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Socioeconomic Determinants of Adaptive Capacity to Climate Variability among Smallholder Crop Farmers in Kuria East Sub-County, Kenya

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Abstract

Climate variability remains an urgent challenge to food security in sub-Saharan Africa, particularly for smallholder farmers who depend on rain-fed agriculture. Better access to collective and institutional support through climate education and access to credit can strengthen their ability to respond effectively to the challenges posed by climate variability. This paper delves into the socioeconomic factors influencing farmers' ability to adapt to climate variability in Kuria East Sub-County, Migori County, Kenya. Using cross-sectional data from 361 smallholder farmers, the paper analyses the socioeconomic factors that determine smallholder farmers' ability to adapt to climate variations while examining their current level of adaptation. The descriptive results show that farmers have low adaptive capacity, mainly due to a lack of access to climate education and financial support. The results of the chi-square test (χ^2) show that access to credit ($p < 0.05$) and climate education ($p < 0.05$) have relatively significant influences on farmers' adaptive capacity. On the other hand, formal education ($p = 0.509$), farm size ($p = 0.497$), and farming experience ($p = 0.249$) have no significant effect on adaptability. Overall, 60.4% of the farmers have low adaptive capacity, mainly due to climate education inadequacy and limited financial support. These results show that socioeconomic conditions determine smallholders' climate adaptation capacity. This underscores the need to strengthen farmer-centered climate information systems and expand inclusive credit mechanisms as these are key drivers of effective and sustained adaptation. The findings provide an empirical basis for guiding the implementation of Kenya's National Climate Change Action Plan (NCCAP) and Sustainable Development Goals (SDGs 13 and 2) at the county level.

Subject Areas

Geography, Climatology

Keywords

Adaptive Capacity, Climate Variability, Smallholder Farmers, Socioeconomic Factors, Kuria East Subcounty, Migori

1. Introduction

Climate variability is a particularly sensitive issue for many smallholder farmers around the world. Smallholder farmers in the Global South who depend on rain-fed agriculture have insufficient technological and institutional support [1]. As a result, climate disasters such as prolonged drought, unpredictable rainfall, and flooding have reduced yields and increased food insecurity in this region [2]. Limited access to technology, financial services, and institutional support constrains their ability to respond effectively to climate challenges [3]. In sub-Saharan Africa, agriculture is driven mainly by smallholder farmers [4]. Recurrent droughts, erratic rainfall, and rising temperatures have reduced yields, increased production uncertainty, and exacerbated food insecurity among rural households in this region [5] [6].

In Kenya, smallholder farmers account for 75% to 90% of total national food production [3] [7]. Smallholder farmers' ability to cope with climate variations is strongly influenced by a number of complex socioeconomic factors. For many farmers, lack of money limits their ability to invest in costly and effective technologies such as irrigation systems, better seeds, and diversification of livelihoods [8]. In Migori County, particularly Kuria East Sub-County, rain-fed agriculture remains the main economic activity [9]. Farmers grow mainly maize, beans, sweet potatoes, and cassava. These crops are directly dependent on two rainy seasons: the long rainy season (March-May, MAM) and the short rainy season (October-December, OND). However, the region continues to experience increasing variability in rainfall and a gradual increase in average temperature [10] [11]. These changes often disrupt the agricultural calendar, increase water stress for crops, and expose smallholders to repeated losses.

According to [12], factors such as access to credit and institutional support networks based on groups and farmers are crucial to farmers' adaptability. Women-headed households are more likely to adopt alternative farming practices than wealthy male-headed households who choose to save [13]. Training in climate-friendly agriculture promotes the use of environmentally friendly management practices [14]. Previous studies have shown mixed results regarding the role of formal education in building adaptive capacity [15] [16], suggesting that access to knowledge rather than schooling alone may have a greater influence. Nevertheless, adaptation remains difficult due to poverty and poor governance in most rural areas of Kenya [17].

The theory of adaptive capacity is a useful analytical tool for understanding how households respond to climate stressors [18]. The Intergovernmental Panel on Climate Change (IPCC) defines adaptive capacity as the ability of systems, institutions, and individuals to adapt to potential damage, moderate losses, or exploit new opportunities [19]. At the household level, adaptive capacity is determined by access to human, financial, social, and institutional resources that enable farmers to adopt appropriate adaptation and resilience strategies. Empirical studies increasingly show that socioeconomic characteristics such as education, access to information, credit, advisory services, and collective action play key roles in farmers' ability to respond effectively to climate variations [8] [12].

Despite the growing body of academic work on agricultural adaptation in sub-Saharan Africa, most studies are based on national or regional analyses that obscure the local heterogeneity of socioeconomic constraints [15]. Adaptation to climate variability remains limited at the grassroots level. In particular, there is a lack of empirical data showing how selected socioeconomic factors influence the adaptive capacity of smallholder farmers in Kuria East Sub-County, Migori County, Kenya. Local data are essential for designing targeted interventions that go beyond general policy prescriptions [20].

This study fills this gap by examining how formal education, farm characteristics, climate education, and access to credit facilities affect farmers' adaptive capacity in Kuria Sub-County, Migori County, Kenya. By identifying the relative importance of these factors at the local level, the study provides empirical evidence for climate adaptation literature and useful information for strengthening community-level climate resilience strategies.

The study informs the effective implementation of Kenya's Climate Change Act (2016) [20] and the National Climate Change Action Plan (NCCAP). This includes integrating climate action across all sectors, strengthening community resilience, and supporting climate adaptation measures at the county level. It provides richer insights into the concrete realization of Kenya's Vision 2030 and the Agricultural Sector Transformation and Growth Strategy (ASTGS 2019-2029), both of which aim to achieve sustainable agricultural development, food security, climate-friendly practices, and climate adaptation for smallholder farmers. The paper is structured as follows: Section 2 describes the methodology, and Section 3 presents the results of the study. Section 4 discusses the findings; Section 5 concludes the paper by highlighting policy implications.

2. Methods

2.1. Study Area

The study was conducted in Kuria East Sub-County, Kenya, which covers an area of approximately 187.9 km^2 [21]. The region has a tropical climate characterized by a bimodal rainfall pattern with a long rainy season from March-May and a short rainy season from October-December. The annual rainfall varies between 800 and 1400 mm, while the average temperature varies between 22˚C and 29˚C

[10]. Agriculture is mainly rain-fed and practiced on small farms, which are usually less than 5 acres in size [11]. The main crops are maize, beans, sweet potatoes, and cassava. Heavy dependence on rainfall and limited irrigation infrastructure makes local agricultural systems particularly vulnerable to climate variations, making this region a fertile area for examining the factors that shape farmers' adaptability (**Figure 1**).

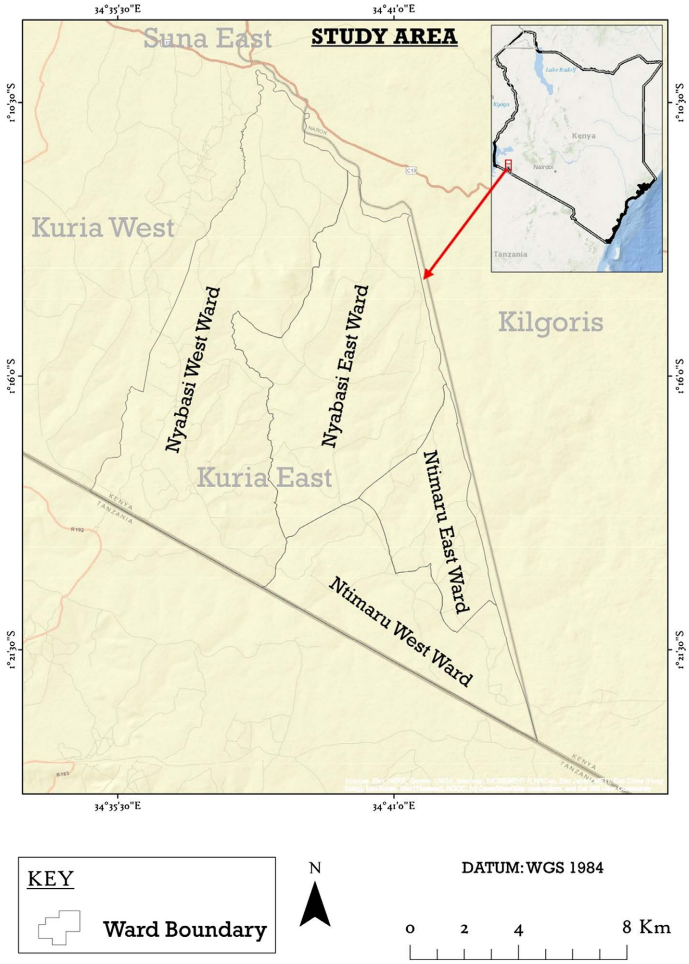

Figure 1. Map of the study area (source: Author).

2.2. Data and Sampling

The study used primary cross-sectional data collected through a structured survey of smallholder farmers. The questionnaire collected information on socioeconomic characteristics, including education level, farm size, farming experience, access to climate education, and access to credit facilities. In this study, climate education refers to farmers' participation in climate-related programs, agricultural advisory events, or climate information trainings organized by agricultural advisors, government agencies, or development organizations. As part of the survey, respondents were asked to indicate whether they had participated in such climate-related training or advisory measures in the last ten years. The variable was coded as a

binary indicator (1 = access to climate education; 0 = no access). The target population consisted of 96,872 persons in the Kuria East Sub-County as per the latest census report [21].

The sample size was determined via Cochran's (1977) formula for finite populations, which yielded an accessible sample of 383 respondents. Farmers were selected through simple random sampling in the two selected wards of Nyabasi East and Nyabasi West to ensure geographical representation. In practice, smallholder farming households within these wards were randomly approached and invited to participate in the survey during field visits, ensuring that eligible crop farmers had an equal opportunity of selection. A total of 361 valid questionnaires were usable, corresponding to a response rate of 94.3%. The design of the survey made it possible to collect comparable quantitative data among farmers to conduct a statistical analysis of the socioeconomic determinants of adaptive capacity.

2.3. Measuring Adaptive Capacity

Adaptive capacity was measured via an index-based approach derived from farmers' use of climate adaptation strategies. Seven common strategies were assessed: i) use of drought-resistant crop varieties, ii) Rainwater harvesting, iii) irrigation methods, iv) shifting crop calendars, v) crop diversification, vi) agroforestry, and vii) soil conservation practices. These measures reflect increasing levels of economic, technical, and institutional requirements and are widely recognized as indicators of farmers' ability to respond to climate challenges.

For each farmer, the adoption of a given practice was coded as a binary variable (1 = adopted; 0 = not adopted). An adaptation capacity score was then calculated as the sum of all adopted measures, as illustrated:

$$AC_i = \sum_{j=1}^{7} P_{ij}$$

where AC_i denotes the farmer's adaptation capacity score for farmer *i*, and P_{ij} represents the adoption of practice *j*. Scores ranged from 0 to 7, with higher values indicating greater adaptation capacity. This additive index method has been widely used in adaptation studies to estimate adaptation capacity at the household level via binary adoption indicators of specific measures [22].

To facilitate the analysis, total adaptation scores were classified into three ordered levels: low adaptive capacity (0 - 3 measures), moderate adaptive capacity (4 - 5 measures), and high adaptive capacity (6 - 7 measures). This categorical variable was then used as a dependent variable in chi-square independence tests to examine its association with certain socioeconomic characteristics.

The seven adaptation measures were weighted equally in the index as each represented a clear and observable adaptation measure available to smallholders in the study area. In contexts where reliable information on the relative effectiveness or costs of different measures is limited, previous adaptation studies generally use equal weighting to avoid subjective bias and maintain transparency in the construction of the index [22] [23]. The classification thresholds used in this study

were chosen to reflect significant differences in the extent of adaptation strategies adopted by farmers. Farmers who used only a few measures were considered to have limited adaptive capacity, while those who implemented multiple strategies were assumed to have a stronger ability to respond to climate variations. This categorization has been widely used in studies of adaptation at the household level to facilitate the interpretation and comparison of levels of adaptive capacity [22] [23].

2.4. Statistical Analysis

The data were analyzed via IBM SPSS Statistics software (version 25). Descriptive statistics, including frequencies, percentages, and cross-tabulations, were used to summarize the socioeconomic characteristics of the respondents and the distribution of adaptive capacity levels among smallholder crop farmers.

The relationships between socioeconomic variables and adaptation ability were examined via chi-square (χ^2) independence tests. The chi-square test was appropriate because both the outcome variables and the explanatory variables were categorical or ordinal. Expected cell counts were examined to ensure the validity of the chi-square test. This approach enabled the study to assess whether there were statistically significant differences in adaptation capacity between socioeconomic groups. When significant correlations were detected, effect sizes were assessed via Cramér's V to determine the strength of the correlations.

Although an ordered logistic regression model was initially considered, diagnostic tests revealed poor model fit and violations of the assumption of equal proportions. Consequently, the inferential analysis focused on chi-square tests, which provided more robust and reliable estimates for the categorical structure of the data. All the statistical tests were performed at 95% confidence level, with significance determined at $p < 0.05$. The analysis was based on 361 valid responses from farmers. All assumptions for chi-square tests, including the minimum number of expected cells, were evaluated prior to analysis.

3. Results

3.1. Descriptive Results

Table 1 summarizes the socioeconomic characteristics of smallholder crop farmers. Almost half (48.5%) of the respondents had only attained primary education, whereas 35.7% had no formal education at all. Only 15.8% had achieved post-primary education. In terms of farming experience, 41.3% of the farmers had between 5 and 10 years of experience, 38.8% had between 11 and 15 years of experience, and 19.9% reported having more than 15 years of farming experience. Most farmers cultivated small plots of land, with 72.9% cultivating between 1 and 2 acres and only 3.0% running farms larger than 3 acres. Access to institutional and information-based support services was limited: only 12.5% of respondents reported having access to credit services, whereas only 20.5% had received climate-related education. Most farmers were therefore dependent on small-scale production systems with limited formal support.

Table 1. Socioeconomic characteristics of smallholder farmers (n = 361).

Variable	Category	Frequency (n)	Percentage
Level of education	No formal education	129	35.7
	Primary education	175	48.5
	Post-primary education	57	15.8
Farming experience	5 to 10 years	149	41.3
	11 to 15 years	140	38.8
	>15 years	72	19.9
Farm size	<1 acre	87	24
	1 to 2 acres	263	72.9
	3 to 5 acres	11	3
Access to credit	Yes	45	12.5
	No	316	87.5
Climate education	Yes	74	20.5
	No	287	79.5

3.2. Distribution of Levels of Adaptive Capacity

The distribution of adaptive capacity among the farmers in the sample is presented in Figure 2. The majority of the farmers (60.4%) were classified as having low adaptive capacity, while 26.3% had moderate adaptive capacity, and only 13.3% were classified as having high adaptive capacity. These results indicate that most smallholders in Kuria East Sub-County have limited technical, financial, and institutional resources to respond effectively to climate variations.

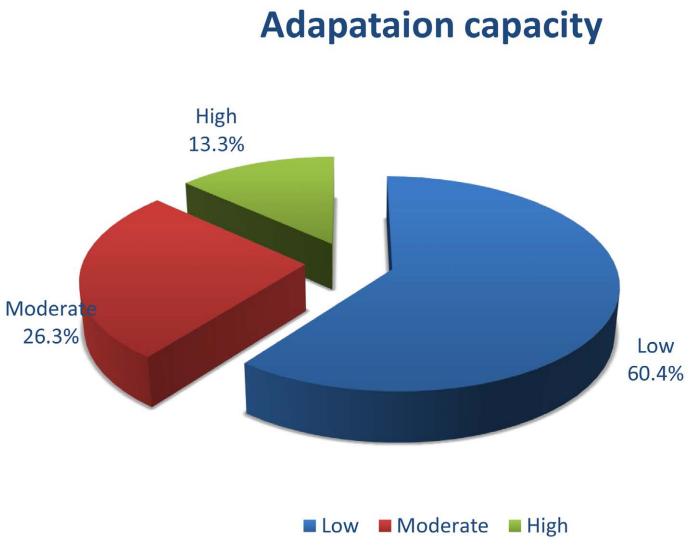

Figure 2. Distribution of farmers' levels of adaptive capacity (source: Author).

3.3. Relationships between Socioeconomic Factors and Adaptive Capacity

Table 2 presents a cross-tabulation of adaptability levels based on climate education and access to credit and provides an overview of the direction and magnitude of the relationship examined in the chi-square analysis that follows. The descriptive cross-tabulations indicate that farmers who had received climate education or had access to credit were more likely to report moderate or high levels of adaptation than those who did not receive such support.

Table 2. Cross-tabulation of adaptation capacity with climate education and access to credit.

Socioeconomic Factor	Low (n, %)	Moderate (n, %)	High (n, %)	Total (n, %)
Climate Education				
Yes	7 (1.9%)	50 (13.9%)	17 (4.7%)	74 (20.5%)
No	140 (38.8%)	18 (5.0%)	129 (35.7%)	287 (79.5%)
Access to Credit				
Yes	9 (2.5%)	27 (7.5%)	9 (2.5%)	45 (12.5%)
No	138 (38.2%)	41 (11.4%)	137 (38.0%)	316 (87.5%)

Note: Percentages are based on the total sample (N = 361). Adaptation capacity categories include "Low", "Moderate", and "High".

Chi-square independence tests were performed to examine the relationships between farmers' socioeconomic characteristics and their adaptive capacity (Table 3). The results indicate that climate education and access to credit were significantly associated with adaptive capacity. Climate education was strongly associated with adaptive capacity ($\chi^2 = 99.03$, df = 2, $p < 0.001$, Cramer's V = 0.524), indicating a large effect and suggesting that trained farmers were significantly more likely to report higher levels of adaptation. Similarly, access to credit facilities was significantly associated with better adaptation outcomes ($\chi^2 = 38.83$, df = 2, $p < 0.001$, Cramer's V = 0.328). In contrast, the level of formal education ($\chi^2 = 3.30$, df = 4, $p = 0.509$), farming experience ($\chi^2 = 5.40$, df = 4, $p = 0.249$), and farm size ($\chi^2 = 3.37$, df = 4, $p = 0.497$) showed no statistically significant associations with adaptive capacity.

4. Discussion

The results show that access to climate education and credit was significantly associated with greater adaptive capacity. The level of formal education, farming experience, and farm size were not significantly correlated. These findings indicate that farmers' ability to respond effectively to climate variations depends less on static demographic characteristics than on access to knowledge, financial capital, and institutional support.

Table 3. Results of the chi-square test (χ^2) between socioeconomic variables and adaptive capacity.

Socioeconomic Factor	χ^2	df	p Value	Cramer's V
Formal				
Education	3.30	4	0.509	-
Farming				
Experience	5.40	4	0.249	-
Farm size	3.37	4	0.497	-
Climate				
Education	99.03	2	0.000	0.524
Access to credit	38.83	2	0.000	0.328

Note: n = 361. The chi-square independence test was used to assess the associations between each socioeconomic factor and adaptation capacity. Significance was assessed at $p < 0.05$.

The positive correlation between climate education and adaptability underscores the central role that information and learning play in farmers' adaptation behavior [18]. Farmers who had received climate education were more likely to adopt a wider range of adaptation methods, suggesting that greater knowledge of risk, technical skills, and increased self-confidence facilitate proactive decision-making. This finding is consistent with data from smallholder systems, which show that extension services and targeted climate awareness programs significantly improve the adoption of climate-friendly agricultural practices [5] [12]. Similar results have been reported in Kenya, where access to extension services and climate information was a decisive factor in adaptation choices [7]. By reducing uncertainty around information, climate education appears to enable farmers to move from reactive to proactive adaptation strategies.

Access to credit also emerged as a factor strongly associated with higher adaptive capacity. Financial capital likely reduces the liquidity constraints that often prevent smallholders from investing in resource-intensive methods such as irrigation systems, soil conservation structures, and agroforestry. This finding is consistent with studies in sub-Saharan Africa showing that financial inclusion facilitates adaptation by reducing barriers to investment and spreading risk [2] [16]. The strong correlation observed here reinforces the idea that adaptation is part of broader institutional and collective systems rather than solely an individual decision.

In contrast, the level of formal education was not associated with adaptability. Although education is often assumed to improve problem-solving skills, the current results suggest that general schooling does not necessarily lead to context-specific adaptation measures. Similarly, nonsignificant effects have been docu-

mented in other smallholder contexts where experiential learning and extension-based training have had greater influences than formal qualifications do [14] [15]. These findings suggest that specialized, practice-oriented knowledge may be more decisive than the number of years of schooling in regard to adaptation behavior.

Similarly, neither farming experience nor farm size was significantly correlated with the level of adaptation. Although experience can contribute to the accumulation of local knowledge, it does not necessarily promote the introduction of innovative or capital-intensive methods, especially when economic or informational constraints remain. Similarly, farm size does not automatically confer adaptation advantages if institutional and financial support mechanisms are lacking. This observation challenges the assumption that resource utilization alone determines resilience and is consistent with broader empirical evidence showing that structural characteristics often play a secondary role compared with access to services and resources [4] [6].

From a theoretical perspective, these findings support adaptive capacity theory, which conceptualizes adaptation as a function of access to resources, institutional support, and knowledge rather than as a purely demographic function [18]. The importance of the informational and economic factors observed here also reflects the IPCC's findings that institutional support and a favorable environment are crucial for strengthening local resilience [19]. Adaptive capacity is therefore socially constructed and shaped by opportunities, services, and governance structures.

These findings have important policy implications. Investments in climate education targeting farmers, extension services, and locally relevant training programs can significantly improve adaptation outcomes. Parallel measures to expand access to affordable credit, savings programs, and farmer organizations can reduce the economic barriers that limit the adoption of climate-friendly technologies. Measures that integrate knowledge, financial support, institutional support, and support for developing farms are likely to be more effective than measures that focus solely on improving formal education or expanding farms. By identifying these leverage points, this study provides localized data that can inform targeted adaptation planning in rural areas of Kenya and similar smallholder systems.

It is important to note that the inferential analysis in this study is based on bivariate chi-square tests, which examine the relationship between two variables at a time. The analysis, therefore, does not isolate the independent effects of each individual socioeconomic factor on adaptive capacity. Some explanatory variables, such as access to credit and climate education, may vary or interact in ways that are not captured by bivariate tests. The results should therefore be interpreted as indications of statistically significant correlations rather than direct causal relationships. Future research may use multivariate modeling methods to better distinguish between the independent contributions of these factors.

5. Conclusion

This study examined the socioeconomic determinants of adaptive capacity among

smallholder crop farmers in Kuria East Subcounty, Kenya. The results show that access to climate education and credit facilities are strongly associated with higher levels of adaptation, whereas formal education, farming experience, and farm size are not significant factors. These findings indicate that adaptive capacity depends more on access to knowledge, financial resources, and institutional support than on static demographic characteristics. To translate these findings into concrete action, local agricultural extension offices, farming cooperatives, and community organizations in Kuria East Sub-County should serve as important platforms for climate education. Crop officers can offer regular training sessions on farms, demonstrations of climate-friendly agriculture, and advisory visits to reach farmers who have limited access to formal training. Particular attention should be given to farmers who are currently excluded from existing programs, including female-headed households and resource-constrained households, through targeted fieldwork and group learning. Inclusive credit mechanisms should be put in place in the form of affordable, flexible, and accessible financial products such as low-interest loans, microcredit, or savings credits tailored to small farms and the seasonal incomes of local farmers. Smallholder farmers in this region should embrace climate-smart agricultural practices such as irrigation, drought-tolerant crop varieties, and integrated pest management systems. These measures will enable farmers to implement several adaptation strategies simultaneously, thereby strengthening community-level resilience to climate variability.

Declarations

The study was approved by the Kenyatta University Ethics Committee (Ref. No. KU/APPROVAL/VOL.1/1) and the Kenyan National Commission for Science, Technology and Innovation (License No.: NACOSTI/P/25/4174385). Additional permissions were granted by the Migori County Governor's Office, the County Director of Education, and the County Commissioner. All the respondents gave their informed consent to participate in the survey from which the data for this study were obtained.

Conflicts of Interest

The authors declare no conflicts of interest.

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