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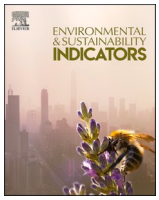

Influence of sustainable livelihood capital on climate variability adaptation strategies

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ABSTRACT

This article argues that access to informational, financial, and human capital influences specific climate variability adaptation strategies. Even though this argument is highly supported within the conventional wisdom circle, the extant literature remains sparing, particularly covering non-arid spaces in the global south. Relying on cross-sectional data covering 150 smallholder crop farmers from southern Ghana, augmented with focus group discussions, we answer the research question: What is the relationship between access to financial, informational, and human capital and climate variability adaptation strategies in a peri-urban geography? The results were estimated using multivariate probit regression. The findings showed that informational, financial, and human capital significantly influenced climate variability adaptation strategies. Specifically, informational capital significantly influenced organic manure application and irrigation. Financial capital through savings significantly influenced crop rotation. Formal and informal credit sources had no significant influence on climate variability adaptation strategies. Human capital - household labour significantly influenced mixed cropping, organic manure, and irrigation. Formal financial institutions are encouraged to adapt tailor-made requirements that are sensitive to the high-level informalities pertaining to peasant farming. And consider reducing loan interest rates to foster financial inclusion. Governments in sub-Saharan Africa could target improving farmers access to informational, financial, and human capital to build resilient climate variability adaptations.

1. Introduction

This article articulates the specificities of how access to information, human, and financial capital influences climate variability strategies in a non-arid space in the global south. Climate change and variability continue to demand global attention, given the pronounced negative effects (climate-related hazards). While climate variability represents changes in weather patterns in a spatial location over a short period of time, climate change manifests as long-term changes in climatic conditions spanning several decades (Kolawole et al., 2016). Christensen et al. (2007) defined climate variability as the fluctuations in the average state of the climate covering temporal and spatial scales beyond individual weather events. Climate change, however, refers to statistical changes in climate over a prolonged period of time covering several years due to natural and anthropogenic activities (IPCC, 2014). This article bothers on how sustainable livelihood capitals (information, human, and financial) influence climate variability adaptation strategies.

The question of how climate information influences farmers adoption or adaptation decisions on climate variability strategies is not in doubt. For instance, Antwi-Agyei et al. (2013) underscored how access and availability to climate information influence adoption and adaptation strategies. Indeed, the literature on climate information and farmers decisions on adaptation measures appear well documented. For instance, Isaya (2015), argued that information sources influenced farmers' adaptation to climate variability. Varied climate information sources exist including radio, television, mobile phones, extension agents, peer farmers, farmer based organisations (FBOs), and family members (Ndamani and Watanabe, 2015). Information sources constitute important conduits that influence climate variability strategies; thus, the specificity of an information source matters. As a case in point, information emanating from agricultural extension and advisory services has proven to improve the resilience and capacity of vulnerable smallholder farmers adaptation to climate variability (Asare-Nuamah et al., 2019; Fuhrer and Gregory, 2014). Oluwatayo (2019) argued that access to information from FBOs influence climate variability adaptation strategies.

Other studies have examined factors that determine the use of climate information (Diouf et al., 2019; Muema et al., 2018; Partey et al.,

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2020). A strand of literature identifies farmers' demographic characteristics as critical factors that affect access to information and consequently the adaptation strategies to climate variability (Belay et al., 2017; Martey and Kuwornu, 2021). The related literature shows that age, education, and gender influence specific information sources and the adaptation measures thereof in adjusting to climate variability.

Specifically, the literature on factors that determine climate information uptake identifies age (Asante et al., 2021; Carr and Owusu-Daaku, 2016; Muema et al., 2018; Omerkhil et al., 2020; Partey et al., 2020). For instance, Muema et al. (2018) showed that in Kenya, older farmers had less affinity for climate information, given their competence and preference for indigenous knowledge. Literature establishes that age positively correlate with climate variability strategies, where older farmers appear more resilient to climate variability (Alemayehu and Bewket, 2017; Keshavarz and Moqadas, 2021). However age has been shown to be inversely correlated with climate variability adaptation strategies (Kgosikoma et al., 2018). The literature, therefore, appears inconclusive, with mixed results.

Educational attainment influences climate variability adaptation (Akponikpè et al., 2010; Asante et al., 2021; Ndamani and Watanabe, 2015). For instance, the literature (Getahun et al., 2021; Anang and Yeboah, 2019) showed that the likelihood of a smallholder farmer adapting to climate variability increases when the individual attains a high level of education. Educational attainment has been established to have no significant relationship with climate variability adaptation strategy (Clay et al., 1998). The literature on how educational attainment influences climate variability adaptation appears mixed and inconclusive in different geographical spaces.

Gender influences access to climate information source and consequently, the climate variability strategies (Asrat and Simane, 2018; Carr and Owusu-Daaku, 2016; Diouf et al., 2019; Gumucio et al., 2020; Partey et al., 2020). In most rural areas, particularly in the global south, men tend to have unlimited and unrestricted access to productive resources such as land relative to women (Ankrah et al., 2020; Acemoglu and Autor, 2012). This hinders smallholder crop farmers' adaptation to climate variability. Some literature established no relationship between gender and climate variability adaptation (Partey et al., 2018).

Even though, information, human, and financial capital influences climate variability strategies. Generally, we find that most of the extant literature focuses on adaptation barriers and who experiences them (Carr and Onzere, 2018; Carr and Owusu-Daaku, 2016; Hansen et al., 2019; Vaughan et al., 2019). Attempts have been however made to examine the extent to which information, human, and financial resources influence climate variabilities strategies.

A strand of the literature shows that the lack of or access to financial capital influences climate variability adaptation strategies. For instance, the literature (Antwi-Agyei et al., 2013; Asante et al., 2021; Keshavarz and Moqadas, 2021) establishes that institutional barriers such as credit access influence climate variability adaptation. Farmers with higher financial capital and savings were more resilient to climate variability in northeast Iran (Keshavarz and Moqadas, 2021). Whereas women with limited access to financial capital have been found to be adversely affected in their adaptation to climate variabilities (Asrat and Simane, 2017). In northern Ghana, Asante et al. (2021) found that access to credit positively correlated with climate variability strategies. Other limited (Belay et al., 2017; Hassan and Nhemachena, 2008; Maddison, 2007) accounts in sub-Saharan Africa establishes a positive relationship between access to financial credit and smallholder farmers climate variability adaptation strategies. Abraham (2018) showed that smallholder farmers appeared more resilient in adapting to the effects of climate variability, given their access to financial capital. However, most farmers face certain constraints in accessing financial capital in Africa. Transactional costs related to credit offered by financial institutions have been explained as a major factor that prevents farmer's from getting access to credit (Ojo and Baiyegunhi, 2020). According to the authors, high interest rates on credit provided by financial institutions reduce the demand for credit by farmers because of their inability to pay back on time. The extant literature shows that financial capital indeed influences climate variability adaptation. However, the specificities of the adaptation strategies they influence remain scarce, particularly considering non-arid spaces in the global south. This article attempts to fill the void.

The availability and access to human capital remain important in smallholder climate variability strategies. The literature (Jacobs et al., 2015) refers to human resource as an individual's characteristics (skills, attributes, experiences) that helps increase productivity. In the context of this article, it includes farm labour. Studies (Asmare et al., 2019; Enimu and Onome, 2018; Gebru et al., 2020; Nonvide, 2017) have shown that access to human capital such as education, labour, and training has the potential to influence adaptation to climate variability. A school of thought (Lockwood et al., 2015; Zheng and Dallimer, 2016) argues that the availability of labour influences farmers adaptive climate variability strategies. Keshavarz and Moqadas (2021) showed that less climate resilient farm households worked as farm labourers in adapting to climate variability. Indeed, this finding is supported by Alam et al. (2018). Guodaar et al. (2021) showed that large household size provides an avenue for family labour but also has implications for household livelihoods and leads to the fragmentation of lands. Ifeanyi-Obi and Nnadi (2014), however, identified family labour as a useful climate variability adaptation strategy in southern Nigeria. In the case of Ghana, some literature (Antwi-Agyei et al., 2013; Ndamani and Watanabe, 2015) argued that inadequate labour constitutes a barrier that influences climate variability adaptation. Jha et al. (2017) showed that human capital influenced climate variability adaptations in India. Other studies (Aniah et al., 2019; Hermans-Neumann et al., 2017; Lawson et al., 2020; Mueller et al., 2020) show how labour out-migration proved to be a useful climate variability adaptation strategy. Most of the studies (Ehiakpor et al., 2016; Williams et al., 2017) establish a positive correlation between family labour and climate variability strategies. However, studies that link access to labour (family and hired labour) and labour availability and how it influences climate variability adaptation remain scarce within non-arid spaces. This article, therefore, contributes to empirical evidence that bridges the gap in knowledge.

Livelihood capital such as information (agricultural extension advisory services), social networks (membership of Farmer Based Organisations), financial (formal and informal credit, savings), and human capital (hired or family labour) enable farmers to effectively adapt to the climate variability crises. However, there is paucity of empirical evidence on how access to these three capital influences smallholder farmers' climate variability adaptation in peri-urban spaces in the global south, particularly from a bird's eye view in a single study. The extant literature appears fragmented and presents evidence considering silos of the resources (financial, information, and human resources). This article's overarching objective is to determine the extent to which access to financial, informational, and human capital influences climate variability adaptation strategies in a peri-urban geography. We hypothesize that access to informational, human, and financial capital positively influences climate variability adaptation strategies.

In explicit terms, this article contributes three ways to the climate variability adaptation literature. First, the article contributes to the scant literature (Owusu et al., 2021) on how access to climate information influences climate variability adaptation in a non-arid space within peri-urban geography in Ghana. This remains essential given the fact that most scholarships on climate variability in Ghana, tend to overly concentrate on northern Ghana. Even though this trend in scholarship is understandable to some extent due to the extremes of the weather conditions experienced in northern Ghana, it is equally important to bring into the conversation, the peri-urban space. Secondly, the article adds to the literature that establishes the nexus between access to or the lack of financial capital and climate variability adaptation in the global south. Finally, the article contributes evidence on how human resource, specifically hired labour, inversely influences climate variability

adaptation strategies, and we distil essential policy implications for adaptation strategies in the global south.

2. Conceptual and theoretical frameworks

The study is embedded in the sustainable livelihoods analysis (SLA). We attempt to explain the nexus between access to livelihood capital (information, human and financial) and smallholder farmers climate variability adaptation strategies. This is similar to other studies on climate variability adaptation strategies (Azad and Pritchard, 2022; Guo et al., 2022). Sen (1982) first introduced sustainable livelihoods in a seminal work on understanding poverty. This birthed terminologies such as sustainable livelihoods and sustainable livelihood analysis. The earlier definition of sustainable livelihoods includes a collection of income-earning activities, abilities, and assets acquired by individuals and households to earn a living and improve long-term welfare outcomes (Chambers and Conway, 1992).

The SLA serves as a useful framework for explaining adaptation, and vulnerability to climate variability. The SLA provides an understanding of how and why individuals make decisions related to livelihoods, and responses to changes in climate (Scoones, 1998). The Department for International Development (DFID) provides a popular normative framework for understanding livelihood analysis. This received support from most development partners (United Nations Development Programme, Food and Agriculture Organization, and Care International). In the DFID framework, decision making is underpinned and shaped by five forms of capital (financial capital, social capital, physical capital, human capital, and natural capital) (DFID, 2000). The DFID framework underscores building resilience and reducing vulnerability using sustainable livelihood capital to undertake activities targeted at improving livelihood outcomes (DFID, 2000). It captures five major variables, i.e. livelihood assets, vulnerability context, livelihood strategies, transforming processes and structures, and livelihood outcomes (DFID, 2000; Liu and Xu, 2016). The availability, access, scale, and effective combination of these capital resources direct farm household's livelihood vulnerabilities, trajectories, and adaptive capacities (Choden et al., 2021). Taking inspiration from this theoretical framework, we focus our study on three capital resources (information/social, human, and financial capital) to provide an understanding of how access to capital shapes the adoption of climate variability adaptation strategies. Physical and natural capitals were left out because our study did not set out to undertake a comprehensive poverty analysis. We however acknowledge this as a possible limitation of the study. The three capitals focussed on are, however critical in understanding climate variability adaptations.

Human capital, in this study, includes labour used in farming activities made up of hired labour and family labour. Human capital consists of all the knowledge, skills, experience, and labour that a farmer possesses that could enable an individual to respond to risks associated with changes and variations in climate (Zanmassou, 2017). Some studies have shown the importance of education and training in attaining skills and knowledge through the theory of human capital (Acemoglu and Autor, 2012)..

Informational capital is used interchangeably with social capital in our conceptualization of the SLA analysis. Social capital refers to the relationships and cooperation that a farmer has with other individuals, and the ability to network with other individuals (Egyir et al., 2015; Gharibvand et al., 2015). Smallholder farmers' ability to deal with the effects of climate variability depends on their access to climate information from various sources (Getahun et al., 2021; Williams et al., 2019)). However, according to Vaughan et al. (2019), the rate at which climate information is distributed through various sources such as the radio, television, mobile phones, FBOs, extension agents in many developing countries appears irregular, and access to this information is relatively low.

The literature establishes several indicators for measuring adaptive capacity and vulnerability predicated on the sustainable livelihood assessment framework inclusive of current adaptive capacity index (CACI), livelihood effect index, integrated agricultural livelihood vulnerability index (IALVI) and (CVI) climate vulnerability index (Das et al., 2023; Gallina et al., 2016; Kang et al., 2019; Leichenko & O'brien, 2002; Li et al., 2015; Mekonen and Berlie, 2021; Pandey and Jha, 2012; Pandey et al., 2017; Taubenböck et al., 2008; Urothody and Larsen, 2010). The assessment of vulnerability is based on three main dimensions of the IPCC framework (sensitivity, adaptive capacity, exposure). The dimension is based on social and environmental consideration specific to sites and varied livelihood sectors at the community level. This renders the framework useful for examining all the multidimensional aspects of adaptation and vulnerability (Leichenko & O'brien, 2002; Pandey et al., 2017). Other models for assessing livelihood vulnerability and risks include the exposure, sensitivity and adaptability framework (Chang et al., 2021; Sano et al., 2015), the pressure and response model (Kang et al., 2019) and the integrated assessment of multi-hazards method (Gallina et al., 2016).

Four indicators were initially used to measure smallholder crop farmers' human and social capital, which included participating in FBO activities, having access to public extension services, having access to private extension services and access to any form of service from Non-Government Organisations (NGOs). However, the last two indicators were not readily available to the farmers in the communities selected. Smallholder farmers' access to labour (household labour, hired labour or both) and training were used to represent their human capital. Access to each indicator by farmers was denoted by 1, and no access was denoted by 0. Access to public extension was used as the only indicator of social capital.

Bryan et al. (2015) characterized financial capital to include formal, informal credit, and savings. This study considers financial capital to include savings, regular profits (income earnings), and formal and informal credit, consistent with the SLA framework. Lax and Krug (2013) argued that financial capital facilitates the adaptation to varied livelihood strategies. Emanating from different perspectives to this debate, other studies (Hammill et al., 2008; Hoff et al., 2005) earlier resonated with this perspective using microfinance as an entry point, that enhances resilient adaptative capabilities. Our study dwells on savings, to illuminate how financial resource improves the adoption of climate variability strategies (See Fig. 1). Financial capital remains necessary for smallholder farmers to implement adaptation strategies to climate variability successfully, such as irrigation, purchasing of inputs such as fertilizers and pesticides. According to Ruiz Meza (2015),

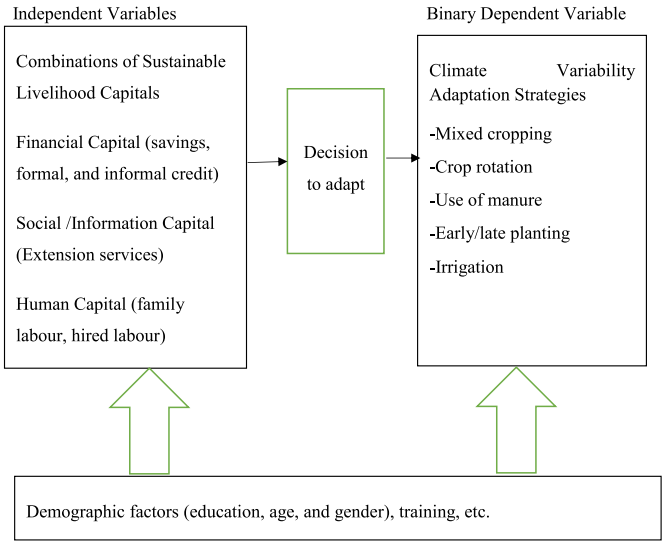

Fig. 1. Conceptual framework.
Source: Authors' conception, 2023

smallholder farmers need to have financial capital available to respond to and recover from the effects of climate variability. Given that it serves as a means of implementing climate adaptation strategies. A farmer's ability to save and obtain both formal and informal credit was used as indicators to measure a farmers' financial capital.

We note that the interactions between capital resources are very useful in adopting climate variability adaptation strategies (Kibria et al., 2018). Capital resource availability, as well as their accessibility, has been identified in the related literature (Chepkoech et al., 2020; Ndamani and Watanabe, 2015; Williams et al., 2019) as factors that influence smallholder crop farmers' adaptation to climate variability. Efforts to adapt to harsh constraints, continually involving modifications, management, and trade-offs among the different capital resources in the short term, can be considered livelihood strategies (Bebbington, 1999). Our study highlights how financial, human, and informational capital influences the adoption of climate variability adaptation strategies (Fig. 1). Jha et al. (2017) showed that financial capital through increased income improves adaptive capacity. The source of labour (family and hired) used on the farm affects specific climate variability adaptation strategies.

In particular, our analysis advances two propositions. First, we note that the access to and the combination of the capital (social, financial, and human) influences the decision to adapt to a specific or a combination of climate variability adaptation strategies. This is similar to insights from the literature (Frusher et al., 2016; Singh and Nair, 2014; Thulstrup, 2015) that establishes the argument that capital influences climate variability adaptation strategies. Finally, and most significant for our analysis, a household's possession of financial capital is a significant resource that shapes access to other capitals (informational/social and human) in influencing the adoption of climate variability adaptation strategies and adaptive capabilities. Thus, financial capital can be exchanged for human and informational capitals. Access to the three capitals, as well as specific climate variability adaptation strategies, are influenced by demographic factors (education, age, and gender), and training (See Fig. 1). Formal education increases an individual's chances of gaining knowledge to prepare for certain occurrences, such as extreme climatic conditions (Enimu and Onome, 2018; Gebru et al., 2020). According to the authors, the more farmers are educated, the more likely they are to adapt to weather risks among farmers. Nonvide (2017) found that the training of farmers significantly influenced their adaptation to climate variability. Training facilitates adaptation to climate variability by improving an individuals' adaptive capacity (Thinda et al., 2020).

2.1. Specification of the multivariate probit regression

We foreground our model specification based on our conceptual framework based on binary dependent variables, including mixed cropping, crop rotation, manure, and irrigation (See Fig. 1). The independent variables include the three main capital – extension and advisory services (information), financial capital (savings, formal, informal credit sources), and human capital (household labour/family labour, hired labour). We employed Multivariate Probit (MVP) regression model to estimate the capital resources influencing farmers' adaptation to climate variability. The multivariate probit model is a generalized probit model that jointly estimates several correlated binary outcomes (Greene, 2002). Since all our dependent variables are binary, we found the MVP regression more suitable to jointly predict the effect of farmers' access to capital (informational, financial, and human) on the adaptation strategies to climate variability. Alternative models that can potentially be used include either probit or logit model. However, using probit or logit model may result in biased estimates since they ignore the correlation or interrelationships among the binary regressands.

Belderbos et al. (2004) state that models such as probit, and logit are inappropriate, especially when adoption practices used as dependent variables are interrelated. This study presents four binary dependent variables (adaptation strategies) against six independent variables (capital resource factors). We state that a farmer's decision to adopt one adaptation strategy does not preclude other strategies, given available resources; hence neglecting the interrelationships among the binary dependent variables may yield a biased estimate.

Following Donkoh et al. (2019), Danso-Abbeam and Baiyegunhi (2017), MVP regression model with four sets of binary dependent variables are specified as equations (1) and (2).

$$Y_{ik}^{*} = \beta_0 + \beta_k X_{ik} + \alpha_k A_{ik} + \varepsilon_k \tag{1}$$

$$Y_{ik} = 1 \; if \; Y_{ik}^{*} > 0 \; and \; otherwise \tag{2}$$

Where K represents the adaptation strategies (mixed cropping, crop rotation, organic manure, and irrigation), Y_{ik}^{*} is a latent variable that captures the observed and unobserved choices associated with the K^{th} adaptation strategy to climate variability, Y_{ik} denotes the binary dependent variables and X_{ik} denotes the vector of the explanatory variables. A_{ik} accounts for unobserved heterogeneity by representing the unobserved climate factors, β_0 is the intercept. β_k and α_k represent parameters to be estimated. ε_k captures the multivariate normally distributed stochastic error term (See Table 1 for measurements of variables).

The multivariate probit model assumes that the error terms jointly follow a multivariate normal distribution with zero conditional mean. Denoting the individual adaptation strategies by alphabets (mixed cropping = C, crop rotation = R, manure = M and irrigation = I), the variance is normalised to unity where $(\mu_C, \mu_R, \mu_M, \mu_I) \approx MVN(0, \Omega)$ and the symmetric variance covariance matrix Ω is specified by equation (3):

$$\Omega = \begin{bmatrix} 1 & \rho CR & \rho CM & \rho CI \\ \rho RC & 1 & \rho RM & \rho RI \\ \rho MC & \rho MR & 1 & \rho MI \\ \rho IC & \rho IR & \rho IM & 1 \end{bmatrix} \tag{3}$$

Where ρ is the tetrachoric correlation coefficient of the error terms with respect to any two of the estimated adoption equations in the model. The variance-covariance matrix off-diagonal elements (e.g., ρCR, ρMC and ρIR) indicate the correlation between the stochastic components of the adaptation strategies employed (Danso-Abbeam and Baiyegunhi, 2017). The correlation is underpinned on the notion that the adoption of one climate variability adaptation strategy may be dependent on another (complementarity or positive correlation) or may be influenced by a set of accessible replacements (substitutability or negative correlation) (Khanna, 2001).

Table 1
Framework for measuring smallholder farmers' access to capital.

Indicators		Type	Dummy variable
Informational Capital	Access to Public Extension services	Dummy	No = 0; Yes = 1
Financial Capital	Ability to save	Dummy	No = 0; Yes = 1
	Ability to obtain formal credit	Dummy	No = 0; Yes = 1
	Ability to obtain informal credit	Dummy	No = 0; Yes = 1
Human Capital	Access to household labour	Dummy	No = 0; Yes = 1
	Access to hired labour	Dummy	No = 0; Yes = 1

Source: Authors' specification, 2023.

3. Materials and methods

3.1. Research design

The study is embedded in a mixed-method approach. The approach involves gathering quantitative and qualitative data, and combining these two forms of data, within the context of philosophical assumptions and theoretical frameworks to analyze the data (Creswell and Creswell, 2017). The combination of quantitative and qualitative data provides a nuanced understanding of a research problem. Additionally, combining quantitative and qualitative helps harness their strengths, compensate for their weaknesses, improves validity and reliability than using either method. Indeed, the literature (Guodaar et al., 2017; Ohene-Asante, 2015) establishes mixed-methods use in climate variability and change studies. Both quantitative and qualitative field data were collected from 10th February 2020 to 9th March 2020. Field data were collected by conducting in-person interviews, complemented by Focus Group Discussions (FGDs). This data collection method has the benefit of providing in-depth data that is both qualitative and quantitative.

3.2. Sampling method and sample size

The study district was purposively selected because of the substantial number of smallholder farmers engaged in food crop production. The Nsawam Adoagyiri Municipal Assembly lies between longitude 0.07°W and 0.27°W and latitude 5.45°N and 5.58°N. The study district spans a land area of about 175 square kilometres (Anum et al., 2022).

The weather conditions in the study site are generally cool given the wet semi-equatorial climate with a double maxima rainfall, recording an average annual rainfall of between 125 cm and 200 cm. The first typical rainy season starts from May to June, with the heaviest rainfall experienced in June and a second rainy season from September to October, accounting for the all-year-round farming practice of two farming seasons based on rain-fed agriculture (Ghanadistricts.com, 2023). The highest temperature averaging 30°C is recorded between March and April. With the lowest average temperature of 26°C recorded in August. The main agro-ecological zones are the coastal savanna grassland (10%) and semi-deciduous forest (90%). Only a limited forest cover is currently available in the municipal (Ghanadistricts.com, 2023).

We obtained from the Department of Agriculture (DoA), a sampling frame of farmers in the Nsawam Adoagyiri Municipal Assembly. This formed the basis upon which five communities (Akraman, Afumkrom, Asantekweku, Sakyikrom, and Bowkrom) were randomly selected (See Fig. 2). The agricultural extension agents (AEAs) indicated a total of 717 farmers present in the five communities. Based on Slovin's formula, used by Yamane (1967), the sample size was computed. Given financial, time constraints, non-availability, and non-responses, 150 smallholder crop farmers were used for this research (See Table 2). The sampling was however proportionate to the population in the selected communities. The sample size used made it easy to get the respondents for the study in time. The crop farmers were randomly selected from a sampling frame obtained from the AEA from the Municipal Assembly.

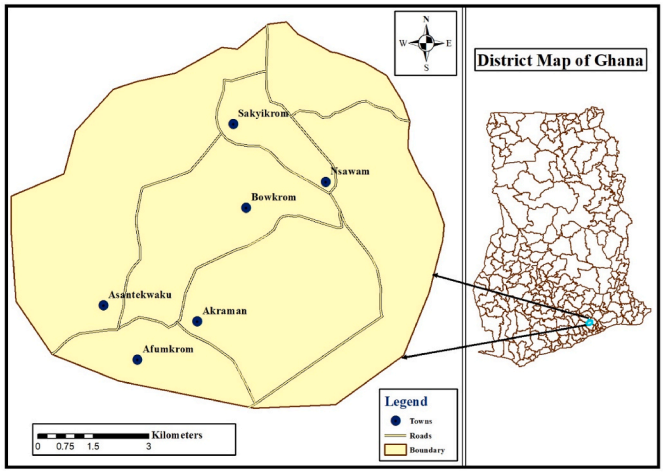

Fig. 2. Map of the study area.

3.3. Sources of data

This study focuses on climate variability, hence data on climate variability, adaptation strategies adopted, and institutional support to smallholder farmers in the Nsawam Adoagyiri Municipal were obtained from primary sources through a cross-sectional survey, semi-structured questionnaires, and focus group discussions. The questionnaire collected information on information sources available to farmers, financial resources, terms of credit, credit access, interest rates, labour sources – family labour hired labour, and how they affect specific adaptation to climate variability. The focus group discussion guides were developed to interrogate major capital resources available to farmers (informational, financial, and human resources) and how they play out on specific climate variability adaptation strategies, the reasons that embed specific adaptation(s) selected by farmers, and how these happen.

3.3.1. Focus group discussion

Focus Group Discussions (FGDs) were carried out to understand individual, and collective opinions regarding the influence that access to resources (informational, financial, and human) have on climate variability adaptation strategies. Participants of the FGDs were purposively selected from the survey respondents to provide relevant information on the trend of climate variability and issues regarding adaptation in the area with the help of an AEA. According to Korstjens and Moser (2018), key participants of FGDs were purposively selected because they held expert knowledge about the phenomenon studied. Two focus group discussions were conducted, and each FGD was made up of six participants consisting of three men and three women. The participants ages ranged from 35 to 62 years and cut across major ethnic groups and religions. The dominant ethnic group was the Akan ethnic group, with the Christian religion dominating, with only few Muslims. This small numbers permitted in-depth discussion among participants. This is supported by Stewart and Shamdasani (2014), who stated that the ideal size for a focus group discussion is usually between five and eight participants. Questions relating to smallholder farmers' ability to access information resource, financial and human resources, how access to the resources happen, who benefits most, what accounts for who benefits and who losses, how the three main resources (financial, informational, and human) influence farmers adaptation to climate variability.

3.4. Method for data analysis

Stata version 14.2 formed the statistical tool used to analyze the data obtained from the cross-sectional survey. Descriptive and inferential analyses were used in the analysis of the data gathered. Descriptive statistics were illustrated with proportions, and tables. Inferential statistics outputs were presented using multivariate probit regression. This

Table 2
Sample structure for selecting smallholder crop farmers.

Town/community	Sample size	Percentage (%)
Akraman	31	20.7
Asantekweku	18	12.0
Afumkrom	41	27.3
Sakyikrom	30	20.0
Bowkrom	30	20.0
Total	**150**	**100.0**

Source: Field data, 2020

estimation approach allows the examination of possible complementary or substitutionary relationships between any two strategies. The multivariate probit regression analysis was used to examine the relationship between access to capital resources and the various climate variability adaptation strategies put in place by the smallholder crop farmers and how certain capital resources influence smallholder farmers' decisions to practice certain adaptation strategies. Descriptive statistics were used to explain the results obtained from the multivariate probit regression analysis. Qualitative data obtained from the FGDs were transcribed, categorized into major and sub-themes that reflected the key research objectives, and questions as used by Ankrah et al. (2021). Analysis of the qualitative interviews was done using Nvivo. Direct quotes from the narratives from the FGDs were used to explain some of the results obtained.

4. Results and discussions

We state from the onset that the results and discussion is based on analysis of climate variability. Table 3 below shows an uneven distribution of men and women who engage in crop farming in the five communities that were sampled through the cross-sectional survey, with the majority (80.7%) being men. A probable explanation for this finding could be that more men are engaged in crop farming than women. This is in line with figures in a report by the Ghana Statistical Service (2020), which indicated that the proportion of males (70%) engaged in arable crop farming exceeds that of females (30%) in Ghana's rural spaces.

Most (74%) farmers had formal education at the primary, junior high school, senior high school, technical, and tertiary levels, while a small (26%) proportion had no formal education. The average year of farming experience was 19 years. This indicates that most of the farmers interviewed had considerable years of experience in farming.

About (32.7%) smallholder crop farmers indicated that they depended on only household labour as their source of labour. The majority (65.3%) of the farmers indicated that they depended on hired labour only, with only (2%) labourers permanently employed on the farm depended on family and hired labour for their crop production.

About (37.3%) smallholder crop farmers owned livestock. Poultry was the most popular livestock that was owned by smallholder crop farmers in the Nsawam Adoagyiri Municipal Assembly. Farmers who owned livestock had an additional source of income from animal products which made this an important strategy to increase income and diversify food sources. The application of poultry manure to farms was widespread in the area because it served as an alternative fertilizer source for crop production (See Table 3).

Table 3
Demographic characteristics of Smallholder farmers in the Nsawam Adoagyiri Municipal.

Demographic characteristics	Percentage (%)
Sex of respondents	
Male	80.7
Female	19.3
Age [Mode(41–50 years)]	34.7
Educational level	
No Formal Education	26.0
Primary Education	51.3
Secondary/Technical/Vocation	22.0
University/Polytechnic	0.7
Average farming experience (years)	18.91
Average Household Size (people)	5.36
Farm Labour	
Household labour only	2.0
Hired labour only	32.7
Both	65.3
Livestock activities	37.3
Farmers who rear animals	
FBO activity	37.3
Farmers who participate in FBO activities	17.3

Source: Field data, 2020.

Table 4 presents the result of the tetrachoric correlations between the binary dependent variables (adaptation strategies) and the model statistics from MVP estimation. The results reveal that the joint probability of adopting all the climate variability adaptation strategies is 1.9%, while the joint probability of using none of the adaptation strategies is 28.2%. The linear predictions show that the probabilities of adopting mixed cropping, crop rotation, manure and irrigation are −99.1%, −101.4%, 55.1% and −180.6%, respectively. Also, the likelihood ratio test for the overall correlation of the error terms is significantly different from zero, indicating that the error terms across the adaptation strategies are not correlated. All the adaptation strategies showed a positive correlation coefficient, indicating a complementarity among the climate variability adaptation strategies. The correlations between crop rotation versus mixed cropping, manure versus mixed cropping, and irrigation versus manure were significant at 1%, 5%, and 1% significance level, respectively. Also, the result showed a perfect complementary relationship between irrigation and manure. This result shows that adoptions of climate variability adaptation strategies among farmers in the study area are not independent. Farmers' adoption of one adaptation strategy may be influenced by the adoption of other strategies.

Table 5 presents the results of the Multivariate Probit Regression (MVP). The likelihood ratio value is statistically significant at the 1% significance level, explaining that at least one of the variable coefficients is statistically different from zero. In other words, the MVP model statistically predicts the interaction between farmers' access to resources and their adaptation strategies to climate variability.

4.1. Relationship between agricultural extension services (informational/social capital) and smallholder farmers' adaptation strategies to climate variability

The related literature suggests that relying on information alone does not solely promote climate adaptation behaviour, given that the channel of communication is important, as well as how information is utilized (Andersson and Keskitalo, 2018; Pandey et al., 2018). Information relating to climate variability is needed for smallholder farmers to plan and develop frameworks for adaptation. Accurate, reliable, and timely information on climate remains essential in adaptation strategies at the individual and community levels. Climate related information helps build resilience and improve livelihood outcomes under adverse climate regimes (Archie et al., 2012; Kumar et al., 2021).This is because reliable and timely information assists farmers in readily relying on information to mitigate the adverse effects of climate variability. For instance, if a farmer is certain of rains during a particular time of the day, it can assist the farmer in knowing when to plant or undertake certain agronomic activities on the farm.

Kumar et al. (2021) argued that climate information communicated through channels such as newspapers, mobile phones, community leaders, and television influences climate variability perception and adaptations differentially. Generally, climate information assists in planned adaptation. Information through agricultural extension officers is a major conduit for disseminating climate information, particularly in most developing countries.

Table 4
Tetrachoric correlations between the binary dependent variables and model statistics.

	Mixed cropping	Crop rotation	Manure	Irrigation
Mixed cropping	1			
Crop rotation	0.503 (0.125)[c]	1		
Manure	0.381 (0.135)[b]	0.179 (0.148)	1	
Irrigation	0.273 (0.167)	0.239 (0.173)	1.000[c]	1

Source: Authors' analysis, 2020. [b] Significant at 5% ($p < 0.05$), [c] Significant at 1% ($p < 0.01$). standard errors are in the parenthesis

Table 5
Multivariate Probit Regression estimates showing access to capital resources that influence smallholder farmers' adaptation to climate variability.

Variable	Mixed cropping		Crop rotation		Manure		Irrigation	
	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err
Extension service	0.093	0.320	0.281	0.358	−1.730[c]	0.422	−1.730[c]	0.389
Savings	−0.075	0.262	0.540[b]	0.253	0.410	0.265	0.447	0.397
Formal credit	4.000	0.682	3.762	0.691	0.931	0.525	−0.152	284.469
Informal credit	0.137	154.766	0.034	156.207	0.277	0.708	3.120	0.900
Household labour	1.003[c]	0.292	0.429	0.307	1.419[c]	0.498	1.485[c]	0.382
Hired labour	−0.076	368.941	−0.323	390.442	−4.299	0317.226	−2.793	896.312
Constant	−5.116	154.768	−5.125	156.209	0.189	0.868	−3.620	284.470

Source: Authors' analysis, 2020. [b] Significant at 5% ($p < 0.05$), [c] Significant at 1% ($p < 0.01$).

Our findings show that access to public extension services was significant but negatively influenced crop farmers' decision to adopt manure and irrigation as adaptation strategies to climate variability. This implies that crop farmers' access to public extension services will reduce their probability of adopting organic fertilizers such as manure to combat the effect of climate variability. We observe that most smallholder farmers in the study area are pineapple farmers who additionally produce other food crops such as maize and vegetables on a limited scale. Generally, private extension services dominate in the study area because of the presence of agribusinesses such as Blue Skies Limited, Bomarts Farms, and other pineapple agribusinesses (PEELCO Limited, Milani Limited, HPW Fresh and Dry Ghana Limited, Gold Coast Fruits, Bio Exotic Company Limited) who provide extension and advisory services for outgrower scheme members (Please see Ankrah (2022). Under, existing outgrower schemes, specific agribusinesses provide agri-inputs such as fertilizers to their outgrowers. Pineapple production is largely dependent on inorganic fertilizers, given that none of the agribusinesses in the study area support organic production of pineapples. This plausibly explains the inverse relationship between extension services and manure use.

We find a negative relationship between agricultural extension services and irrigation. Indeed, the farming system in the study area remains largely dependent on the natural rains. Therefore, the production is conditioned on the onset of the rains. This renders smallholder farmers vulnerable to the adverse effects of climate variability and change. Agricultural insurance could serve as an important risk mitigation strategy, but Ankrah et al. (2021) indicated in their study that agricultural insurance remains very low among smallholder farmers. These constitute plausible reasons why agriculture production is considered a high-risk investment. Investment in irrigation is good, given that beyond the benefits of agricultural production, Okyere et al. (2022) indicated that irrigation leads to improvements in wellbeing. The challenge, however, is that the financial capital required for investment in irrigation is high and way beyond what the average smallholder farmer can afford. This is contrary to the finding that farmers get access to agricultural extension and advisory services through extension agents, they are more likely to adapt to the adverse effects of climate variability, such as erratic rainfall patterns through irrigation. Specifically, Enimu and Onome (2018) and Gebru et al. (2020) support the finding that farmers' access to extension services positively influences their use of some adaptation strategies to climate variability. Jha et al. (2017) showed that access to irrigation constitutes a useful adaptation strategy that improved resilience to climate variability in India.

In a focus group discussion, farmers indicated that:

> "*We mostly benefit from the Agricultural Extension Agents (AEAs) who work for Blue Skies Company. They often come around to provide advisory services for our major crop – pineapple. We depend solely on rainfall as our source of irrigation. We are smallholder farmers, and we cannot afford irrigation technologies on our farms unless the company provides that for us. So far, even though periodically, the rains delay, there has not been any concern about having in place irrigation facilities. Therefore, any effort by extension to encourage us to invest in irrigation will be misdirected and will not yield the needed results" (Participants of FGD, March 9, 2020).*

The implication is that educational campaigns by Agricultural Extension Agents (AEAs) should not be directed towards investment in irrigation, given that this does not inure positive gains for irrigation. Rather, extensive education can be directed to other climate variability strategies that will potentially yield positive dividends.

4.2. Relationship between financial capital and smallholder farmers' adaptation strategies to climate variability

Taking inspiration from the conceptual and theoretical framework, we argue that financial capital influences human and informational resources, that shapes the adoption of climate variability adaptation strategies. The ability to save was the only financial resource that showed a significant positive relationship with crop rotation but had no significant relationship with the other climate variability adaptation strategies. The results imply that, as smallholder crop farmers' access to financial capital increases through savings, they are more likely to use crop rotation as a climate variability adaptation strategy, all other things being equal. Therefore, farmers are encouraged to improve their savings culture to effectively adapt to climate variability. Azad and Pritchard (2022) showed that financial capital enables households to enhance adaptive capacity. Specifically, the authors show how individuals with savings can better adapt to floods in northern Bangladesh. Panman et al. (2022), showed that savings help individuals to better adapt to shocks, including repeated flooding. The capital accumulated from savings can be ploughed into diversified income generating activities to minimize the negative effects of climate variabilities. Farmers can then conveniently purchase the needed agro inputs for farming, including improved seeds, fertilizers, and pesticides. During focus group discussions, farmers indicated that:

> "*Farming is a capital-intensive venture, but the returns are also very high. Thus, if one does not spend all the profit obtained from farming and saves, the individual can be better off in welfare outcomes and better adapt to the climate variability effects. Indeed, for the few farmers who save, we realized that they rotate crops grown on their farms" (Participants of FGD, March 15, 2020).*

In another focus group discussion, participants indicated that:

> *"In the past, some Non-Governmental Organizations encouraged us to save with formal financial institutions or even at our farmer group level. We realized that members who had savings could always purchase fertilizers even when the prices kept increasing, and typically, they have improved yields relative to farmers who do not save. Eventually, farmers who save can diversify their crop portfolios and practice crop rotation" (Participants of FGD, March 20, 2020).*

Indeed, it was widespread among participants engaged in the focus group discussions that savings encouraged investments in fertilizers, other agro inputs, and eventually enhanced the practice of crop rotation. Rotating crops on the same field enhances soil fertility and breaks

diseases and pest cycles. The pineapple crop takes over 15 months to reach maturity and harvest, rotating crops on the same land, therefore, allows diversification of crop farming and reduces the risk in monocropping.

Though farmers' access to formal and informal credit was not significant, they showed a positive relationship with adopting several climate variability adaptation strategies. Abraham and Fonta (2018) explained that farmers rely on both formal and informal credit to help them cope with the adverse effects of climate variability. Azad and Pritchard (2022) showed that microfinance from the Grameen Bank facilitates climate variability adaptation, through a better adjustment to floods, farm repairs, and relocation among others. However, informal sources of credit such as friends, family, and other relatives are the most preferred choices. This highlights the structural challenges related to formal sources of credit.

In focus group discussions, participants indicated that:

"We have always had difficulties accessing money from the formal financial institutions present in our communities. The requirements are too stringent and do not conform to the informalities that exist within the operation of our farming activities. Additionally, the interest rates are skyrocketing and do not permit sustainable production. Most of us, therefore, resort to credit from informal sources including friends, family members, and some welfare schemes within our Farmer Based Organizations" (Participants of FGD, March 20, 2020).

It became apparent from the focus group discussions that credit from informal sources remained a prominent source among most smallholder farmers. Most smallholder farmers expressed concern that the processes required for accessing credit appear bureaucratic and cumbersome, hence excluding most smallholder farmers from accessing formal credit. Even more striking is the high interest rates on credit from formal credit sources.

Also, in another focus group discussion, farmers indicated that:

"Accessing loans from formal credit sources is always tedious. They will tell you to bring this, bring that. The farming we practice is not done along formal lines, it is highly informal, with the absence of farm records on our purchases and sales. So, by default, the financial requirements for accessing loans exclude most farmers right from the onset. Even for the few farmers who access bank loans, the interest rates are so high that it prevents farmers from making profits. All the profit obtained is basically used to service debts" (Participants of FGD, March 15, 2020).

Indeed, Azad and Pritchard (2022) rightly conclude in their study that financial capital improves agricultural resilience and limits the vulnerability of households to future floods in the case of Bangladesh. The authors described financial capital to be catalytic to farmers adaptive behaviour.

4.3. Relationship between smallholder farmers' access to human capital and climate variability adaptation strategies

Access to household labour had a positive significant relationship with farmers' decision to adopt mixed cropping, manure application, and irrigation as adaptation strategies to climate variability. This could be explained by the respondents' preference for household or family labour. According to the farmers, they preferred household labour because it remained readily available. This finding was supported by participants in a focus group discussion:

"Most farmers use family labour on their farms because it is available all the time. Family farming is common among farm households. So, spouses assist each other on their farms. But for our pineapple farms, we tend to use hired labour since that is our main farming business" (Participants of FGD, March 9, 2020).

We observed an increased preference for family labour on food crop farms but an increased use of hired labour on pineapple farms. Hired labour is used on pineapple farms mostly for land preparation activities, planting, forcing, and harvesting. Hired labour is not typically used for mixed cropping, crop rotation, manure, and irrigation. Thus, inverse results were obtained in Table 5 for climate adaptation strategies. The implication is that it is not economically viable to hire labour to perform mixed cropping, crop rotation, manure, and irrigation on the farm. Given that they are likely to yield negative returns.

Manure is usually made by farmers in their backyard without employing the services of hired labour. The debris and compost gathered are used in the composition of manure. Given that the materials for making manure are gathered locally, farmers tasked family members to assist in collecting and making composts. We found that in the study area, compost is not commercially produced, but mainly produced by farm households.

In another FGD, participants indicated that:

"We tend to use hired labour on our pineapple farms most often. Blue Skies for instance, will not allow the use of children on farms because it is against the fair-trade practices. But for our food crops farms that we undertake to supplement our family consumption and income, we let family members assist us on the farms. This is a cultural heritage, and we do it to keep the tradition " (Participants of FGD, March 9, 2020).

The presence of Blue Skies Company Ltd and other agribusiness insists on compliance with the fairtrade and Global Good Agricultural Practices (Global GAP). It is therefore, not permitted for farmers to use minors on their farms. Additionally, NGOs present in the study area have adequately educated farmers on the need to avoid the use of school children on family farms, particularly for commercial farming. Our result contradicts the findings of Asmare et al. (2019), who showed that farmers' dependence on household labour when faced with the effects of climate variability reduced due to household members' involvement in other income-generating activities. Indeed, most related studies show that commercially oriented farmers rely more on hired labour on their farms. Jha et al. (2017) showed that reducing labour migration, improves resilience to climate variability. And effective human resource management remains central to building climate resilience.

5. Conclusion and policy recommendation

The article argues that smallholder farmers' access to informational, financial, and human capital significantly influences climate variability adaptation strategies in a peri-urban geography. Our results reveal that the decision to adopt climate variability adaptation strategies in southern Ghana, are jointly influenced by farmers' access to different capital specifically, informational, financial, and human capital. The results show that farmers' access to informational capital (public extension services) negatively influenced the adoption of climate variability adaptation strategies such as irrigation and manure application.

Human capital (household labour) had a significant positive influence on the adoption of climate variability strategies such as mixed cropping, manure application, and irrigation.

We find a positive influence between access to financial capital and climate variability adaptation. Specifically, we find a positive influence of savings on crop rotation as a climate variability adaptation strategy. Smallholder farmers are encouraged to improve their savings culture and harness the synergies in their informal savings to participate and broaden their livelihood portfolios, given the adverse effects of climate variabilities.

Given, the variabilities in climate and the unpredictable nature of the climate, we find our findings very useful for other peri-urban spaces within non-arid regions in Sub-Saharan Africa. Specifically, our findings have implications for governments in SSA investment in financial, informational, and human capital toward climate variability resilience. Agricultural extension and advisory services should target education and advocacy on low agricultural technologies and resource cost-effective adaptation strategies that enhance the resilience of

smallholder farmers to the adverse effects of climate variability.

We suggest that formal financial institutions be encouraged by the government to have tailored credit facilities that accommodate the informalities characteristic of peasant farming, by further reducing interest rates on agricultural credit to widen and sustain participation. Governments in sub-Saharan Africa, particularly through agricultural extension and advisory services, could target improving farmers access to informational, financial, and human capital to build resilient climate variability adaptations in the global south.

5.1. Limitations of study

The authors note that the study was limited to just one administrative region in Ghana. Even though communities with different characteristics were studied to improve reliability and validity of the study. It will be useful if more non-arid administrative regions in Ghana are included in future studies.

Our study did not consider all the five capitals under the sustainable livelihoods' framework. We however believe that the three capitals (social, human, and financial) considered are critical to understanding climate variability adaptation strategies.

Disclosure of interest

The authors have no potential conflict of interest.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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References

Abraham, T.W., 2018. Estimating the effects of financial access on poor farmers in rural northern Nigeria. Financial Innovation 4 (1), 1–20. https://doi.org/10.1186/s40854-018-0112-2.

Abraham, T.W., Fonta, W.M., 2018. Climate change and financing adaptation by farmers in northern Nigeria. Financial Innovation 4 (1), 1–17. https://doi.org/10.1186/s40854-018-0094-0.

Acemoglu, D., Autor, D., 2012. What does human capital do? A review of Goldin and Katz's The race between education and technology. J. Econ. Lit. 50 (2), 426–463. https://doi.org/10.1257/jel.50.2.426.

Akponikpè, P.I., Johnston, P., Agbossou, E.K., 2010. Farmers' perception of climate change and adaptation strategies in Sub-Saharan West-Africa. In: 2nd International Conference: Climate, Sustainability and Development in Semi-arid Regions August.

Alam, G.M., Alam, K., Mushtaq, S., Leal Filho, W., 2018. How do climate change and associated hazards impact on the resilience of riparian rural communities in Bangladesh? Policy implications for livelihood development. Environ. Sci. Pol. 84, 7–18. https://doi.org/10.1016/j.envsci.2018.02.012.

Alemayehu, A., Bewket, W., 2017. Determinants of smallholder farmers' choice of coping and adaptation strategies to climate change and variability in the central highlands of Ethiopia. Environmental Development 24, 77–85. https://doi.org/10.1016/j.envdev.2017.06.006.

Andersson, E., Keskitalo, E.C.H., 2018. Adaptation to climate change? Why business-as-usual remains the logical choice in Swedish forestry. Global Environ. Change 48, 76–85. https://doi.org/10.1016/j.gloenvcha.2017.11.004.

Anang, B. T., & Yeboah, R. W. (2019). Determinants of off-farm income among smallholder rice farmers in Northern Ghana: Application of a double-hurdle model. *Adv. Agric., 2019*. doi:10.1155/2019/7246176.

Aniah, P., Kaunza-Nu-Dem, M.K., Ayembilla, J.A., 2019. Smallholder farmers' livelihood adaptation to climate variability and ecological changes in the savanna agro ecological zone of Ghana. Heliyon 5 (4), e01492. https://doi.org/10.1016/j.heliyon.2019.e01492.

Ankrah, D.A., 2022. Ghana's pineapple innovation history: an account from stakeholders in Nsawam Adoagyiri Municipal Assembly. African Journal of Science, Technology, Innovation and Development 14 (7), 1–17. https://doi.org/10.1080/20421338.2021.1988414.

Ankrah, D.A., Agyei-Holmes, A., Boakye, A.A., 2021a. Ghana's rice value chain resilience in the context of COVID-19. Social Sciences & Humanities Open 4 (1), 100210. https://doi.org/10.1016/j.ssaho.2021.100210.

Ankrah, D.A., Freeman, C.Y., Afful, A., 2020. Gendered access to productive resources–evidence from small holder farmers in Awutu Senya West District of Ghana. Sci. Afr. 10, e00604 https://doi.org/10.1016/j.sciaf.2020.e00604.

Ankrah, D.A., Kwapong, N.A., Eghan, D., Adarkwah, F., Boateng-Gyambiby, D., 2021b. Agricultural insurance access and acceptability: examining the case of smallholder farmers in Ghana. Agric. Food Secur. 10 (1), 1–14. https://doi.org/10.1186/s40066-021-00292-y.

Antwi-Agyei, P., Dougill, A.J., Fraser, E.D., Stringer, L.C., 2013. Characterising the nature of household vulnerability to climate variability: empirical evidence from two regions of Ghana. Environ. Dev. Sustain. 15 (4), 903–926. https://doi.org/10.1007/s10668-012-9418-9.

Anum, R., Ankrah, D.A., Anaglo, J.N., 2022. Influence of demographic characteristics and social network on peri-urban smallholder farmers adaptation strategies-evidence from southern Ghana. Cogent Food & Agriculture 8 (1), 2130969. https://doi.org/10.1080/23311932.2022.2130969.

Archie, K.M., Dilling, L., Milford, J.B., Pampel, F.C., 2012. Climate change and western public lands: a survey of US federal land managers on the status of adaptation efforts. Ecol. Soc. 17 (4). https://www.jstor.org/stable/26269209.

Asante, F., Guodaar, L., Arimiyaw, S., 2021. Climate change and variability awareness and livelihood adaptive strategies among smallholder farmers in semi-arid northern Ghana. Environmental Development 39, 100629. https://doi.org/10.1016/j.envdev.2021.100629.

Asare-Nuamah, P., Botchway, E., Onumah, J.A., 2019. Helping the helpless: contribution of rural extension services to smallholder farmers' climate change adaptive capacity and adaptation in rural Ghana. Int. J. Rural Manag. 15 (2), 244–268. https://doi.org/10.1177/0973005219876211.

Asmare, F., Teklewold, H., Mekonnen, A., 2019. The effect of climate change adaptation strategy on farm households welfare in the Nile basin of Ethiopia: is there synergy or trade-offs?. In: International Journal of Climate Change Strategies and Management https://doi.org/10.1108/IJCCSM-10-2017-0192.

Asrat, P., Simane, B., 2017. Adaptation benefits of climate-smart agricultural practices in the Blue Nile Basin: empirical evidence from North-West Ethiopia. In: Climate Change Adaptation in Africa. Springer, pp. 45–59. https://doi.org/10.1007/978-3-319-49520-0_4.

Asrat, P., Simane, B., 2018. Farmers' perception of climate change and adaptation strategies in the Dabus watershed, North-West Ethiopia. Ecological processes 7 (1), 1–13. https://doi.org/10.1186/s13717-018-0118-8.

Azad, M.J., Pritchard, B., 2022. Financial capital as a shaper of households' adaptive capabilities to flood risk in northern Bangladesh. Ecol. Econ. 195, 107381 https://doi.org/10.1016/j.ecolecon.2022.107381.

Bebbington, A., 1999. Capitals and capabilities: a framework for analyzing peasant viability, rural livelihoods and poverty. World Dev. 27 (12), 2021–2044. https://doi.org/10.1016/S0305-750X(99)00104-7.

Belay, A., Recha, J.W., Woldeamanuel, T., Morton, J.F., 2017. Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia. Agric. Food Secur. 6 (1), 1–13. https://doi.org/10.1186/s40066-017-0100-1.

Belderbos, R., Carree, M., Diederen, B., Lokshin, B., Veugelers, R., 2004. Heterogeneity in R&D cooperation strategies. Int. J. Ind. Organ. 22 (8–9), 1237–1263.

Bryan, B.A., Huai, J., Connor, J., Gao, L., King, D., Kandulu, J., Zhao, G., 2015. What actually confers adaptive capacity? Insights from agro-climatic vulnerability of Australian wheat. PLoS One 10 (2), e0117600. https://doi.org/10.1371/journal.pone.0117600.

Carr, E., Onzere, S., 2018. Really effective (for 15% of the men): lessons in understanding and addressing user needs in climate services from Mali. Carr, ER, and SN Onzere 82–95. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3736463.

Carr, E., Owusu-Daaku, K., 2016. The shifting epistemologies of vulnerability in climate services for development: the case of M ali's agrometeorological advisory programme. Area 48 (1), 7–17. https://doi.org/10.1111/area.12179.

Chambers, R., Conway, G., 1992. Sustainable Rural Livelihoods: Practical Concepts for the 21st Century. Institute of Development, Studies (UK).

Chang, H., Pallathadka, A., Sauer, J., Grimm, N.B., Zimmerman, R., Cheng, C., Iwaniec, D.M., Kim, Y., Lloyd, R., McPhearson, T., 2021. Assessment of urban flood vulnerability using the social-ecological-technological systems framework in six US cities. Sustain. Cities Soc. 68, 102786.

Chepkoech, W., Mungai, N.W., Stöber, S., Lotze-Campen, H., 2020. Understanding adaptive capacity of smallholder African indigenous vegetable farmers to climate change in Kenya. Climate Risk Management 27, 100204. https://doi.org/10.1016/j.crm.2019.100204.

Choden, K., Nitschke, C.R., Stewart, S.B., Keenan, R.J., 2021. The potential impacts of climate change on the distribution of key tree species and Cordyceps in Bhutan: implications for ecological functions and rural livelihoods. Ecol. Model. 455, 109650 https://doi.org/10.1016/j.ecolmodel.2021.109650.

Christensen, J.H., Hewitson, B., Busuioc, A., Chen, A., Gao, X., Held, R., Jones, R., Kolli, R.K., Kwon, W., Laprise, R., 2007. *Regional Climate Projections: Climate Change: the Physical Science Basis. Contribution Of Working Group I to the* Fourth Assessment Report of the IPCC.

Clay, D., Reardon, T., Kangasniemi, J., 1998. Sustainable intensification in the highland tropics: Rwandan farmers' investments in land conservation and soil fertility. Econ. Dev. Cult. Change 46 (2), 351–377. https://www.journals.uchicago.edu/doi/abs/10.1086/452342?casa_token=0knXEzeWt5wAAAAA:z11YotHZJyZk-Hi7QXLy7ixJJxDRhk18rrPKT72sDaElDwr-bYEg8nMj6cGKQtXzIknOri5iBJbm.

Creswell, J.W., Creswell, J.D., 2017. Research Design: Qualitative, Quantitative, and Mixed Methods Approaches. Sage publications.

Danso-Abbeam, G., Baiyegunhi, L.J., 2017. Adoption of agrochemical management practices among smallholder cocoa farmers in Ghana. African Journal of Science, Technology, Innovation and Development 9 (6), 717–728.

Das, S., Majumder, S., Sharma, K.K., 2023. Assessing integrated agricultural livelihood vulnerability to climate change in the coastal region of West Bengal: implication for spatial adaptation planning. Regional Studies in Marine Science 57, 102748. https://doi.org/10.1016/j.rsma.2022.102748.

DFID, 2000. Sustainable Livelihoods Guidance Sheet. Department for International Development, London, United Kingdom.

Diouf, N.S., Ouedraogo, I., Zougmoré, R.B., Ouedraogo, M., Partey, S.T., Gumucio, T., 2019. Factors influencing gendered access to climate information services for farming in Senegal. Gend. Technol. Dev. 23 (2), 93–110. https://doi.org/10.1080/09718524.2019.1649790.

Donkoh, S.A., Azumah, S.B., Awuni, J.A., 2019. Adoption of improved agricultural technologies among rice farmers in Ghana: a multivariate probit approach. Ghana J. Dev. Stud. 16 (1), 46–67. https://doi.org/10.4314/gjds.v16i1.3.

Egyir, I.S., Ofori, K., Antwi, G., Ntiamoa-Baidu, Y., 2015. Adaptive capacity and coping strategies in the face of climate change: a comparative study of communities around two protected areas in the coastal savanna and transitional zones of Ghana. J. Sustain. Dev. 8(1), 1 - 158 https://doi.org/10.5539/jsd.v8n1p1.

Ehiakpor, D.S., Danso-Abbeam, G., Baah, J.E., 2016. Cocoa farmer's perception on climate variability and its effects on adaptation strategies in the Suaman district of western region, Ghana. Cogent Food & Agriculture 2 (1), 1210557.

Enimu, S., Onome, G., 2018. Determinants of climate change adaptation strategies among farm households in delta state, Nigeria. Curr Inves Agri Curr Res 5 (3). https://doi.org/10.32474/CIACR.2018.05.000213, 2018. CIACR. MS. ID. 000213 In (Vol. 8, pp. 61–68): UPINE PUBLISHERS Open Access L Current Investigations in Agriculture and.

Frusher, S., van Putten, I., Haward, M., Hobday, A.J., Holbrook, N.J., Jennings, S., Marshall, N., Metcalf, S., Pecl, G.T., Tull, M., 2016. From physics to fish to folk: supporting coastal regional communities to understand their vulnerability to climate change in Australia. Fish. Oceanogr. 25, 19–28.

Fuhrer, J., Gregory, P.J., 2014. Climate Change Impact and Adaptation in Agricultural Systems: Soil Ecosystem Management in Sustainable Agriculture, 5. CABI.

Gallina, V., Torresan, S., Critto, A., Sperotto, A., Glade, T., Marcomini, A., 2016. A review of multi-risk methodologies for natural hazards: consequences and challenges for a climate change impact assessment. J. Environ. Manag. 168, 123–132.

Gebru, G.W., Ichoku, H.E., Phil-Eze, P.O., 2020. Determinants of smallholder farmers' adoption of adaptation strategies to climate change in Eastern Tigray National Regional State of Ethiopia. Heliyon 6 (7), e04356. https://doi.org/10.1016/j.heliyon.2020.e04356.

Getahun, A.B., Ayal, D.Y., Ture, K., Zeleke, T.T., 2021. Determinants of climate variability adaptation strategies: A case of Itang Special District, Gambella Region, Ethiopia. Clim. Serv. 23, 100245. https://doi.org/10.1016/j.cliser.2021.100245.

Ghana Statistical Service, 2020. Ghana Census of Agriculture-National Report. G.S. Service.

Ghanadistricts.com, 2023. *Ghana districts*. Accra, Ghana: Ghana districts. Retrieved from. https://www.ghanadistricts.com/Home/LinkDataDistrict/6440.

Gharibvand, H.K., Azadi, H., Witlox, F., 2015. Exploring appropriate livelihood alternatives for sustainable rangeland management. Rangel. J. 37 (4), 345–356. https://doi.org/10.1071/RJ15027.

Greene, W.H., 2002. The Behavior of the Fixed Effects Estimator in Nonlinear Models. www.stern.nyu.edu/~wgreene.

Gumucio, T., Hansen, J., Huyer, S., Van Huysen, T., 2020. Gender-responsive rural climate services: a review of the literature. Clim. Dev. 12 (3), 241–254. https://doi.org/10.1080/17565529.2019.1613216.

Guo, A., Wei, Y., Zhong, F., Wang, P., 2022. How do climate change perception and value cognition affect farmers' sustainable livelihood capacity? An analysis based on an improved DFID sustainable livelihood framework. Sustain. Prod. Consum. 33, 636–650. https://doi.org/10.1016/j.spc.2022.08.002.

Guodaar, L., Beni, A., Benebere, P., 2017. Using a mixed-method approach to explore the spatiality of adaptation practices of tomato farmers to climate variability in the Offinso North District, Ghana. Cogent Social Sciences 3 (1), 1273747. https://doi.org/10.1080/23311886.2016.1273747.

Guodaar, L., Bardsley, D.K., Suh, J., 2021. Integrating local perceptions with scientific evidence to understand climate change variability in northern Ghana: a mixed-methods approach. Appl. Geogr. 130, 102440 https://doi.org/10.1016/j.apgeog.2021.102440.

Hammill, A., Matthew, R., McCarter, E., 2008. Microfinance and Climate Change Adaptation.

Hansen, J., Vaughan, C., Kagabo, D., Dinku, T., Carr, E., Körner, J., Zougmoré, R., 2019. Climate services can support african farmers' context-specific adaptation needs at scale. Front. Sustain. Food Syst. 3, 21. https://doi.org/10.3389/fsufs.2019.00021.

Hassan, R.M., Nhemachena, C., 2008. Determinants of African farmers' strategies for adapting to climate change: multinomial choice analysis. African Journal of Agricultural and Resource Economics 2 (311–2016-5521), 83–104. https://doi.org/10.22004/ag.econ.56969.

Hermans-Neumann, K., Priess, J., Herold, M., 2017. Human migration, climate variability, and land degradation: hotspots of socio-ecological pressure in Ethiopia. Reg. Environ. Change 17 (5), 1479–1492. https://doi.org/10.1007/s10113-017-1108-6.

Hoff, H., Warner, K., Bouwer, L.M., 2005. The role of financial services in climate adaption in developing countries. Vierteljahrshefte Wirtschaftsforsch. 74 (2), 196–207. https://doi.org/10.3790/vjh.74.2.196.

Ifeanyi-Obi, C., Nnadi, F., 2014. Climate change adaptation measures used by farmers in South-South Nigeria. J Environ Sci Toxicol Food Technol 8 (4), 1–6.

IPCC, 2014. In: Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E. S., Levy, A.N., MacCracken, S., Mastrandrea, P.R., White, L.L. (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). C. Cambridge University Press.

Isaya, E.L., 2015. Sources of Agricultural Information for Women Farmers in Hai and Kilosa Districts, Tanzania. Publication Number osu1420647091) The Ohio State University, Ohio, USA. http://rave.ohiolink.edu/etdc/view?acc_num=osu1420647091.

Jacobs, B., Nelson, R., Kuruppu, N., Leith, P., 2015. An Adaptive Capacity Guide Book: Assessing, Building and Evaluating the Capacity of Communities to Adapt in a Changing Climate. http://hdl.handle.net/10453/36221.

Jha, S.K., Mishra, S., Sinha, B., Alatalo, J.M., Pandey, R., 2017. Rural development program in tribal region: a protocol for adaptation and addressing climate change vulnerability. J. Rural Stud. 51, 151–157. https://doi.org/10.1016/j.jrurstud.2017.02.013.

Kang, P., Chen, W., Hou, Y., Li, Y., 2019. Spatial-temporal risk assessment of urbanization impacts on ecosystem services based on pressure-status-response framework. Sci. Rep. 9 (1), 1–11.

Keshavarz, M., Moqadas, R.S., 2021. Assessing rural households' resilience and adaptation strategies to climate variability and change. J. Arid Environ. 184, 104323 https://doi.org/10.1016/j.jaridenv.2020.104323.

Kgosikoma, K.R., Lekota, P.C., Kgosikoma, O.E., 2018. Agro-pastoralists' determinants of adaptation to climate change. International Journal of Climate Change Strategies and Management. https://doi.org/10.1108/IJCCSM-02-2017-0039.

Khanna, M., 2001. Sequential adoption of site-specific technologies and its implications for nitrogen productivity: a double selectivity model. Am. J. Agric. Econ. 83 (1), 35–51. https://doi.org/10.1111/0002-9092.00135.

Kibria, A.S., Costanza, R., Groves, C., Behie, A.M., 2018. The interactions between livelihood capitals and access of local communities to the forest provisioning services of the Sundarbans Mangrove Forest, Bangladesh. Ecosyst. Serv. 32, 41–49. https://doi.org/10.1016/j.ecoser.2018.05.003.

Kolawole, O.D., Motsholapheko, M.R., Ngwenya, B.N., Thakadu, O., Mmopelwa, G., Kgathi, D.L., 2016. Climate variability and rural livelihoods: how households perceive and adapt to climatic shocks in the Okavango Delta, Botswana. Weather, Climate, and Society 8 (2), 131–145. https://doi.org/10.1175/WCAS-D-15-0019.1.

Korstjens, I., Moser, A., 2018. Series: practical guidance to qualitative research. Part 4: trustworthiness and publishing. Eur. J. Gen. Pract. 24 (1), 120–124. https://doi.org/10.1080/13814788.2017.1375092.

Kumar, P., Pandey, R., Fürst, C., Joshi, P., 2021. The role of information infrastructure for climate change adaptation in the socio-ecological system of the Central Himalaya: availability, utility, and gaps. Socio-Ecological Practice Research 3 (4), 397–410.

Lawson, E.T., Alare, R.S., Salifu, A.R.Z., Thompson-Hall, M., 2020. Dealing with climate change in semi-arid Ghana: understanding intersectional perceptions and adaptation strategies of women farmers. Geojournal 85 (2), 439–452. https://doi.org/10.1007/s10708-019-09974-4.

Lax, J., Krug, J., 2013. Livelihood Assessment: A Participatory Tool for Natural Resource Dependent Communities. https://www.econstor.eu/handle/10419/87578.

Leichenko, R.M., O'brien, K.L., 2002. The dynamics of rural vulnerability to global change: the case of southern Africa. Mitig. Adapt. Strategies Glob. Change 7 (1), 1–18. https://doi.org/10.1023/A:1015860421954.

Li, Y., Xiong, W., Hu, W., Berry, P., Ju, H., Lin, E., Wang, W., Li, K., Pan, J., 2015. Integrated assessment of China's agricultural vulnerability to climate change: a multi-indicator approach. Climatic Change 128 (3), 355–366.

Liu, Y., Xu, Y., 2016. A geographic identification of multidimensional poverty in rural China under the framework of sustainable livelihoods analysis. Appl. Geogr. 73, 62–76. https://doi.org/10.1016/j.apgeog.2016.06.004.

Lockwood, M., Raymond, C.M., Oczkowski, E., Morrison, M., 2015. Measuring the dimensions of adaptive capacity: a psychometric approach. Ecol. Soc. 20 (1). https://www.jstor.org/stable/26269733.

Maddison, D., 2007. The Perception of and Adaptation to Climate Change in Africa, 4308. World Bank Publications.

Martey, E., Kuwornu, J.K., 2021. Perceptions of climate variability and soil fertility management choices among smallholder farmers in northern Ghana. Ecol. Econ. 180, 106870. https://doi.org/10.1016/j.ecolecon.2020.106870.

Mekonen, A.A., Berlie, A.B., 2021. Rural households' livelihood vulnerability to climate variability and extremes: a livelihood zone-based approach in the Northeastern Highlands of Ethiopia. Ecological processes 10 (1), 1–23. https://doi.org/10.1186/s13717-021-00313-5.

Mueller, V., Sheriff, G., Dou, X., Gray, C., 2020. Temporary migration and climate variation in eastern Africa. World Dev. 126, 104704 https://doi.org/10.1016/j.worlddev.2019.104704.

Muema, E., Mburu, J., Coulibaly, J., Mutune, J., 2018. Determinants of access and utilisation of seasonal climate information services among smallholder farmers in Makueni County, Kenya. Heliyon 4 (11), e00889. https://doi.org/10.1016/j.heliyon.2018.e00889.

Ndamani, F., Watanabe, T., 2015. Farmers' perceptions about adaptation practices to climate change and barriers to adaptation: a micro-level study in Ghana. Water 7 (9), 4593–4604. https://doi.org/10.3390/w7094593.

Nonvide, G.M.A., 2017. Effect of adoption of irrigation on rice yield in the municipality of Malanville, Benin. Afr. Dev. Rev. 29 (S2), 109–120. https://doi.org/10.1111/1467-8268.12266.

Ohene-Asante, S.N., 2015. *Climate Change Awareness and Risk Perception in Ghana: A Case Study of Communities Around the Muni-Pomadze Ramsar Site* University of Ghana].

Ojo, T., Baiyegunhi, L., 2020. Determinants of climate change adaptation strategies and its impact on the net farm income of rice farmers in south-west Nigeria. Land Use Pol. 95, 103946 https://doi.org/10.1016/j.landusepol.2019.04.007.

Okyere, C.Y., Ankrah, D.A., Ahene-Codjoe, A.A., 2022. Intra-household health effects of irrigation in Southern Ghana. Irrigat. Drain. 71 (1), 268–285. https://doi.org/10.1002/ird.2630.

Oluwatayo, I.B., 2019. Vulnerability and adaptive strategies of smallholder farmers to seasonal fluctuations in production and marketing in southwest Nigeria. Clim. Dev. 11 (8), 659–666. https://doi.org/10.1080/17565529.2018.1521328.

Omerkhil, N., Kumar, P., Mallick, M., Meru, L.B., Chand, T., Rawat, P., Pandey, R., 2020. Micro-level adaptation strategies by smallholders to adapt climate change in the least developed countries (LDCs): insights from Afghanistan. Ecol. Indicat. 118, 106781 https://doi.org/10.1016/j.ecolind.2020.106781.

Owusu, V., Ma, W., Renwick, A., Emuah, D., 2021. Does the use of climate information contribute to climate change adaptation? Evidence from Ghana. Clim. Dev. 13 (7), 616–629. https://doi.org/10.1080/17565529.2020.1844612.

Pandey, R., Jha, S., 2012. Climate vulnerability index-measure of climate change vulnerability to communities: a case of rural Lower Himalaya, India. Mitig. Adapt. Strategies Glob. Change 17 (5), 487–506. https://doi.org/10.1007/s11027-011-9338-2.

Pandey, R., Jha, S.K., Alatalo, J.M., Archie, K.M., Gupta, A.K., 2017. Sustainable livelihood framework-based indicators for assessing climate change vulnerability and adaptation for Himalayan communities. Ecol. Indicat. 79, 338–346. https://doi.org/10.1016/j.ecolind.2017.03.047.

Pandey, R., Kumar, P., Archie, K.M., Gupta, A.K., Joshi, P., Valente, D., Petrosillo, I., 2018. Climate change adaptation in the western-Himalayas: household level perspectives on impacts and barriers. Ecol. Indicat. 84, 27–37. https://doi.org/10.1016/j.ecolind.2017.08.021.

Panman, A., Madison, I., Kimacha, N.N., Falisse, J.-B., 2022. Saving up for a Rainy Day? Savings Groups and Resilience to Flooding in Dar Es Salaam, Tanzania.

Partey, S.T., Dakorah, A.D., Zougmoré, R.B., Ouédraogo, M., Nyasimi, M., Nikoi, G.K., Huyer, S., 2020. Gender and climate risk management: evidence of climate information use in Ghana. Clim. Change 158 (1), 61–75. https://doi.org/10.1007/s10584-018-2239-6.

Partey, S.T., Zougmoré, R.B., Ouédraogo, M., Campbell, B.M., 2018. Developing climate-smart agriculture to face climate variability in West Africa: challenges and lessons learnt. J. Clean. Prod. 187, 285–295. https://doi.org/10.1016/j.jclepro.2018.03.199.

Ruiz Meza, L.E., 2015. Adaptive capacity of small-scale coffee farmers to climate change impacts in the Soconusco region of Chiapas, Mexico. Clim. Dev. 7 (2), 100–109. https://doi.org/10.1080/17565529.2014.900472.

Sano, M., Gainza, J., Baum, S., Choy, D.L., Neumann, S., Tomlinson, R., 2015. Coastal vulnerability and progress in climate change adaptation: an Australian case study. Regional Studies in Marine Science 2, 113–123.

Scoones, I., 1998. Sustainable rural livelihoods: a framework for analysis, 72. https://opendocs.ids.ac.uk/opendocs/handle/20.500.12413/3390.

Sen, A., 1982. Famines and Poverty- an Essay on Entitlements and Deprivation. Oxford University Press.

Singh, P.K., Nair, A., 2014. Livelihood vulnerability assessment to climate variability and change using fuzzy cognitive mapping approach. Climatic Change 127 (3), 475–491. https://doi.org/10.1007/s10584-014-1275-0.

Stewart, D.W., Shamdasani, P.N., 2014. Focus Groups: Theory and Practice, 20. Sage publications.

Taubenböck, H., Post, J., Roth, A., Zosseder, K., Strunz, G., Dech, S., 2008. A conceptual vulnerability and risk framework as outline to identify capabilities of remote sensing. Nat. Hazards Earth Syst. Sci. 8 (3), 409–420. https://doi.org/10.5194/nhess-8-409-2008.

Thinda, K., Ogundeji, A., Belle, J., Ojo, T., 2020. Understanding the adoption of climate change adaptation strategies among smallholder farmers: evidence from land reform beneficiaries in South Africa. Land Use Pol. 99, 104858 https://doi.org/10.1016/j.landusepol.2020.104858.

Thulstrup, A.W., 2015. Livelihood resilience and adaptive capacity: tracing changes in household access to capital in Central Vietnam. World Dev. 74, 352–362. https://doi.org/10.1016/j.worlddev.2015.05.019.

Urothody, A., Larsen, H., 2010. Measuring climate change vulnerability: a comparison of two indexes. Banko Janakari 20 (1), 9–16.

Vaughan, C., Hansen, J., Roudier, P., Watkiss, P., Carr, E., 2019. Evaluating agricultural weather and climate services in Africa: evidence, methods, and a learning agenda. Wiley Interdisciplinary Reviews: Clim. Change 10 (4), e586. https://doi.org/10.1002/wcc.586.

Williams, P.A., Crespo, O., Essegbey, G.O., 2017. Economic Implications of a Changing Climate on Smallholder Pineapple Production in Ghana. http://hdl.handle.net/123456789/1070.

Williams, P.A., Crespo, O., Abu, M., 2019. Adapting to changing climate through improving adaptive capacity at the local level–The case of smallholder horticultural producers in Ghana. Climate Risk Management 23, 124–135. https://doi.org/10.1016/j.crm.2018.12.004.

Yamane, T., 1967. Elementary Sampling Theory, first ed. Prentice Hall Inc. *Englewoods Cliffs*, New Jersey, USA, p. 405.

Zanmassou, C., 2017. Smallholder Farmers' Adaptive Capacity and Choice of Adaptation Strategies against Weather Risks in Northern. *Benin* University of Ghana.

Zheng, Y., Dallimer, M., 2016. What motivates rural households to adapt to climate change? Clim. Dev. 8 (2), 110–121. https://doi.org/10.1080/17565529.2015.1005037.