those who had no access to credit. From the marginal predictions, the marginal change of a farmer who received credit to have an average impact of climate change on their livelihood is 0.119 while the marginal effect of a revealed low or very low climate impacts on farmer's livelihood is 0.015. This means that access to credit is more likely to reduce climate impacts on the farmers' livelihoods. Generally, financial constraint is a major factor hindering the growth of the agriculture sector. Therefore, with access to credit, the farmers can invest more capital into their economic activities that would reduce or dispel the impacts of climate change.

Contrary to the expectations of the study, the number of unemployed household members led to a reduction in climate impacts or threats on farmers' livelihood. Thus, the higher the number of unemployed household members, the higher the

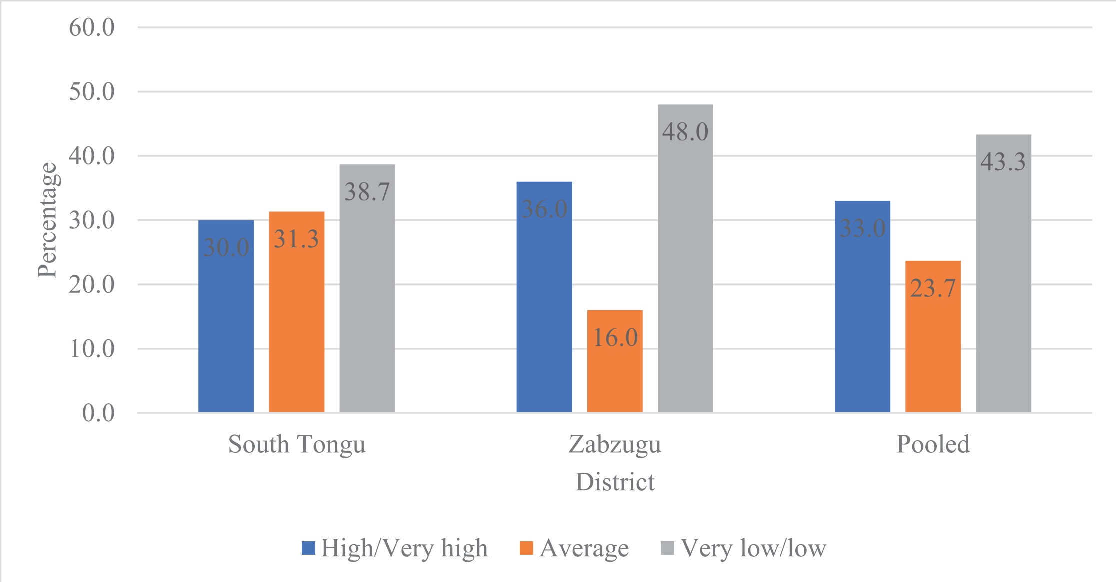

Fig. 3. Climate vulnerability level of farm households
Source: Source: field data, 2019.

probability of having less impact of climate change on the farmer's livelihood. This effect is higher for average marginal change than for very low or low marginal change category.

The effect of household's welfare, measured by consumption expenditure, was positive in explaining the effect of climate change on farmers' livelihoods. The implication is that farmers with high welfare tended to indicate a low threat or impact from climate change on their livelihoods. This is conceivable since households with higher welfare could better cope with the impacts of climate shocks than those with lower welfare.

Among the climate variables considered, only flood was statistically significant in explaining the perceived level of climate impact on households' livelihood. This means that the more frequent the occurrence of floods, the higher the impacts and threats of climate change on household's livelihood. The marginal effect increases from lower climate impacts on livelihoods to high impacts on livelihoods.

Households' climate vulnerability levels in Ghana

Fig. 3 shows the climate vulnerability levels among farm households in the selected districts. Overall, 43.3% of the farmers indicated that their households had low or very low climate vulnerabilities. The remaining 23.7% and 33% respectively indicated an average and a high to very high climate vulnerability levels. Based on the location, the result shows that the majority of farmers in Zabzugu district revealed extreme climate vulnerability (low/very low and high/very high climate vulnerabilities) of their households compared to the respondents in the South Tongu district. For South Tongu district, the percentage distribution gradually declined from very low to very high climate vulnerabilities. Consistently, it was expected that households in Zabzugu district would indicate higher climate vulnerability because the district is geographically located in the northern part of the country where climatic conditions are harsher than in the southern part of the country. Empirical evidence from Dumenu & Obeng [9] showed that guinea savanna, where Zabzugu district is located, is most vulnerable to climate change in Ghana. Ncube et al. [13] estimated that the majority of their sampled households are moderately vulnerable to climate change.

Determinants of households' revealed climate vulnerability

The pooled data in Fig. 3 was used to estimate the factors explaining the revealed climate vulnerability of the farm households using an ordered probit regression and the result presented in Table 3. The factors that significantly influenced the revealed climate vulnerability levels of the farm households include education, credit, FBO membership, number of unemployed household members, nonfarm income, environmental warning and droughts. Although the pseudo R-squared from the regression model was low, the overall relevance is justified by the significance of the Chi-square value.

The results show a positive effect of education on climate vulnerability. This means that as the level of education increases, the probability of becoming less vulnerable to climate change also increases. Thus, the more educated revealed less vulnerability to climate change. This is consistent with the research expectation since education improves the understanding of the farmers on climate change and their ability to adopt strategies that would reduce their vulnerabilities. While

Table 3
Determinants of households' climate vulnerability .

Variables	Coef.	Std. Err.	$P > z$	Marginal effects Average	Very low/low
District	−0.236	0.247	0.338	0.011	−0.092
Age	−0.007	0.006	0.232	0.0003	−0.003
Sex	0.193	0.155	0.214	−0.009	0.075
Education	0.053***	0.018	0.003	−0.002	0.021
Credit	0.544**	0.223	0.015	−0.025	0.212
FBO	1.088***	0.295	0.000	−0.050	0.425
Unemployed HH	0.097***	0.033	0.003	−0.004	0.038
Consumption expenditure	−0.0007	0.0013	0.597	0.00003	−0.00028
Non-farm income	0.0003***	0.0001	0.000	−0.00001	0.00012
Environmental warning	−0.652***	0.163	0.000	0.030	−0.255
Flood	−0.679	0.661	0.304	0.031	−0.265
Drought	−1.319*	0.699	0.059	0.061	−0.515
Water source	0.148	0.207	0.475	−0.007	0.058
Cooking energy	0.503	0.374	0.178	−0.023	0.196
Cut 1	−0.233	0.442			
Cut 2	0.516	0.442			

Source: field data, 2019.
NOTE: Vulnerability was defined as 0 = High/Very high, 1 = average 2 = low/very low; Chi square = 56.65***, Pseudo R^2 = 0.0978; ***, ** and * indicates significance at 10%, 5% and 1%, respectively.

the marginal effect was positive for education, leading to low or very low climate vulnerability, it was negative for average climate vulnerability. Ncube et al. [13] found that knowledge on climate change reduces the probability of becoming moderately or severely vulnerable to climate change and recommended for the provisioning of educational programs on climate change.

Expectedly, credit had its positive effect on climate vulnerability level. This implies that the probability of becoming less vulnerable to climate change increases with access to credit. This is because farmers who had access to credit could invest in their farms in order to increase their incomes and improve food availability. This justifies the need to deliberately challenge the existing bottlenecks in financial delivery to farmers and then improve the provision of credit facilities to farmers. Empirically, credit has been identified by Nazari et al. [12] as one of the main tools to improve the vulnerability of poor farm households. For Ncube et al. [13], external support such as remittances as well as participation in formal community credit schemes reduces the climate vulnerability of households.

The effect of FBO membership on climate vulnerability level was positive and statistically significant. This means that farmers who were members of a farmer association had a higher probability of becoming less vulnerable to climate change. This can be explained through the importance of social capital in societal development and the fight against the negative impacts of climate change. While the marginal effect of a farmer achieving low or very low vulnerability to climate change is 0.425, the marginal effect of a farmer becoming averagely vulnerable to climate change decreased by only 0.050. Antwi-Agyei et al. [5] explained that households could rely on informal networks when shocks occur, as a coping mechanism.

Non-farm income had a positive effect on households' climate vulnerability levels. Thus, the probability of becoming less vulnerable to climate change increases as non-farm income increases. This is consistent with the *a priori* expectation of the research based on two reasons. First, non-farm income is obtained from activities outside the farm and these activities are often less affected by changes in the climatic conditions. Secondly, farmers can invest income from non-farm activities in the procurement of farm inputs to boost their production. Nonetheless, the results show negligible marginal effects of non-farm income on climate vulnerability. Consistently, Adzawla & Baumüller [1] estimated that livelihood diversification into activities such as non-farm activities reduces climate vulnerability among farming households in Northern Ghana by 7%.

Drought had its expected negative effect on the climate vulnerability level of the farmers. The occurrence of drought decreases crop production [13], thereby, reducing the income of the farmers and further exposing them to the impacts of climate change. Nazari et al. [12] explained that drought is a creeping natural hazard that leads to social, economic and environmental losses. Contrary to the *a priori* expectation of the research, the number of unemployed household members and receiving environmental warning decreases the probability of becoming less vulnerable to climate change.

Households' climate resilience

Fig. 4 shows the levels of climate resilience as revealed by the farmers. The climate resilience of farmers was high since over 80% of the farmers indicated an average to very high resilience. While the majority (50.7%) of the respondents in Zabzugu district indicated high or very high resilience to climate change, the majority (48.7%) of farmers in South Tongu district indicated an average resilience to climate resilience. Contrary to this study, Tesso et al. [20] found that over 50% of their respondents were less resilient to climate change since they recovered from shocks after 2 years. The determinants of the revealed resilience levels of the farmers is provided in Table 4.

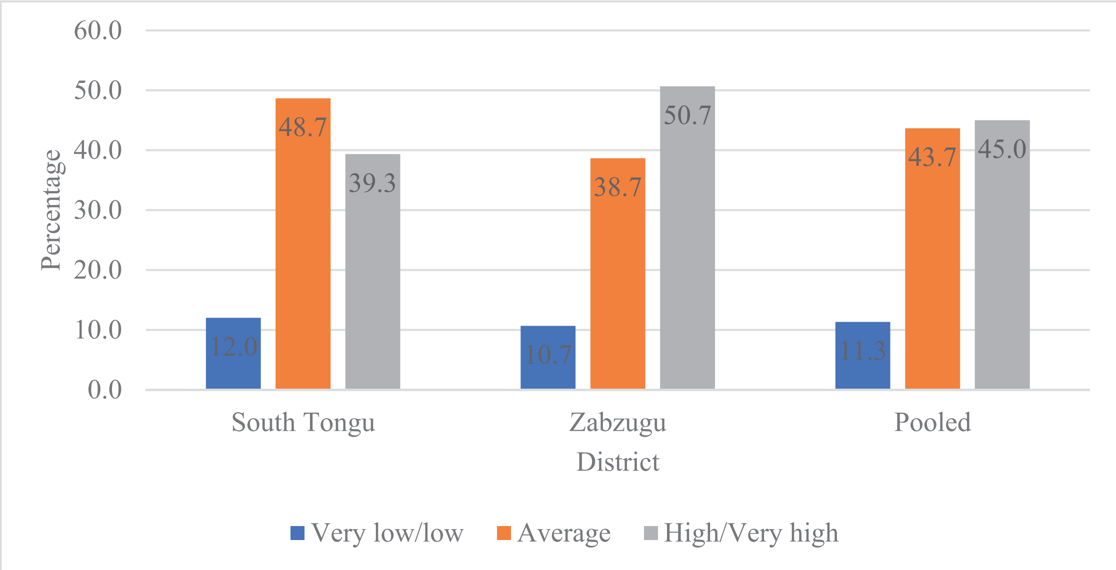

Fig. 4. Climate resilience levels of farmers
Source: Source: field data, 2019.

Table 4
Factors influencing farmers' resilience to climate change.

Variables	Coef.	Std. Err.	$P > z$	Marginal effects Average	High/Very high
District	−1.020***	0.250	0.000	0.242	−0.402
Age	0.008	0.006	0.200	−0.002	0.003
Sex	−0.032	0.149	0.832	0.008	−0.012
Education	0.008	0.017	0.662	−0.002	0.003
Credit	−0.392*	0.219	0.074	0.093	−0.154
FBO	−0.570**	0.271	0.036	0.135	−0.225
Unemployed HH	0.001	0.001	0.372	0.000	0.000
Consumption expenditure	−0.101***	0.032	0.002	0.024	−0.040
Non-farm income	−0.00002	0.00005	0.74700	0.000004	−0.00001
Environmental warning	−0.245	0.158	0.119	0.058	−0.097
Flood	−0.236	0.669	0.725	0.056	−0.093
Drought	−2.097***	0.719	0.004	0.497	−0.827
Water source	0.659***	0.210	0.002	−0.156	0.260
Cooking energy	−0.496	0.342	0.148	0.118	−0.196
Cut 1	−2.487	0.438			
Cut 2	−0.970	0.424			

Source: field data, 2019.
Note: Resilience is defined as 0 = low/very low, 1 = average 2 = high/very high; Chi square = 56.65***, Pseudo R = 0.0978; ***, ** and * indicates significance at 10%, 5% and 1%, respectively.

Determinants of households' resilience to climate change

From Table 4, the factors that significantly influenced the revealed resilience of farmers to climate change include the location, credit access, FBO membership, consumption expenditure, drought and source of water. The estimated model is justified by the significance of the Chi-square value. The effect of location (district) is negative, suggesting that farmers who are located in South Tongu district had lesser probabilities of being resilient to climate change than those located in the Zabzugu district of Ghana. Although this is contrary the expectations, it can be attributed to the fact that the harsh climatic condition of the Zabzugu district can compel farmers in the district to develop high resilience strategies to climate change. The implication is that areas with favourable climatic conditions would become less resilient to shocks from climate change.

Overall, credit, FBO membership and consumption expenditure had a negative effect on resilience of the farmers, and these are contrary to the a priori expectations of the study. These results suggest that farmers who received credit, farmers belonging to a farmer group and farmers with high consumption expenditure are less resilient to climate change. Tesso et al. [20] explained that access to financial services is crucial to recover from natural hazards and that cash constraints limit the use of improved seed varieties which is said to improve resilience. Asmamaw et al. [8] estimated that membership and access to services provided by community-based organization increases the resilience of households.

Drought had a negative effect on resilience of the farmers. This implies that farmers who experienced more droughts are less resilient to climate change. This is because the occurrence of drought weakens the adaptive capacity of the farmers and makes them less resilient. Relatedly, Asmamaw et al. [8] estimated that having had advance knowledge in floods improves the resilience of households. Consistent with the research expectations, farmers who use pipe borne water for domestic activities other than boreholes, rain water or river water have high probabilities of becoming more resilient to climate change. This is because these farmers may notoverly rely on rainfall to provide water for domestic activities.

Conclusions and policy recommendations

The implications of climate change on the socioeconomic development of households and nations is becoming more intense in recent years. The changes in climatic conditions have varying implications based on several factors, including the economic activity of the people. This study analysed holistically the climatic condition of farm households in two districts (one from the south and the other from the north) of Ghana. Unlike previous studies, this study combined analysis on impacts, vulnerability and resilience of farmers to climate change, within a subjective approach.

The result established that the age, credit access, households without non-farm economic activity, household per capita consumption and number of times of flood experienced in recent years had statistically significant effects on the level of climate change impact on the farmers' livelihoods. The revealed climate vulnerability of the farmers was significantly influenced by education, credit, FBO membership, number of unemployed household members, nonfarm income, environmental warning and droughts. On the other hand, the resilience of the farmers was significantly influenced the location, credit access, FBO membership, consumption expenditure, drought and source of domestic water. This study is important as it provides clarity on how the effect of socioeconomic and other factors do alter the aspect of climate change been analysed. Such delineations allows for more specific climate actions. From the evidence provided by the results, the study concluded that some of the factors that significantly influence one aspect of climate change does not necessarily have significant influence on another aspect. Even if they do, the direction of effect may not be necessarily universal. For instance, although credit is important in reducing the vulnerability and climate impacts on households' livelihoods, it does not significantly enhance the climate resilience of the households. Therefore, a broader strategy is required to address climate change consequences other than relying on specific factors. Nonetheless, considering the overall role of credit on farming households, the provisioning of credit facilities to farmers remain key in responding to the quest to maintaining a decent livelihood amid climate change. Since water is a basic requirement for human survival and an important factor for improving the resilience of farmers (determined by drought in the models), there is the need to improve the provision of irrigation water to farming communities to move them away from over relying on rainfall for their domestic and farm water needs.

Declarations of Competing Interest

None

References

[1] W. Adzawla, H. Baumüller, Effects of livelihood diversification on gendered climate vulnerability in northern Ghana, Environ., Development and Sustainability (2020), doi:10.1007/s10668-020-00614-3.
[2] W. Adzawla, H. Baumüller, S.A. Donkoh, R. Serra, Effects of climate change and livelihood diversification on the gendered productivity gap in northern Ghana, Climate and Development (2019) 1–13, doi:10.1080/17565529.2019.1689093.
[3] W. Adzawla, A. Kane, Effects of climate shocks and climate adaptation through livelihood diversification on gendered welfare gaps in northern Ghana, Int. J. Environ. Climate Change 9 (2) (2019) 104–119, doi:10.9734/ijecc/2019/v9i230100.
[4] P. Aniah, M.K. Kaunza-nu-dem, J.A. Ayembilla, Smallholder farmers' livelihood adaptation to climate variability and ecological changes in the savanna agro ecological zone of Ghana, Heliyon 5 (2019) 10.1016/j.heliyon.2019.e01492 1-25.
[5] P. Antwi-Agyei, A.J. Dougill, E.D.G. Fraser, L.C. Stringer, Characterising the nature of household vulnerability to climate variability: empirical evidence from two regions of Ghana, Environ., Development and Sustainability 15 (2013) 903–926, doi:10.1007/s10668-012-9418-9.
[6] P. Antwi-Agyei, H.C. Quinn, G.S.K. Adiku, N.S.A. Codjoe, J.A. Dougill, R. Lamboll, B.D.K. Dovie, Perceived stressors of climate vulnerability across scales in the Savannah zone of Ghana: a participatory approach, Reg. Environ. Change (2016), doi:10.1007/s10113-016-0993-4.
[7] C. Arndt, F. Asante, J. Thurlow, Implications of climate change for Ghana's economy, Sustainability 7 (2015) 7214–7231, doi:10.3390/su7067214.
[8] M. Asmamaw, S.T. Mereta, A. Ambelu, Exploring households' resilience to climate change-induced shocks using climate resilience index in Dinki watershed, central highlands of Ethiopia, PLoS ONE 14 (7) (2019) 1–21, doi:10.1371/journal.pone.0219393.
[9] W.K. Dumenu, E.A. Obeng, Environmental science & policy climate change and rural communities in Ghana : social vulnerability, impacts, adaptations and policy implications, Environ. Sci. Policy 55 (2016) 208–217, doi:10.1016/j.envsci.2015.10.010.
[10] G. Fernandino, C.I. Elliff, I.R. Silva, Ecosystem-based management of coastal zones in face of climate change impacts: challenges and inequalities, J. Environ. Manage. 215 (2018) 32–39, doi:10.1016/j.jenvman.2018.03.034.
[11] L. Jones, T. Tanner, " subjective resilience ": using perceptions to quantify household resilience to climate extremes and disasters, Reg. Environ. Change (2016), doi:10.1007/s10113-016-0995-2.
[12] S. Nazari, G. Pezeshki, H. Sedighi, H. Azadi, Vulnerability of wheat farmers : toward a conceptual framework, Ecol. Indic. 52 (2015) 517–532, doi:10.1016/j.ecolind.2015.01.006.
[13] M. Ncube, N. Madubula, H. Ngwenya, N. Zinyengere, L. Zhou, J. Francis, T. Madzivhandila, Climate change, household vulnerability and smart agriculture: the case of two south African provinces, Jamba: J. Disaster Risk Studies 8 (2) (2016) 6–8, doi:10.4102/jamba.v8i2.182.
[14] T.T.X. Nguyen, J. Bonetti, K. Rogers, C.D. Woodroffe, Indicator-based assessment of climate-change impacts on coasts : a review of concepts, methodological approaches and vulnerability indices, Ocean Coast. Manage. 123 (2016) 18–43, doi:10.1016/j.ocecoaman.2015.11.022.

[15] H. Nyantakyi-Frimpong, R. Bezner-Kerr, The relative importance of climate change in the context of multiple stressors in semi-arid Ghana, Global Environ. Change 32 (2015) 40–56, doi:10.1016/j.gloenvcha.2015.03.003.
[16] A. Ojha, A.K. Pattnaik, J. Rout, Climate change impacts on natural resources and communities: a geospatial approach for management, Lakes and Reservoirs: Res. Manage. 23 (1) (2018) 34–42, doi:10.1111/lre.12209.
[17] J. Panthi, S. Aryal, P. Dahal, P. Bhandari, N.Y. Krakauer, V.P. Pandey, Livelihood vulnerability approach to assessing climate change impacts on mixed agro-livestock smallholders around the Gandaki river basin in Nepal, Reg. Environ. Change (2015), doi:10.1007/s10113-015-0833-y.
[18] P. Smith, P.J. Gregory, Climate change and sustainable food production, Proc. Nutr. Soc. 72 (1) (2013) 21–28, doi:10.1017/S0029665112002832.
[19] T. Tanner, D. Lewis, D. Wrathall, R. Bronen, N. Cradock-Henry, S. Huq, F. Thomalla, Livelihood resilience in the face of climate change, Nat. Clim. Change 5 (1) (2015) 23–26, doi:10.1038/nclimate2431.
[20] G. Tesso, B. Emana, M. Ketema, Analysis of vulnerability and resilience to climate change induced shocks in north Shewa, Agric. Sci. 3 (6) (2012) 871–888 10.4236/as.2012.36106 Agricultural.
[21] P.K. Thornton, P.J. Ericksen, M. Herrero, A.J. Challinor, Climate variability and vulnerability to climate change: a review, Glob. Change Biol. 20 (11) (2014) 3313–3328, doi:10.1111/gcb.12581.
[22] A. Toreti, S. Bassu, A. Ceglar, M. Zampieri, Climate change and crop yields, In Encyclopedia of Food Security and Sustainability 1 (2019), doi:10.1016/b978-0-08-100596-5.22010-6.
[23] D.K. Twerefou, P. Chinowsky, K. Adjei-Mantey, N.L. Strzepek, The economic impact of climate change on road infrastructure in Ghana, Sustainability 7 (9) (2015) 11949–11966, doi:10.3390/su70911949.
[24] UNEP, Emissions gap report 2018 (2018) Retrieved from http://www.un.org/Depts/Cartographic/english/htmain.htm .
[25] T. Wheeler, J.von Braun, Climate change impacts on global food security, Science 341 (6145) (2013) 508–513.
[26] WMO, WMO statement on the State of the Global Climate in 2018 (2019), doi:10.1029/2018GL079362.
[27] T. Wossen, T. Berger, N. Swamikannu, T. Ramilan, Climate variability, consumption risk and poverty in semi-arid northern Ghana : adaptation options for poor farm households, Environ. Development 12 (2014) 2–15, doi:10.1016/j.envdev.2014.07.003.