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Constraints on Farmers' Adaptive Capacity to Climate Variability and Change

Abstract

This paper explores the constraints on adaptive capacity of crop farmers in two districts in different agroecological zones- Atwima Mponua (Semi-Deciduous Forest Zone) and Ejura-Sekyeredumase (Transition Zone) of the Ashanti Region of Ghana. A comparative-case mixed-methods research design was adopted using household survey questionnaires, focus group discussions (FGDs) and in-depth interviews with key informants. The study involved 150 farming households from each district. The study found that farmers' adaptive capacity to either plan or implement adaptive strategies have not always been successful due to lack of resources amongst other things. Constraints mentioned by farmers include lack of infrastructure, and secured land rights whilst the local institutions mentioned inadequate financial resources and poor technological capacity. Robust policy formulation and implementation aimed at equipping farmers with resources and strengthening institutional capacities is necessary to enhance the adaptive capacity of crop farmers to climate variability and change impacts.

Keywords: Climate variability and change, Adaptation, Adaptive capacity, Institutional support, Constraints.

1. Introduction

There is incontrovertible evidence to suggest that the global temperature has risen over the last century, which has resulted in unpredictable and unprecedented variations in the climate and its adverse impacts on human lives (IPCC (Intergovernmental Panel for Climate Change), 2018). There is evidence of an overall increase in the number of warm days and nights, and rise in sea levels globally (Field et al., 2015). Although positive impacts are expected in some cases (e.g. increases in crop yields such as cotton, sugar beets in higher latitudes) (Dunne et al., 2019), overall, it is projected that most climate change impacts are likely to be negative, including changes in precipitation patterns, higher occurrence of extreme weather events, and reduction in yields of most crops (Field et al., 2015).

In Africa, it has been observed that the yields of staple crops such as maize, wheat and sorghum have decreased (Ketiem et al. 2017). The vulnerability of the agricultural sector, particularly amongst poor farmers, is expected to increase (Boko et al., 2012; Dasgupta et al., 2014).

Allen et al. (2011) defines the concept of adaptation as the process of change to actual or expected climate and its effects, in order to manage harm or exploit valuable opportunities in human system. Porter et al. (2014) assert that effective crop adaptation can lead to increase in crop yield by 10% to 20% under persistently drier soil conditions. The United Nations Framework Convention on Climate Change (UNFCCC) (2021) categorize adaptation activities as local, district, regional, national and international. At these levels however, the adaptation strategies are collective and involve cross-scale interaction where the different levels of strategies converge (UNFCCC, 2021). Asrat and Simane (2018) suggest effective adaptation strategies that build farmers' capacity to adapt to climatic impacts should be flexible, well-coordinated across sectors and between agencies at the farm-level and utilize local knowledge.

Adaptive capacity is considered as resources including financial capital, physical capital, social capital, human capital and natural capital for mitigating climate change impacts (Abdul-Razak and Kruse, 2017). Abdul-Razak and Kruse (2017) assert that the capacity of farmers to adapt to climate change related risks is based on access to assets, and their capacity to respond to the risks is based on institutional support.

Morton (2017) notes that the role of local institutions includes supporting farmers to obtain information (including weather and climate), skills and technologies to improve their livelihoods. This means that collaborative efforts among the local institutions is crucial for enhancing adaptive capacity of farmers.

Constraints to adaptive capacity are factors that restrict actors to plan and implement adaptation measures or restrict the effectiveness of adaptation opportunities implemented already or for a natural system to change in ways that maintain productivity (Sallawu et al., 2020). Generally, adaptive capacity in sub-Saharan Africa is low due to wide spread of poverty, frequent natural disasters and organisational problems (Boko et al. 2012).

In Ghana, climate projections indicate rising temperature levels and rainfall variability (Codjoe and Owusu, 2011; Stanturf et al., 2011). It is highly likely that there will be a decrease in the yields of major crops if effective adaptation strategies are not implemented to tackle farmers' vulnerability (Stanturf et al., 2011; Limantol et al., 2016).

In Atwima Mponua District, the unsustainable farmland management practices and increased deforestation contribute to drought risks and high soil temperatures (Ghana Statistical Services (GSS), 2014). A study by Fosu-Mensah et al. (2012) in Ejura-Sekyeredumase District point to climate variability and change as a major contributing factor to food insecurity and poor livelihoods of farmers.

Some studies have been conducted to explore constraints on adaptive capacity (e.g. Yaro et al., 2015; Sallawu et al. 2020). However, these studies narrowly focused on the constraints singularly from either the farmers' or the local institutions' perspectives. This paper extends the findings of these studies by exploring the constraints on adaptive capacity both from the perspectives of farmers and the local institutions.

2. Theoretical Framework of Adaptive Capacity

Smallholder farmers are faced with multiple factors that affect their ability to adapt to climate variability and change impacts. Different approaches have been adopted in assessing the constraints of smallholder farmers' adaptive capacity. The Seemingly Unrelated Regression (SUR) model was adopted for the study because it has been adopted in other studies (e.g. Nilakantan et al. 2013; Ojo and Baiyegunhi, 2020) due to its simplicity. The model is used to determine predicted values of different adaptive capacity constraint categories. Farmers' socioeconomic characteristics affect their constraint status in adapting to climate variability and change impacts (Ojo and Baiyegunhi, 2020). The equations for farmers' adaptive capacity constraint factors are specified by Foltz (2004) as follows:

$y_i^* = X^*_i \beta i + \varepsilon_i$ $\quad i = 1 \ldots N$ Equation 1

where, y_i the observed variable = 1 if $y_* i > 0$, when a farmer is constrained by a factor, and 0 if $y_* i \leq 0$; X_i is a vector of covariates; βi, parameters to be estimated, while ε_i is the error term.

Farmers' adaptive capacity constraint factors (access to Land; climate information; credit; irrigation; adaptation strategies; inputs, storage facilities, market; and labour) are modelled in the analysis.

The equations for each adaptive capacity constraint is specified as follows:

$y_{1i} = \delta_i X_i + v_i$ Equation 2

where y_{1i} is a binary variable which takes a value of 1 for a factor constrained by farmer i and 0 if otherwise.

δi, is coefficient to be estimated; and v_i, is a random error terms.

The stacked model with respect to expression X, where ∑ represents the variance and covariance matrix in the model, for the ith observation, N x N the covariance matrix of the disturbance is calculated by:

$$\begin{matrix} y_1 \\ y_2 \\ y_n \end{matrix} == \begin{bmatrix} X_1 & 0 & 0 \\ 0 & X_2 & 0 \\ 0 & 0 & X_n \end{bmatrix} \begin{matrix} \beta_1 \\ \beta_2 \\ \beta_n \end{matrix} + \begin{matrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_n \end{matrix} = X\beta + \varepsilon \qquad \text{Equation 3}$$

A positive sign correlation coefficient implies the likelihood of farmers' adaptive capacity being constrained by a determinant factor. A negative coefficient implies the less likelihood of farmers' adaptive capacity being constrained by a factor.

3. Materials and methods

3.1 Study areas

The two case study areas are Atwima Mponua and Ejura-Sekyeredumase districts of Ashanti Region of Ghana. (Figure 1).

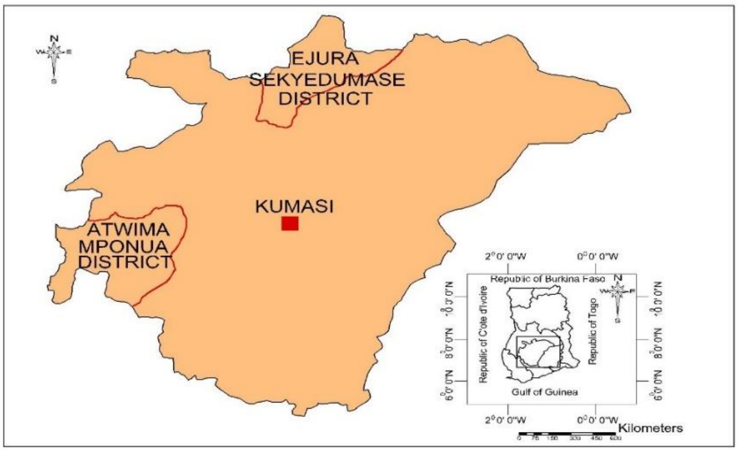

Figure 1. Case study districts in Ashanti Region of Ghana
Source: Author's construct

Atwima Mponua lies approximately 103 km west of Kumasi, the regional capital (Figure 2).

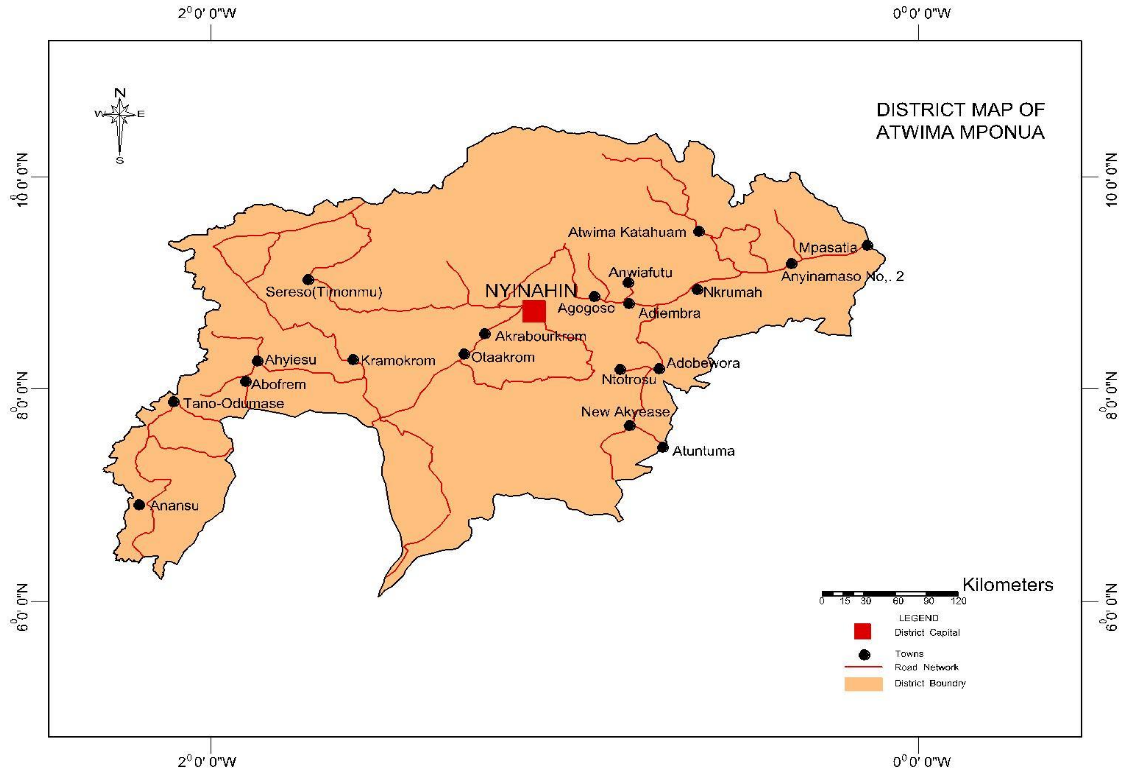

Figure. 2. Study communities in Atwima Mponua District in Ashanti Region of Ghana.
Source: Author's construct

Ejura-Sekyeredumase lies approximately 106 km north of Kumasi (Figure 3).

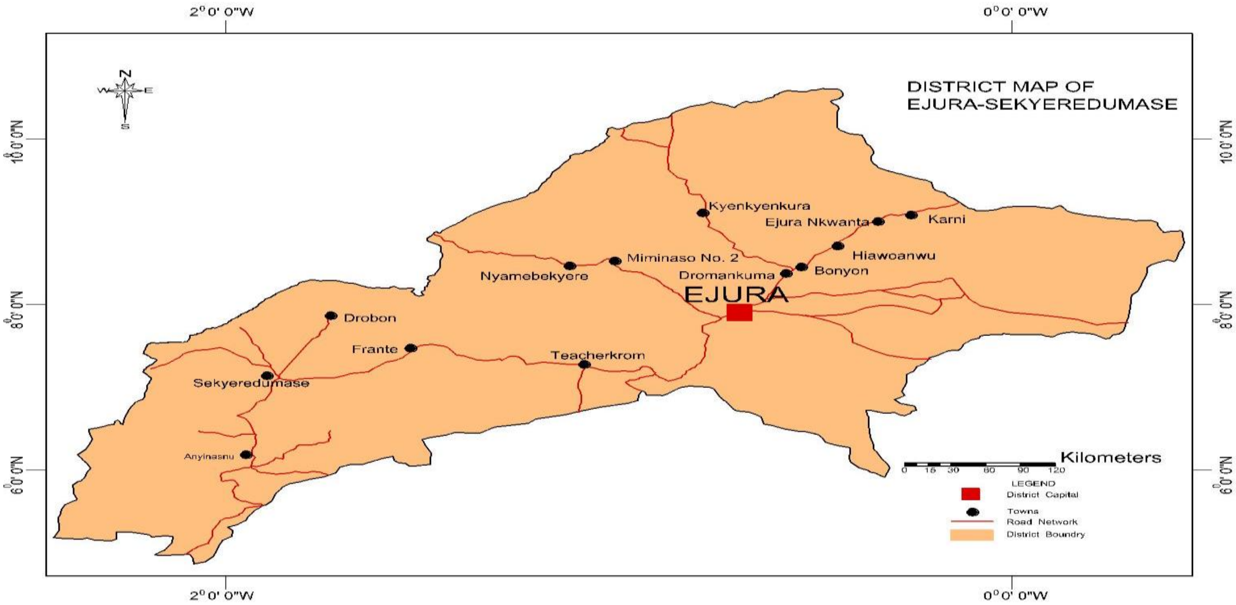

Figure. 3. Study communities in Ejura-Sekyeredumase District in Ashanti Region of Ghana.
Source: Author's construct

The main livelihood activity in both districts is crop farming, which is rainfed. The choice of the study areas is based on the findings of studies conducted across the agro-ecological zones in Ghana (Stunturf et al., 2011), which indicate that there is evidence of decline in precipitation and increasing temperature, rendering agriculture vulnerable. Table 1 provides a description of the study areas.

Table 1. Profile of the Study Areas

Feature	**Atwima Mponua District**	**Ejura-Sekyeredumase District**
Coverage Size	Approximately 894.15 km^2	Approximately 1,782 km^2
District Capital	Nyinahin	Ejura
Agroecological Zone	Deciduous Forest Climatic Zone	Transition of the Deciduous and Guinea Savannah Zones
Location	Latitude 60 32'N and 60 75'N Longitude 2000′W and 2032' W	Latitudes 7˚9’ N and 7˚36’N Longitudes 1˚5’W and 1˚39’ W
Rainfall	Bi-modal pattern March to July: 1700 – 1850 mm August to November: 1000 - 1250 mm per year	Bi-modal pattern, experienced in the south and a unimodal pattern in the north. Experiences 1200mm per year
Mean Annual Temperature Range	27 ^{0}C in August and 31 ^{0}C in March	21 ^{0}C in August and 35 ^{0}C in March.
Population size	Total population- 108,235 Males: 55,719 (51.5%) Females: 52,516 (48.5%)	Total population- 88,753 Males- 45,855 (51.7%) Females - 42,898 (48.3%)
Literacy level for Age 11^+	Literate- 70.6% Illiterate- 29.4%	Literate- 62.8%. Illiterate- 37.2%
Literacy in terms of Gender	Males-56.2% Females (43.8%)	Males- 66.5 % Females - 33.5%
Main Economic Activity	66% of the population engage in agriculture	60.2% of the population engage in agriculture
Farming Systems	Mono-cropping, mixed cropping and plantation cropping	Mono-cropping

Source: Ghana Statistical Service (2014)

3.2 Research Design

A comparative-case mixed-methods research design, involving qualitative and quantitative techniques were used to explore constraints on adaptive capacity of crop famers.

Sampling Participants

In Atwima Mponua District (referred to hereafter as the Forest Zone), the communities were: Nyinahin, Adiembra, Otaakroom, Anansu and Kramokrom. In Ejura-Sekyeredumase District (referred to hereafter as the Transition Zone), the communities were: Ejura, Sekyeredumase, Frante, Anyinasu and Drobon.

A list of participants –traditional leaders, crop farmers, and Agricultural Extension officers (AEOs) was obtained from the Extension Department of the Ministry of Food and Agriculture. Stratified random sampling was adopted to select farmers to make the sample representative in terms of age, gender and years of experience. A simple random sampling using a computer-generated random number table was applied to select 150 household heads from each district. Households are defined as ' a group of people who own the same productive resources, live together and feed from the same pot' (Aniah et al., 2019, p. 9).

Sample Size

The binomial sampling size calculator set at 8% confidence interval (http://www.surveysystem.com/sscalc.htm) was used to calculate the sample size in each district. $CI^1 = \sqrt{\frac{\hat{p} + z \times p\ (1 - p) \times (N - n')}{N-1}}$

Where:

CI^1 = sample size

z = z score

p̂ = the population proportion

n, n' = sample size

N = population size

The population size of Atwima Mponua District is 144,524; and the total population of the five settlements chosen is 18,281 (GSS, 2014).

The total population of Ejura-Sekyeredumase District is 104,584; and the total population of the five settlements chosen is 15,761 (GSS, 2014). Using the sample size calculator and setting the confidence level at 95%, the sample size needed for each district is 150.

Sampling of Key and Additional Informants

The key informants constituted traditional leaders, AEOs and District Meteorological staff. A snowballing method (a non-probability sampling technique where existing participants recruit future participants from among their acquaintances (Robert et al., 2010) was adopted to select the key informants.

3.3 Data Collection

Data collection started with reconnaissance visit to the study areas to identify prospective participants, see the topography and learn about the weather patterns and agricultural activities. Next, was a pilot study to test the research questionnaires with small groups of participants. Then, the main data collection, which involved quantitative and qualitative data.

Quantitative data was gathered through household survey using structured questionnaire Sequentially, qualitative data, involved one-to-one interviews and FGDs held with the key informants using semi-structured questions. The objective of the data collection was to explore farmers' livelihood assets and to allow them to share their experiences about the climate for the past 20-30 years; adaptation strategies adopted to minimise climate related risks; and the constraints they face in planning and implementing adaptation strategies. Four FGDs were held at each location. The size of focus groups ranged from 8 to 12 participants with gender differentiated.

3.4. Data Analysis

The Statistical Package for Social Sciences (version 18) software was used to analyse the field data. Quantitative data were analysed using descriptive statistics. Qualitative data from interviews and focus groups were first categorised into themes before being entered into the computer. The Fisher T- tests was used to compare data between farmers in the two study areas. Ordinary Least Square (OLS) analysis was used to assess the relationship between socio economic variables (representing the livelihood assets) and constraints farmers face. Key informant interviews and FGDs were used to triangulate any ambiguities observed in the data.

4.0 Results

The results of the data collection and the systematic literature review are presented in this section as follows: Farmers' access to livelihood assets (human, financial, physical, social and natural capitals); household heads' perceptions about changes in climate. On-farm adaptation strategies adopted by farmers; Constraints on adaptive capacity from farmers and institutional actors' perspectives; and the cross-scale interactions of the livelihood assets and constraints of household heads.

4.1 Farmers' Access to Livelihood Assets

Out of the 300 household heads, 86.3% were male and 13.7% were female. The breakdown for the individual Zones are: Forest Zone- 82.7% male, 17.3% female; Transition Zone- 78.6% male, 21.3% female.

The level of access to livelihood assets by households determines the extent of their adaptive capacity to minimise climate related risks. Farmers were asked to identify the livelihood assets they own and the support they receive (Table 2).

Table 2. Farmers' Access to Livelihood Assets

Livelihood Asset	Forest Zone N=150	Transition Zone N=150	Fisher T- Test P-Value
Human Capital			
Educational level of household head			$P<0.0001^{***}$
None	40(27.2%)	102(68.0%)	
Primary	95(63.0%)	48(32.0%)	
Secondary	10(6.8%	0	
Tertiary	5(3.0%)	0	
Extension Services / Support			
Access to Extension Support	72 (48.0%)	81 (54.0%)	NS
No access	78	69	
Diversification			
Engaging in off -farm livelihood diversification	91 (61%)	78 (52%)	NS
Farmers who do not engage in any off-farm diversification activities	59 (39.3%)	72 (48%)	
Labour Force			
Access to labour support	75 (50%)	78 (52%)	NS
No access to labour support	75 (50%)	72 (48%)	
Financial Capital			
Agriculture	112(74.7%)	115(76.9%)	NS
Non-agriculture	30(20.0%)	30(20.0%)	
Remittances	8(5.30%)	5(3.1%)	
Main sources of non-agricultural income			
Wage labour	50(33.3%)	35(23.3%)	
Petty trading	58(38.7%)	29(19.3%)	

Running shop	15(10.0%)	17(11.3%)	
Others	27(18.0%)	69(46.0%)	
Yearly income			
Less than GH¢500	61(40.7%)	65(43.3%)	
GH¢500- GH¢1000	80(53.3%)	78(52.0%)	
GH¢1000- GH¢2000	6(4.0%)	5(3.3%)	
More than GH¢2000	3(2.0%)	2(1.3%)	
Financial Support			NS
Loan acquired	72(48.0%)	87(58.0%)	
No acquisition of loan	78(52.0%)	63(42.0%)	
Assistance from Government/NGO(non-governmental organisation)			$P<0.00027^{***}$
Access to credit facility	23(15.3%)	51(34.0%)	
Lack of access to credit facility	127(84.6%)	99(66.0%)	
Expenditure			
Farm input e.g. fertilizers, farm equipment	20 (13.3%)	33 (22.0%)	$P<0.05^{*}$
Non-farm inputs expenditure (e.g. clothing, health)	130(86.7%)	117(78.0%)	
Physical Capital			
No valuable asset	16(36.0%)	22(14.7%)	NS
Valuable Asset (e.g. TV, radio, mobile phone)	134(89.3%)	128(85.3%)	
No valuable farm equipment	77(51.3%)	62(41.6%)	NS
Valuable Farm equipment (*Hiring of Tractor, barns)*	73(48.7%)	88(58.4%)	
Social Capital			
No association	90(60.0%)	82(54.7%)	NS
Any forms of association	60(40.0%)	68(45.0%)	
Church	*12(8.0%)*	*30(20.0%)*	
Farmers' Co-operative	*36(24.0%)*	*20(13.3)*	
Clubs	*12(8.0%)*	*18(12.0%)*	
Natural Capital			
Types of Farmland ownership			$P<0.0001^{***}$
Own land	56(37.3%)	20(13.3%)	
Other forms of land ownership	94(62.7%)	130(86.7%)	
Share-cropping	*56(37.3%)*	*65(43.3%)*	
Cash-renting	*28(18.7%)*	*50(33.3%)*	
Communal Land	*10(6.7%)*	*15(10.0%)*	
Other Natural Capital			

*Significant at 5%, ** significant at 1%, ***significant at 0.1% levels NS Not significant
Source: Field Data, 2021

Human Capital

The Forest Zone presents larger number of farmers with higher level of education (secondary= 6.8%; tertiary= 3.0%) than the Transition Zone. Chi-square value (χ^2 =29.52, p

= 5.54E-08) – (See Appendix 1) shows a strong association between educational level attained by household heads and access to information. Less household heads in the Forest Zone (48.0%) have access to extension services compared to 54.0% in the Transition Zone. More household heads in the Forest Zone (61.0%) engage in off-farm livelihood diversification than Transition Zone (52.0%).

Financial Capital

Sources of household income in the Forest and Transition Zones were: crop farming (74.7%; 76.9%), non-agriculture (20.0%; 20.0%) and remittances (5.3%; 3.1%).) respectively. On average 41% of farmers earn about GH¢500 ($113.63) annually in both Zones with more farmers from the Transition Zone. Large proportion of household heads (Forest Zone= 84.6%, Transition Zone= 66.0%) had not accessed credit facility from financial institutions within the past 12 months.

Physical Capital

Ownership of mobile phones is higher among farmers in the Forest Zone (10.0%) compared with those in the Transition Zone (3.3%). A substantial number of farmers in both Zones [Forest (63.0%) and Transition (52.0%)] have access to radio.

Social Capital

A considerable number of household heads in both Zones (Forest= 54.7%; Transition= 60.0%) have no social affiliations, with the number, slightly higher in the Transition Zone.

Natural Capital

Farmers in both Zones undergo different forms of land ownership: Own land (Forest = 37.3%; Transition=13.3%); share cropping (Forest=10.0%; Transition= 43.3%.); cash-renting (Forest=18.7%; Transition=33.3%).

The Fisher T- Test values indicate that human capital shows significance of association between the Zones in terms of educational level (P<0.0001), at 0.1%. Financial capital shows significance of association in terms of: access to credit facility (P<0.00027), expenditure on farm input (P<0.05) at 0.1% and 5% respectively. Natural capital shows significance of association in terms of ownership of land (P<0.0001) at 0.1%.

4.2 Farmers' Perceptions about Changes in Climate Pattern

Most household heads in both Zones (Forest= 68.7%; Transition= 81.7%) had observed changes in the weather pattern for the past 20-30 years (Table 3).

Table 3. Observed Changes in Climate Pattern

Observed Changes in Climate Pattern	**Respondents (%) Forest Zone**	**Respondents (%) Transition Zone**
High/extreme temperature	84.6	97.6
Increased severe hot days and nights	69.2	51.2
More frequent droughts and occasional floods	40.4	74.0
Erratic and reduced rainfall patterns	96.1	99.2
More frequent and stronger warmer wind flow patterns	51.9	72.4

Source: Field Data, 2021

The observed changes were more visible in temperature and rainfall pattern than the rest of the climate variables. In the Forest Zone, reduced and erratic rainfall and increased temperature are common occurrences whilst in the Transition Zone in addition to these changes, droughts and occasional floods are frequent.

4.3 On-Farm Adaptation Strategies Adopted by Farmers

Farmers had adopted on-farm adaptation strategies to manage the negative impacts of climate variability and change (Table 4).

Table 4. On-farm Adaptation Strategies adopted by Households

Adaptation Strategies	Forest Zone (%)	Transition Zone (%)
No adaptation strategy reported	44.0	32.0
Changing planting date	11.3	16.0
Crop diversification	8.7	3.3
Agro-forestry	3.3	0.0
Mulching	1.3	10.7
Zero tillage	4.0	6.7
High yielding crop cultivar	6.0	12.0
Cover crops	4.0	8.0
Chemical fertilizer	2.0	4.7
Hand irrigation	8.7	2.0
Increasing plot size	6.7	4.7
Total	**100**	**100**

Source: Field Data, 2021

During FGDs, it emerged that farmers have seen improved crop yields over the years through adopting changing planting date to coincide with the onset and cessation of rains. Planting different cultivars of cereal crops, typically maize, was mentioned as an emerging farm adaptive practice in both Zones (Forest= 6.0%; Transition= 12.0%). In the Transition Zone, 10.7% adopted mulching relative to 1.3% in the Forest Zone. However in the Forest Zone, crop diversification is widely adopted (8.7%) relative to the Transition Zone (3.3%).

Generally, the study recorded low percentage of responses by farmers with 44.0% and 32.0% in the Forest and Transition Zones respectively not undertaken any adaptation measures. This is mainly due to factors that restrict farmers' capacities to either plan or implement suitable adaptation strategies.

4.4 Constraints on Adaptive Capacity from Farmers' Perspective

It is important to stress that the constraints mentioned by farmers do not act in isolation, rather interact to impose negative impacts on the livelihoods of households. For instance, the lack of access to farmland prevents implementation of adaptation strategies such as agro-forestry. Figure 4 presents the various constraints farmers face.

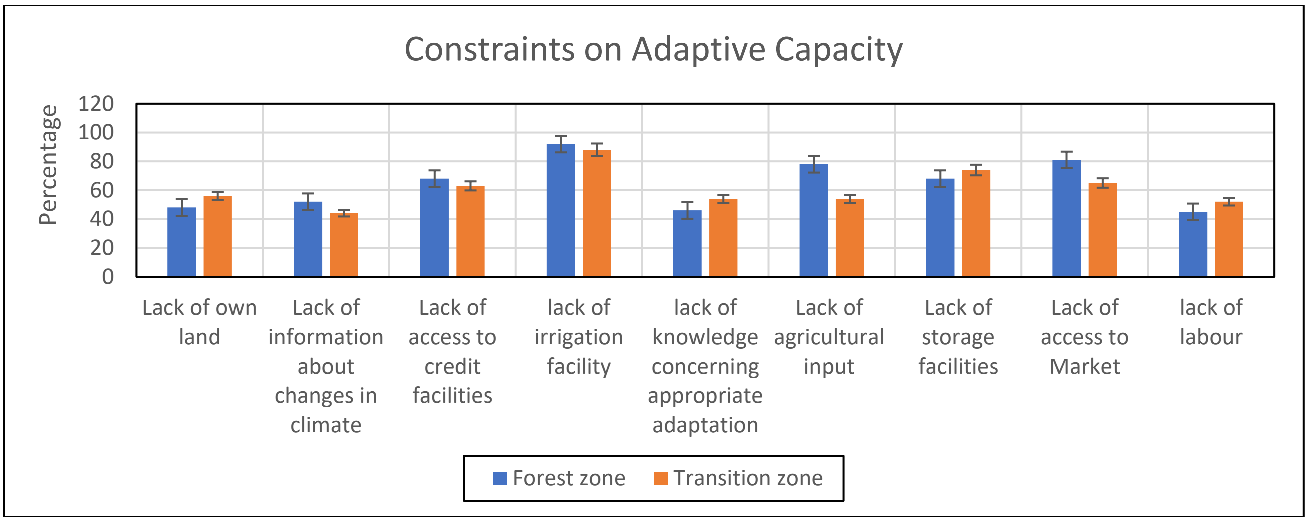

Figure 4. Households Heads' Constraints. Note: Error bars are at 95% confidence level.

Lack of infrastructure, Inputs and readily available Markets

In the Forest and Transition Zones, 92.0% and 88.0% of household heads, respectively, cited lack of irrigation as one of the main factors that has exacerbated their vulnerability to unfavourable rainfall trends. In the Forest Zone, a farmer noted that:

> *'Although we have streams, we rely on manual transportation to irrigate our farms, which is highly labour-intensive'.* [Farmer , FGD, Adiembra]

The concern was reiterated in the Transition Zone by another farmer that:

> *The boreholes are drying up and we can't have enough water to drink so we don't even think about how to water our crops.* [Farmer, FGD, Frante].

The statements show that the very livelihoods of farmers are endangered.

In the Forest and Transition Zones, 68.0% and 74.0% respectively mentioned lack of storage facilities as a constraint. The study found that farmers in both study locations use traditional granaries as storage facilities, which usually attract pests and allow grain to deteriorate. Feedback from FGDs in both Zones revealed that farmers are faced with poor market system and are therefore compelled to sell their produce at cheaper prices.

Farmers from both Zones [(Forest= 78.0%; Transition Zone= 54.0%) mentioned high cost of inputs such as hybrid seeds and fertilizer as a constraint.

Lack of Access to Secured Land Right

Lack of ownership of farmlands was cited by 48.0% and 54.0% of farmers in the Forest and Transition Zone respectively. Farmers acquired land under different forms of ownership-customary freehold (family land); Common law freehold (acquired by both strangers and members of the community); leasehold; and contractual arrangements e.g. share-cropping

(Ubink and Quan, 2007). Ubink and Quan (2007) note that under customary freehold, subjects of the stool (chieftainship) are not rationed in the amount of land they can occupy and farm except by their own capacity to farm. Our results, however, show that crop farmers' access to the usufruct was affected by several factors.

In the Forest Zone, where relatively higher number of farmers owned land, few farmers (3.3%) have adopted agro-forestry. Participants in FGDs in the Transition Zone expressed that lack of secured land rights serves as a setback to take initiatives to choose adaptation strategies such as agro-forestry. This was particularly, among women and migrant farmers.

Feedback from FGDs in both Zones indicates that some farmers were being allocated communal lands by community leaders, which are usually non-productive. Farmers who acquired land mainly through leasehold expressed their concern that the landlords usually apportion virgin lands to be used for a short period. The study revealed that in the case of the cash-renting system, an acre of land ranges from GH¢50.00 to GH¢100.00 per farming season. This was too expensive for the farmers.

4.5 Constraints on Adaptive Capacity from Institutional Actors' Perspective

Feedback from interviews with the staff of the Meteorological Services and the Agricultural Extension Services (AES) indicates that the expected benefits of their services to farmers have not been realized.

Constraints on Adaptive Capacity from Agricultural Extension Officers' Perspective

Inadequate Transport Facilities

The AEOs recognised poor transport facilities as a major constraint to offering extension services to farmers. In the Forest Zone, an AEO provided a typical response during a key informant interview:

> 'The transport arrangements to visit farming communities are not enough. We either walk or borrow a motorbike/bicycle when visiting farmers' [AEO, key informant interview, Kramokrom]

In the Transition Zone, an AEO revealed that:

> *'I have to walk 34km through paths that teem with snakes and other dangerous animals to visit the communities'* [AEO, key informant interview, Drobon]

The narrations imply most farmers are not likely to get the essential AES to enhance their adaptive capacity.

Lack of Extension Staff

Interviews with the AEOs revealed that the number of Extension Field staff is low. An AEO in the Forest Zone highlighted that:

> *'I have seen not less than a 100 AEOs come and go in the last 5 years due to poor incentives and motivation'.* [AEO, key informant interview, Otaakrom]

Another AEO in the Transition Zone stated that:

> *'Due to the government's inaction to promote AES, the ratio of frontline extension worker to farmers is about 1:1000 compared to the desired level of 1:400'* – [AEO, key informant interview, Ejura].

The low levels of staffing are attributed to lack of incentives which often leads to poor motivation.

Inadequate Financial Resources

The government funds are extremely meagre as noted by an AEO in the Forest Zone during key informant interview that:

> *'The funding provided to the Extension Department is very low to equip us provide meaningful services'.* [AEO, key informant interview, Otaakrom]

In the Transition Zone, an AEO reiterated that:

> *'In the past year, we received only GH¢22,150 ($5034.09, an increase of 5% over the previous year's funding allocation), which is too small to provide valuable support to all farmers'.* [AEO, key informant interview, Ejura]

The narrations imply that inadequate funding is likely to incapacitate AEOs in the delivery of services.

Unsustainable Agricultural Extension Services

The AEOs expressed their views that suggest that the current policies which expect services to be offered free of charge is not sustainable. An AEO in the Forest Zone highlighted that:

> *'We* mobilise farmers who want to pursue large scale commercial farming to receive paid extension services'. [AEO, key informant interview, Otaakrom]

In the Transition Zone, an AEO made a remark that:

'We agreed with farmers to pay towards our travel to their farmlands so we can provide extension services. These farmers have seen over 200% increase in crop productivity'. [AEO, key informant interview, Ejura]

Feedback from FGDs affirm that the paid extension delivery system has helped some farmers to increase yield by adopting adaptive strategies such as high yielding crop cultivars and zero tillage.

Constraints on Adaptive Capacity from the Perspective of Meteorological Staff

Poor Collaboration among the Local Institutions

The study found that there were satellite stations managed by NGOs with advanced equipment to understand the weather patterns. However, these stations work in isolation. The Meteorological Officer in the Forest Zone stated that:

> *'There is lack of partnership among the policy implementation organisations to share data and information needed for effective implementation of climate change policies'.* [Meteorological Officer, key informant interview, Nyinahin]

In the Transition Zone, Meteorological Officer revealed that:

> *'We rarely collaborate with other organisations involved in weather and the AEOs. We just broadcast the weather forecast'* [Meteorological Officer, key informant interview, Ejura].

Poor collaboration among organisations imply that farmers may be missing out key weather information needed to enhance their adaptive capacity.

Limited Technological Capability

The District Meteorological staff in the Forest Zone acknowledged the inaccuracies of weather forecasts as follows:

> *'We are not able to produce accurate weather forecast due to frequent power cuts'.* [Meteorological Officer, key informant interview, Nyinahin].

In the Transition Zone, the District Meteorological Officer noted that:

> *'Our stations are not fully equipped with advanced equipment. Besides, we are faced with frequent power cuts and so miss valuable information'.* [Meteorological Officer, key informant interview, Ejura].

Lack of advanced equipment and frequent power cuts imply that the meteorological team are unable to provide reliable information.

4.5 Testing the Explanatory Power of Capital Indicators and Constraints to Adaptive Capacity

We assessed the influence of the capital indicators as explanatory variables on the constraints on farmers' adaptive capacity using the SUR in STATA. First, we undertook a standard OLS regression. The relationship between a dependent variable Y and an explanatory variable X can be hypothesised as a linear model (Sarker and Gow, 2014):

$Y=\beta_0+\beta_1 X+\mu$, (1)

where β_0 and β_1 are regression coefficients, μ is an error term.

For each observation of a dataset, this equation is given as:

$y_i=\beta_0+\beta_1 x_i+\mu_i,\ i=1,2,\ldots\ldots\ldots,n$ (2)

where y_i is the ith value of the dependent variable Y, x_i is the ith value of the explanatory variable, X is a vector of all explanatory capital variables and u_i is the error in the approximation of y_i.

Analysis of the SUR model is categorised into farmers' household characteristics and institutional access.

Table 5. Definitions and Summary of Independent Variables used in the model

Explanatory Variables	Description of Variables	Value
Gender of household head	Gender of the household head	Female=0 Male=1
Age of household head	Age of the head of the household head	Years
Educational level of household head	Level of education attained by household head up to primary and above	Access=1 Otherwise=0
Household size	Number of family members of a Household	Number
Household farm income	Annual income level of household	Ghana cedis (GH¢)
Ownership of Physical asset	If household own a physical asset	1=Own, 0=Otherwise
Access to weather information	If household has access to weather information	0= No 1=Yes
Access to extension services	If household has access to extension services.	0= No 1=Yes

Table 6. Results of Seemingly Unrelated Regression for Constraints to Farmers' Adaptive Capacity

	Farmers' Adaptive Capacity Constraints								
	Model 1 Farmland	**Model 2 Climate Information**	**Model 3 Credit facility**	**Model 4 Irrigation facility**	**Model 5 Adaptation strategies**	**Model 6 Agricultural Input**	**Model 7 Storage facilities**	**Model 8 Market**	**Model 9 Labour**
Explanatory Variables	**Coefficient/ p-value**	**Coefficient/ p-value**	**Coefficient/ p-value**	**Coefficient/ p-value**	**Coefficient/ p-value**	**Coefficient/ p-value**	**Coefficient/ p-value**	**Coefficient/ p-value**	**Coefficient/ p-value**
Gender of household head									
Forest	1.217** (p=0.011)	0.173 (p=0.105)	0.117 (p=1.000)	0.126 (p=0.147)	0.493 (p=0.231)	-0.4310 (p=0.354)	-0.011 (p=0.102)	8.567 (p=0.238)	-0.321 (p=0.452)
Transition	1.427*** (p=0.000)	0.007 (p=0.421)	0.383** (p=0.025)	0.013 (p=0.209)	-0.447 (p=0.167)	0.273 (p=0.231)	0.026 (p=0.702)	1.451 (p=0.109)	0.026 (p=0.560)
Age									
Forest	0.851 (p=0.120)	0.021 (p=0.357)	-0.021 (p=0.801)	-0.141 (p=0.503)	0.178 (p=0.181)	0.055 (p=0.121)	-0.015 (p=0.116)	-0.016 (p=0.215)	0.201 (p=0.301)
Transition	0.012 (p=0.103)	-0.931 (p=0.531)	-0.147 (p=0.327)	0.1689 (p=0.128)	1.354 (p=0.164)	0.432 (p=0.327)	0.101 (p=0.512)	0.323 (p=0.153)	0.103 (p=0.677)
Educational level									
Forest	0.102 (p=0.303)	-0.017 (p=0.400)	1.341*** (p=0.003)	0.413 (p=0.132)	0.217** (p=0.012)	1.217 (p=0.031)	0.015 (p=0.671)	0.121 (p=0.351)	-0.033 (p=0.139)
Transition	0.005 (p=0.503)	-1.201 (p=0.452)	0.483*** (p=0.001)	-0.0013 (p=0.422)	0.447*** (p=0.001)	0.018 (p=0.400)	-0.215 (p=0.313)	0.415 (p=0.112)	0.142 (p=0.188)
Household size									
Forest	0.121 (p=0.122)	0.534 (p=0.652)	0.012 (p=0.131)	-0.401 (p=0.313)	0.113 (p=0.203)	0.313 (p=0.120)	0.002 (p=0.367)	-0.225 (p=0.210)	1.462 (p=0.142)
Transition	0.012 (p=0.351)	-0.123 (p=0.165)	0.021 (p=0.3051	-0.127 (p=0.213)	-0.400 (p=0.571)	0.211 (p=0.811)	-0.011 (p=0.105)	0.045 (p=0.242)	-1.102 (p=0.211)

Ownership of Physical asset (radio/TV) Forest	0.040 (p=0.216)	1.020* (p=0.082)	0.674 (p=0.509)	0.652 (p=0.356)	0.0224 (p=0.631)	0.622 (p=0.397)	0.012 (p=0.151)	0.006 (p=0.378)	2.063 (p=0.211)
Transition	0.438 (p=0.301)	0.280* (p=0.068)	-1.112 (p=0.233)	0.213 (p=0.137)	0.123 (p=0.295)	0.721 (p=0.32)	0.267 (p=0.512)	-0.254 (p=0.151)	0.652 (p=0.125)
Household annual farm income Forest	1.432 (p=0.240)	-0.553 (p=0.165)	1.214 (p=0.503)	-0.016 (p=0.420)	0.108| (p=0.161)	6.317** (p=0.026)	0.032 (p=0.430)	1.815 (p=0.651)	-0.169 (p=0.143)
Transition	1.216 (p=0.252)	-0.151 (p=0532)	0.054 (p=0.410)	0.018 (p=0.426)	0.151 (p=0.107)	7.658** (p=0.047)	0.321 (p=0.157)	-0.234 (p=0.112)	0.022 (p=0.643)
Access to extension services Forest	0.301 (p=0.321)	1.472** (p=0.031)	1.361 (p=0.670)	0.101 (p=0.412)	1.672* (p=0.031)	0.474 (p=0.250)	0.005 (p=0.132)	1.665 (p=0.137)	1.462 (p=0.144)
Transition	1.260 (p=0.632)	1.907 (p=0.046*	1.121 (p=0.219)	1.021 (p=0.126)	1.108* (p=0.036)	0.871 (p=0.114)	0.062 (p=0.530)	0.1353 (p=0.121)	1.102 (p=0.127)

				Summary of Model Outcomes	
Breusch-Pagan Test: Chi- Square Forest Transition					1042.26 > 0.000[a] 1039.42 > 0.000[a]
Prob >Chi-Square Forest Transition					0.002[a] 0.000[a]
Base Outcome					Forest Zone

***, **, *Significant at 1%, 5%, and 10% probability level, respectively. – indicates that adaptation strategy is not applicable in the ecosystem.

Household characteristics

The SUR results indicate that all the household characteristics which inform the adaptive capacity of farmers are statistically significant and positively correlated with at least one of the constraints to adaptive capacity except household size and age.

Gender of farmer is statistically correlated with constraint of access to farmland in both Zones [Forest- Coefficient =1.217** (p= 0.011); Transition-Coefficient =1.427*** (p= 0.000)]. The educational level of farmer is statistically correlated with constraint of knowledge about adaptation strategies in both Zones [Forest- Coefficient =0.217* (p= 0.012); Transition-Coefficient= 0.447*** (p= 0.004)]. Ownership of physical asset i.e. television and radio is statistically significant with constraint of access to information about climate in both Zones- [Forest- Coefficient =1.020* (p= 0.082); Transition- Coefficient =0.280* (p= 0.068)]. Household annual income (which includes sale of agricultural produce and off-farm activities and remittances from family members) is statistically correlated with constraints of agricultural input in both Zones [Forest Coefficient =6.317** (p= 0.026); Transition- Coefficient =7.658** (p= 0.047)].

The main differences in the findings are that the coefficients indicates a strong correlation between gender and constraint of access to farmland in the Transition Zone relative to Forest Zone.

Access to Institutional Support

The SUR values show that in both Zones [Forest- Coefficient= 1.341*** (p= 0.003); Transition- Coefficient= 0.483*** (p= 0.001)], household heads' level of education has a positive and significant impact on constraint on access to credit facility.

Similarly, the coefficients of both Zones [Forest= 1.472** (0.031); Transition = 1.907* (p=0.046)] indicate that farmers' access to extension services correlate with constraints on access to information about climate; and knowledge about climate adaptation strategies [Forest Zone= 1.672* (0.031); the Transition Zone= 1.108* (p=0.036)].

5.0 Discussion

5.1 Enhancing Adaptive Capacity through Farmers' Access to Livelihood Assets

The study finding indicates that farmers in both study areas are endowed with various livelihood assets that enhance their ability to plan and implement various adaptation strategies. Regarding human capital (educational level), households heads in the Forest Zone could be said to have higher adaptive capacity than those in the Transition Zone. Higher education levels can reflect increased technical skill of farmers and facilitate their access to institutional support. This finding supports Ndamani and Watanabe (2017). The study found that most of farmers in both Zones are low-income earners. It could be inferred from the findings that farmers in the Forest Zone have higher adaptive capacity with regard to access to physical capital (TV and radio) than those in the Transition Zone, hence enhancing their capacity to access climate and weather forecast information. The findings indicate that in both Zones, a substantial number of farmers (about 60%) had no social affiliation. Although relatively more household heads in the Transition Zone had affiliations with social networks than those in the Forest Zone. Thus, the full benefits achieved through social networks are lost. This finding matches with Dapilah et al. (2019) study. More farmers in the Forest Zone could be said to have higher adaptive capacity than those in the Transition Zone regarding natural capital (secured land tenure). However, access to secured land rights does not always translate into increased adaptive capacity.

5.2 Farmers' Perceptions about Changes in Climate

Changes in climate observed by farmers in the Forest Zone agree with other studies [e.g. Stanturf et al. (2011)]; and Fosu-Mensah et al. (2012), Klutse et al. (2013) in the Transition Zone. The evidence also confirms the findings of other international organisations that climate change is increasing the vulnerability of poor farmers (e.g. Dasgupta et al.,2014; Porter et al., 2014). More household heads in the Transition Zone claimed to have observed changes in climate than in the Forest Zone. This could be due to the location of the district (semi-arid region), characterised by highly variable climatic conditions, therefore a marginal change in temperature and rainfall could be observed easily.

5.3 Adaptation Strategies adopted by Farmers

The on-farm adaptation choices mentioned by households in the Transition Zone (e.g. crop diversification and agro-forestry) match with those found by Fosu-Menash et al. (2012); Limantol et al. (2016), and international studies (e.g. Dasgupta et al., 2014). Whereas agro-forestry is practised in the Forest Zone the strategy is rarely pursued by farmers in the Transition Zone.

5.4 Constraints on Adaptive Capacity from Farmers' Perspective

Lack of infrastructure, Inputs and readily available markets

Generally, farmers in both study areas emphasised that they plant crops using nearby rivers for irrigation. This practice was also observed by Antwi-Agyei et al. (2016) in the Transition Zone with many farmers engaging in manual watering of crops during the dry season. Farmers are faced with poor marketing systems, which confirms Laube et al. (2012). The study found that farmers were compelled to plant landraces from previous harvested seeds, which leads to reduction in plant vigour and yield performance. This finding confirms Atlin et al. (2017).

Access to Secured Land Ownership

This study found that farmers go into different forms of land tenure, which have not all the time supported farmers to adopt adaptation strategies such as agro-forestry. This finding agrees with Antwi-Agyei et al. (2015).

5.5 Constraints on Adaptive Capacity from Institutional Actors' Perspective

The study revealed that paid extension services, has enhanced farmers' adaptive capacity through equipping them with technology to increase crop productivity. This implies that the vulnerability of farmers who cannot afford the paid services will continually increase if the constraint is not addressed. The lack of effective collaboration among institutions, inaccuracies in data due to outdated equipment implies that farmers' access to reliable climate information is hampered.

5.6 Impact of Capital indicators and Institutional Factors on Adaptive Capacity

This study revealed that gender is a determinant factor of access to farmland, which restricts adoption of adaptation strategies such as agro-forestry. This finding is in consonance with Antwi-Agyei et al. (2015). In contrast with Ojo and Baiyegunhi (2020), age of farmer does not statistically correlate with constraint on access to credit facilities. Farmers with higher educational background are more likely to understand the causes and impacts of changes in climate variables better, and have access to technology as found by Acquah and Onumah (2011).

The results of household size are not statistically significant with all the constraints to adaptive capacity in both Zones. This finding is in contrast with Mabe et al. (2014) that bigger household sizes tend to increase adaptive capacity by undertaking farming activities such as weeding and irrigation. Rather, the finding agrees with Acquah and Onumah (2011) and Ndamani and Watanabe (2017) that smaller household with members living abroad may indirectly influence adaptive capacity through remittances.

6. Conclusions

This study compares similarities and differences between two study areas: Atwima Mponua and Ejura-Sekyeredumase districts. The findings indicate that farmers in Atwima Mponua District are more likely to have higher adaptive capacity than those in Ejura-Sekyeredumase District. This is reflected in human capital (educational level), which enhances productivity; and natural capital (secured land ownership), which enhances their capacity to adopt adaptation practice e.g. agro-forestry. However, farmers in Ejura-Sekyeredumase District could be said to have a higher adaptive capacity than those in Atwima Mponua District in terms of access to credit facilities and expenditure on agricultural inputs. Overall, the analysis revealed that a good number of farmers in both districts are low-income earners, which could impact negatively on their ability to either plan or implement effective adaptation strategies.

Farmers in both districts had observed changes in the climate such as higher/extreme temperatures, reduced and erratic rainfall over the past 20-30 years. In addition to these changes, droughts and occasional floods are frequent in Ejura-Sekyeredumase District .

Farmers in both districts had adopted diverse on-farm adaptation strategies such as crop diversification and agro-forestry. Whereas crop diversification is common in Atwima Mponua District, agro-forestry is rarely practiced in Ejura-Sekyeredumase District.

Additionally, while these adaptation strategies were effective, the study identified some constraints farmers faced in their effort to plan or implement them. The constraints were reflected in three dimensions: farmers, AEOs and meteorological staff perspectives.

From the perspective of farmers, they were constrained due to factors such as: Lack of infrastructure; readily available markets; and lack of secured land ownership. For example, farmers go into different forms of land tenure, which restrict their capacity to adopt effective adaptation strategies. Access to modernised irrigation facilities limits farmers in both districts' ability to minimise climate related risks.

The AEOs in both districts perceived that their roles were hampered by inadequate transport facilities, staffing and financial resources in delivery of extension services. According to the meteorological staff in both districts, they were constrained by limited technological capability resulting in unreliable information about weather forecasts. Also, inadequate collaboration with other local institutions, which can have a negative impact on the validity and use of data for seasonal forecasts.

Quantitative analysis indicates household characteristics such as: age, gender, and educational level as determinants of constraint on adaptive capacity amongst crop farmers in both districts. Among the household characteristics, gender is highly statistically significant with constraint on access to farmland in both districts.

Policy Recommendation

This study contributes to research on climate change adaptation by providing empirical evidence to deepen our understanding of the constraints smallholder crop farmers face to either plan or implement adaptive strategies from different dimensions-farmers and local institutions. The policy implications that aim at enhancing farmers' adaptive capacity in the study areas and sub-Sahara Africa are more widely outlined.

The current method of irrigation (hand carrying) is considered labour intensive. The local government should support farmers in both districts by providing modernised irrigation systems, using motorised pumps.

Financial capital is a prerequisite for enhancing adaptive capacity of farmers in terms of acquisition of farmland, inputs and implementing robust adaptation strategies. The governmental and private organisations should ensure that more financial resources at affordable interest rate are made available to crop farmers.

Local weather forecasts could be made available on a regular basis via mobile phone systems, television, radio, and the community gong-beater.

The government should think about new approaches to budgeting and financing the local institutions to improve and sustain quality of services.

Collaboration among the partner organisations in both districts is important and should be encouraged. One concrete example is sharing of information/data using a common platform for data access and management.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Appendix 1: Chi-square Distribution of Level of Education to Access of Climate Change Information

	Households with some level of Formal Education and Access to Information	Households without Formal Education and Access to Information	Row Total
Forest	95	55	150
Transition	48	102	150
Column Total	143	157	300
Expected=Column Total X Row Total /Total			
Forest	71.50	78.50	
Transition	78.50	71.50	
$\frac{(O-E)^2}{E}$	7.724	7.035	
	7.724	7.035	
X^2 (Sum of $\frac{(O-E)^2}{E}$	29.518		
Chi-square Test	5.54E-08		