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Exploring variation in adaptation levels to climate extremes among farmers of the Kyoga Agro ecological zone in Uganda using a cross sectional design

Chombo Oketcho^{1*}, Paul Isolo Mukwaya², George Oriangi¹ and Yeeko Kisira¹

Abstract

Background Adaptation to climate change among smallholder farmers is a paramount step in achieving sustainable livelihoods in line with SDG 1, 2 and 13 since these communities face significant challenges due climate extremes which impacts on impacts on their only means of livelihood. Determining the levels in adaptation is crucial in understanding the socio-economics of the impact of climate change in the rural communities. The study investigated adaptation levels and determinants among smallholder farmers in the Kyoga Agro-ecology of Uganda.

Methods A quantitative cross-sectional survey involving 384 face-to-face household interviews using structured questionnaires was conducted. Farmers, selected based on climate change awareness, were targeted to respond to their reported adaptation levels. Descriptive statistics analyzed adaptation levels among smallholder farmers of various socioeconomic characteristics across different subzones. A Multinomial Logistic (MNL) model examined the determinants of variation in adaptation levels.

Results Majority of the respondents, 85.9% in the BCMS and 93.8% in the TS sub zone observed that indeed climate change is occurring. Female farmers in the TS subzone were significantly less likely to adopt 3–4 ($p < 0.01$) or 5–7 ($p < 0.01$) adaptation strategies compared to the base category (1–2 strategies), while the relationship in the BCMS subzone was negative but not significant. Male farmers consistently demonstrated greater capacity to adopt higher levels of adaptation strategies.

Annual income was positively and significantly related to adoption of 3–4 ($P < z = 0.70$) and 5–7 ($P < z = 0.013$). Also Education was positively and significantly associated with adopting 5–7 adaptation strategies in both the TS and BCMS subzones compared to the base category (1–2 strategies). Primary education showed significance at $P < z = 0.05$ in TS ($P < z = 0.018$) and BCMS ($P < z = 0.03$), while secondary education was also significant in TS ($P < z = 0.052$) and BCMS ($P < z = 0.014$). Essential support, particularly for female farmers, is crucial to bridge the gender gap.

Conclusion The findings are pivotal for informing the formulation of inclusive adaptation strategies among farmers in various subzones. We recommend that the ongoing reforms in the National Adaptation Plans of Uganda and international development frameworks in line with climate adaptation consider socio-economic disparities among famers.

Keywords Adaptation levels, Climate Change, Inclusive smallholder planning, Kyoga Agro-ecological zone, Uganda

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Introduction

The persistent climate induced hazards underscore global implications, particularly for rural communities heavily reliant on local food and water resources. Such reliance heightens vulnerability to climate variations, [1–3]. Disruptions to these vital systems, as discussed by [4–6] not only threaten development but also exacerbate existing challenges in poverty eradication efforts. The emergence of climate variability, as observed by [7, 8] further complicates matters, introducing instabilities in precipitation and temperature patterns across seasons.

Globally, scholars have emphasized the mounting challenges faced by smallholder farmers, incorporating a broad spectrum of agricultural problems, some relating to climate extremes while others related to other socio-economic factors [4, 8]. These challenges manifest in various forms, including diminished productivity attributed to accelerated soil erosion, degraded soil fertility, prolonged dry spells, floods, rising temperatures, and the surge in pests and diseases infestation [9, 10]. Notably, recent years have witnessed increasingly erratic weather patterns, adversely affecting the level of moisture in soils hence leading to diminished outputs or total loss in agricultural production [11]. Such variability in rainfall onset and cessation complicates agricultural planning, frequently resulting in crop losses hence causing insufficiency in food and general wellbeing of the people.

In the African context, the adverse impact of climate change combined with weak adaptive capacity at the micro level of households brings the need to ascertain viable and sustainable adaptation strategies to the centre of policy analysis and debate [12]. The interplay of climate change impacts and poor adaptive levels is underpinned by institutional, physical and household factors such as landholding size, farming experience among others [13]. In addition, the constraint of precise weather information, which is common in many African countries, accelerates the risks associated with smallholder farming [14] hence increasing the uncertainties faced by farmers.

Adaptation assumes paramount importance, particularly in sub-Saharan countries including where heightened vulnerability coincides with limited adaptive capacity, a concern underscored by studies like [12, 13]. Adaptation entails the adjustment of natural or human systems to actual or anticipated climatic stimuli, thereby mitigating adverse impacts or capitalizing on beneficial opportunities [15]. The most common strategies used in agricultural adaptation include; the cultivation of new crop varieties and livestock breeds suited to drier conditions, practice of irrigation techniques, promotion of crop diversification, implementation of integrated crop-livestock farming systems, and adjustments to planting schedules [16].

Reduction in vulnerability to climate variability and change calls for innovative studies and approaches customised to managing climate risks as well as helping farmers to adapt to climate change. This therefore calls for the need to first understand how farmers perceive climate change at the local scale, that is, historical or observed weather trends. The fact that farmers have perceived that climate has changed in the last twenty years has been documented by several studies for instance [17, 18] and this indeed points out that farmers in Uganda have developed a number of local coping strategies through indigenous knowledge to improve their of level resilience and adaption.

Some studies have endeavoured to assess the determinants of the selection of adaptation strategies across the different farming systems for example crop growing, live-stock rearing, as well as the mixed crop-livestock production methods in Africa [9, 19, 20]. However, these studies often yield highly generalized findings, with no parameter estimates to specify and delineate country to country effects and adaptation strategies due to the common similarities among included nations. In Uganda in particular, research has been carried out into different aspects of climate change adaptation [21] for instance, identifies various adaptation practices that farmers employ as a result of different factors, including gender dynamics [22] spells out the adaptation strategies prevalent in certain regions, such as Pallisa district, which falls within the study area. Additionally, [9] scrutinized climatic risks confronting farmers and elucidated on the risk management and adaptation measures adopted by them. According to [23] farmers operating on small scale in Uganda exhibit limited adaptive capacity owing to adverse socio-economic conditions, challenging biophysical environments, technological inadequacies, and deficient infrastructure. Climate-smart agriculture initiatives are not extensively promoted by governmental agencies, with existing efforts often fragmented and primarily geared toward bolstering production rather than prioritizing ecosystem preservation and climate resilience.

In the study area, climate extremes such as prolonged dry spells, high temperatures, and early cessation of rainfall [24] are increasingly manifesting agricultural drought conditions in most of the Kyoga plains [25]. Prolonged dry spells have resulted in significant soil water deficit for crop yields and thus failure causing food scarcity and livelihood jeopardy among smallholder farmers who rely on rain-fed agriculture in the Kyoga Basin.

Whereas the existing studies point out the adaptation strategies used by smallholder farmers in the different parts of Uganda and Africa as well as the factors that determine their choice, none of these studies addresses

the variation in the level of adaptation strategies among smallholder farmers and the determinants of these variations. To this end, our study aimed to (i) establish the variation in the level of adaptation among smallholder farmers of different socioeconomic characteristics, and, (ii) analyse the factors that determine the variation in the level of adaptation among smallholder farmers in the Kyoga plains of Uganda. This information is critical in the country's current livelihood programmes and plans of poverty eradication and food security including the National Adaptation Plan for Agriculture (NAP-Ag) that calls for climate resilient farming systems among smallholders [26].

Theoretical framework

The Theory of Planned Behavior (TPB) offers a highly relevant framework for understanding smallholder adaptation behaviors. Adaptation is closely aligned with TPB, a theory widely used to analyze human actions [24, 25]. Although TPB has been effectively applied in fields such as food consumption and health-related behaviors [27–29]. The application TPB to climate change adaptation has gained prominence in rural African setting globally e.g. [30–33]. TPB's three core components—behavioral beliefs (attitudes toward behavior), normative beliefs (subjective norms), and control beliefs (perceived behavioral control) are critical in shaping behavioral intentions [34]. We applied these elements to assess adaptation levels among vulnerable smallholder farmers. Behavioral beliefs influence attitudes toward adaptation strategies, normative beliefs shape the perceived social pressure to take up those strategies, and control beliefs relate to perceived ease or difficulty in implementing adaptive behaviors. Together, these factors contribute to the development of behavioral intentions, which in turn guide adaptation levels among the farmers. Thus, the theoretical framework guided the current discussion on smallholders' practice of resilience-building strategies, depending on their sense of control and social influences.

Materials and methods

The study setting and contextualization

The study was conducted in two districts of Pallisa and Tororo in the Kyoga plains of Uganda (Fig. 1), which is one of the agroecological zones in the country as depicted in Fig. 1, [35] MAAIF 2010 classification (as seen in Fig. 2). The zone comprises the districts of Kayunga, Kamuli, Iganga, Bugiri, Busia, Tororo, Manafwa, Mbale, Pallisa, Kumi, Soroti, Kaberamaido, southern Lira and southern Apac. The zone is divided into two subzones referred to as farming systems, based on the variation in their climatic features namely, the southern, known as the Banana Cotton Millet System (BCMS) and northern,

known as the Teso system (TS). The BCMS subzone comprises of the districts of Kayunga, Kamuli, Iganga, Bugiri, Busia, Tororo and others. This area receives an average rainfall of 1215 – 1556 mm which comes in two seasons, from March to May and August to November, and one dry season from December to February. In the dry months, evaporation surpasses rainfall, whereas during the rainy seasons, rainfall matches or exceeds evaporation.

The TS sub zone, comprises of Pallisa, Kumi, Soroti, Kaberamaido, Lira and Apac, among others. The area receives 1215 – 1465 mm of rainfall which comes in one season, that is, between March and November and one dry season that occurs between December and March. Just like in the BCMS sub zone, evaporation exceeds rainfall during dry months and rainfall is greater or equal to evaporation during dry months.

The temperature ranges between 24–36°C in the entire agro-ecological zone. The altitude ranges from 914 – 1800 m above sea level. The land is mainly flat and swampy and the soils range from low to moderate fertility. This agro-ecological zone was deemed appropriate for the study due its importance as a focal area for Uganda given its significance in the Nile basin. The area has valuable resources for agricultural production for example fresh water, vegetation, soil, to mention but a few. However, the human welfare indicators such as health, population, poverty, food security and others, indicate a very low level of livelihood among the people [21, 26].

The agro-ecological zone has a fast-growing population rate of 4–6% with the poverty and food security situation worse than the national average. Bukedi sub region from which the study districts (Pallisa and Tororo), were picked, is ranked as the highest in multi-dimensional poverty in the Uganda, with a poverty level of 78% of the population while the other sub regions within the agro-ecological area are comparatively lower for instance; Teso (50%), Lango (36%) and Busoga (60%). These are however still very high compared to the national average of 21.4% and 37.5% for eastern Uganda [24]. Tororo and Pallisa districts which form part of the agro-ecological zone are particularly vulnerable to climate change risks especially droughts and floods. Tororo often faces prolonged droughts which lead to biodiversity loss, shortages in tree products, land degradation, soil erosion, reduced fertility, and lower crop harvests (cassava), as shown in Fig. 3b.

Drought and floods are major issues in Tororo, affecting nearly all sub-counties due to the area's flat terrain, making it highly susceptible to flooding during heavy rains. Pallisa on the other hand is usually prone to floods, which raises its level of sensitivity and eventual vulnerability. In addition, Pallisa is located in the semi-arid zone of Uganda that stretches from southern to northeastern

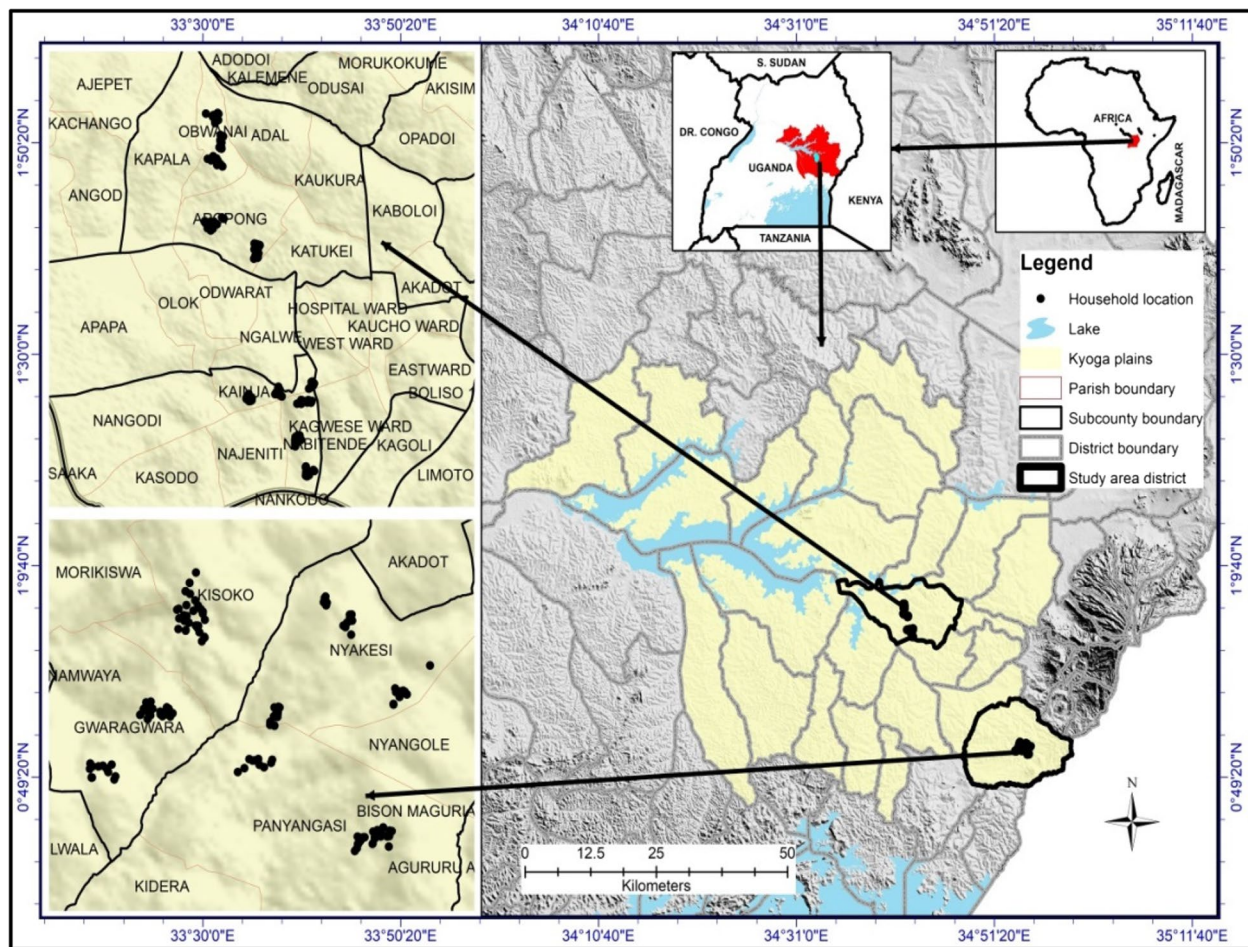


Fig. 1 Location of the study site

parts of the country, where exposure to climatic risks combines with high levels of poverty to worsen vulnerabilities [25]. Pallisa district is one of the poorest and most highly vulnerable to drought risk leading to crop failure (Sweet potatoes) as depicted in Fig. 3a [36]. Studies further show that this area has experienced high frequency of droughts in the last 20 years [27, 30].

Research design and approach

The cross-sectional research design was used in the study to understand the adaptation levels among smallholder farmers. The design has been widely used by scholars who deploy survey approaches for data collection [37, 38]. Data from smallholder farmers ascertaining their perception of climate conditions and whether or not they had adopted some adaptation strategies to overcome the challenges posed by climate change, was obtained using structured questionnaires with pre-determined research questions and responses from which the farmers chose. The data collection tool

(questionnaire) incorporated inputs from smallholder farmers during the field visits for the reconnaissance and pretesting exercise. The farmers provided all the possible responses for each question that helped in the formulation of the final structured questionnaire. This made it easy during data collection where farmers were able to choose their most accurate adaptation levels from the list of options provided at the end of the questions. A target household size of 102,492 for Tororo district [39] and 65,777 for Pallisa [40] district making a total of 168,269 households constituted the population for this study. A sample size of 384 was derived using the Krejcie and Morgan's formula [41] of sample size determination denoted as;

$$n = \frac{x^2 NP(1 - P)}{e^2(N - 1) + x^2 P(1 - P)} \quad (1)$$

Where;

n , is the sample size,

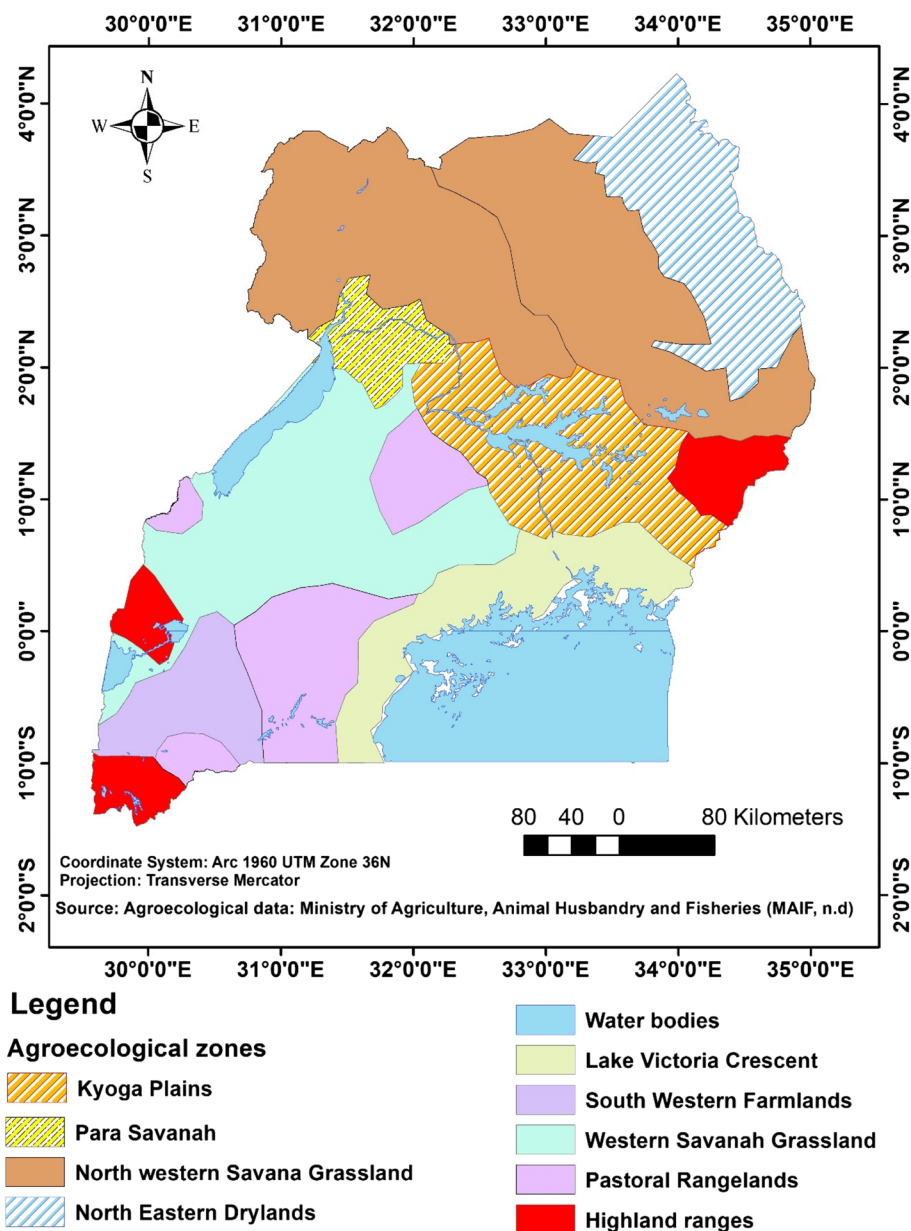


Fig. 2 Spatial distribution of the Agro-ecological zones of Uganda (MAIF, 2010)

N , is total number of the targeted population,
 e , is the level of precision and,
 χ^2 , is the chi square for 1 degree of freedom at the desired confidence level (3.841).

A sample size of 384 households was computed for the survey. The sample size of 384 was then equally divided for the two study districts where each district had 192 face to face household interviews during the survey using random sampling procedure. The equal distribution of the overall sample size allowed a comparable results analysis.

Using a structured questionnaire, we collected quantitative data on the socioeconomic characteristics and how these underpinned adaptation levels to climate change among smallholder farmers. Field surveys have been widely used to collect data through household interviews to obtain the socio-demographic factors whose focus in this study was major [42]. In addition, the face to face interview provided a deep interaction and rich discussions to accurately validate the quantitative perceptions of the famers during the field visits [43].



Fig. 3 a Wilting sweet potato garden in Pallisa district (drought) (b) failed cassava garden in Tororo district (Photos taken on 20.th August 2023)

To maintain high data quality and validity, we organized multiple field visits in 2022 and 2023, where we collaborated with local leaders and experts to outline the study's objectives. Preceding the survey, we conducted reconnaissance activities to identify prevalent adaptation strategies within the region. This served as a benchmark against which farmers' reported strategies were compared, enhancing the credibility of survey findings. The insights garnered from the reconnaissance phase boosted the robustness of our survey instrument. We then circulated the draft questionnaire tool to five university professor who were part of the first authors team of promoters who rated it as fit for data collection. We executed the household survey with the assistance of two female and two male graduate research assistants with proficiency in both English and local languages (Dhopadhola for Tororo and Lugwere and Ateso for Pallisa) to ease interaction with respondents.

To ensure reliability of the questionnaire too, we conducted questionnaire pretest exercise on 30 participants in the study area where inconsistencies and unclear questions were revised to increase reliability and validity. In addition, the recruited research assistants acted as insiders and fluently interacted with the participants. Here, we got appropriate explanations in local languages to obtain valid responses. The first author keenly followed the interpretation of the responses to match those that were required by the questions to uphold the academic integrity.

We conducted a one-day training with the research assistants on data collection skills following the survey

tool including question interpretation, ethical considerations, probing skills and proficient use of the Global Positioning System (GPS) to accurately record household locations. We then used the coordinates to generate spatial interpolation maps based on the sampled households using the Inverse Distance Weighted (IDW) tools in ArcGis 10.8. This tool, which has been widely used to estimate unknown values based on the weighted average of nearby known values, has been recommended across the world as being efficient in filling missing spatial values [44–46]. The influence of each point decreases with distance, making it suitable for datasets where points are relatively evenly distributed.

Data analysis

Before, we asked for adaptation strategies and the levels, farmers were asked if they had noted any changes in climate, that is, increase or decrease in temperature, no change in temperature levels; increase or decrease in precipitation and so on. Those who said they had perceived climate change were further asked whether they had adopted some adaptation strategies to deal with the challenges of climate change or not and so on, as explained in the research design ("[Research design and approach](#)" section) above. We generated frequencies to describe the farmers' perception of changes in climate and level of practice of adaptation strategies using the Statistical Products and Service Solutions (SPSS) formerly known as Statistical Package for the Social Sciences (SPSS).

The count of adaptation strategies selected by each farmer was categorized into ranges: 1–2 strategies denoting a low level, 3–4 strategies indicating a moderate level, and 5–7 strategies representing a high level of adaptation. This categorization aimed to gauge the extent of adaptation endeavors undertaken by farmers, of different socioeconomic characteristics and how this varied among smallholder farmers across the agro-ecological zone. Throughout the survey, we conducted discreet observations to verify the implementation of reported adaptation strategies, seamlessly integrated with questionnaire administration. An observation guide was utilized to facilitate this process. Besides, the authors organized dissemination workshops with the respondents to triangulate the quantitative results and increase accuracy and reliability.

We then ran a multinomial logistic regression model to analyze the drivers of variation in the levels of adaptation to climate change among farmers. Farmers' level of adaptation, that is, the number of adaptation strategies that a farmer adopts (1 to 2, 3 to 4 and 5 to 7), can be influenced by a number of determinant factors including, gender, age, among others. This variable, categorical classes of adaptation levels were modelled against the multiple independent variables with underlying categories such as sex with its groups of male and female among others. The MNL is a statistical method that has been suitably used to establish relations between multiple categorical outcomes based on one or more independent variables as shown in Table 1 [47].

To explain the MNL model, y , denotes a random variable taking on values $\{1, 2, \dots, J\}$ for J , a positive integer, and let x denote a set of determining variables. In the case of our study, y denotes a set of adaptation levels, that is, 1 to 2, 3 to 4 or 5 to 7 and x , the different socioeconomic characteristics of the farmers (as described in "Research design and approach" section), that determine their level of adaptation to climate change. Then question then is, *ceteris paribus*, how changes in the elements of x (socioeconomic characteristics of the farmers) affect the response probabilities in y , (the level of adaptation of farmers) as seen in the equations below;

$$(P(y = j/x), j = 1, 2, 3, \dots, J). \quad (2)$$

Since the probabilities must sum up to unity, $P(y = j/x)$ is determined once we know the probabilities for $j = 2, \dots, j$.

Let x be a $1 \times K$ vector with the first element unity. The MNL model has response probabilities:

Table 1 Hypothesized explanatory variables and their descriptive statistics for Multinomial Logistic model

Predictor variables	Variable description	Hypothetical relationship
Age (yrs)	1. ≤ 30	$\pm$
	2. 30 – 39	
	3. 40 – 49	
	5. 60+	
Gender	1 = Male	$\pm$
	2 = Female	
Belonging to a social group	0 = No	$\pm$
	1 = Yes	
Access to information	1 = Yes	+
	2 = No	
Access to loans	1 = Yes	+
	2 = No	
Level of Education	1. No education	$\pm$
	2. Primary	
	3. Secondary	
	4. Higher	
Technologies used	0. None	$\pm$
	1. 1 – 2	
	2. 3 & above	
House hold size	1. ≤ 5 members	$\pm$
	2. 5 – 9 members	
	3. 10–15 members	
	4. 15+ members	
Monthly income	1. Less 10,000UGX	+
	2. 10 – 100,000 UGX	
	3. 110000 – 200000 UGX	
	4. 210000 – 300000 UGX	
	5. ≥ 300000 UGX	
Farm size	1. Less 2 acres	$\pm$
	2. 2 – 4 acres	
	3. 4– 6 acres	
	4 6+ acres	

Source: Authors

$$P(y = j/x) = \frac{\exp(x\beta_j)}{1 + \sum_{h=1, \dots, J}^J} \quad (3)$$

Where β_j is $K \times 1$, $j = 1, \dots, J$

The model is advantageous because it permits the analysis of decisions across more than two categories, allowing determination of choice probabilities for different categories [5, 21, 28]. Table 1 shows the hypothesized relationship between the explanatory variables and their descriptive statistics for MNL regression.

Results and discussion

Socio-demographic profile of the respondents

We divided the 384 total sample size across the studied districts equally with 50% respondents from each

to make up the 100% needed for the study. The male respondents dominated the sampled respondents with 60% and 40% female respondents as seen in Table 2. Of this, the majority 53% were aged between 30–49 years

Table 2 The socio-demographic characteristics of the respondents

Socio-demographic characteristics		F(n)/384	%
Districts	Pallisa	192	50
	Tororo	192	50
Age (Yrs)	18 –30 years	53	14
	30–39 years	100	26
	40–49 years	103	27
	50–59 years	70	18
	60 years +	58	15
	< 20 years	115	30
Farming experience	20–30 years	164	42
	31–40 years	57	15
	41–50 years	33	9
	50 years +	15	4
	No formal education	64	17
Education level	Primary education	213	55
	Secondary education	85	22
	Tertiary education	22	6
	< 2acres	128	33
Farm size (acres)	2–4 acres	206	54
	4–6 acres	35	9
	> 6 acres	14	4
	Male	232	60
Sex	Female	152	40
	< 10,000 UGX	35	9
Monthly income (ugx) (1USD=37,500UGX)	10,000–100,000 UGX	255	66
	100,100–200,000 UGX	53	14
	200,100–300,000 UGX	19	5
	> 300,000 UGX	24	6
Group membership	No	124	32
	Yes	260	68
Received weather information	No	33	9
	Yes	351	91
Source of weather information	Government	22	6
	Farmers	105	27
	News	221	58
	Relatives	35	9
Access to farm extension services	Yes	208	54
	No	178	46
Access to credit for farming activities	yes	223	58
	No	161	42
Household size	< 5 members	149	39
	5–9 members	132	34
	10–15 members	72	19
	15 members +	32	8

Source: Field data

followed by respondents aged above 50 years were 33%. The survey had only 14% of the respondents who were aged between 18 to 30 years of age. With farming experience, the majority 72% of the respondents had practiced agriculture for less than 30 years. Only 28% had farming experience beyond 31 years in the study area. The majority 55% of these participants had primary education as their highest level of education followed by those with secondary education at 22%. Only 6% constituted those who had tertiary education levels. In line with farm size, the majority 87% of the respondents had less than 4 acres of farm size and only 13% had more than 4 acres of farm size. The majority 78% of the farmers earned less than 100,000 UGX (27 USD) monthly. Only 25% earned more than 27 USD among the respondents. The majority of the respondents belonged to a social group with 68% and only 32% did not associate with social groups. Concerning household size, the majority 53% of the smallholder farmers who participated in the study had between 5 to 15 members. 39% had household sizes less than 5 members. Only 8% reported having more than 15 members in the household by the time of data collection.

In line with other determinants that supported household adaptation such as access to weather information, the majority of the farmers reported to access such services by 91% and only 9% did not receive weather information. Of the 91% of farmers, 58% got information regarding weather forecasts from news updates majorly through radio. Others such as 27% got weather information from their colleagues and only 9% could access the information from relatives and family members. Access to extension services was highly reported by 54% of the respondents and 46% did not access extension services. Finally, the majority 58% of the respondents accessed

credit for farming activities and only 42 reported not to be accessing the credit services by the time of data collection as shown in Table 2.

Perception on the climate change extremes

According to [29], for farmers using traditional agricultural techniques to adapt to climate change, they must first recognize that the climate has changed. Afterwards, they need to identify and implement potentially useful adaptation strategies. Accordingly, before finding out whether they adapt to climate change, the farmers were asked about their perception whether climate is changing or not over the previous years. Majority of the respondents, 85.9% in the BCMS and 93.8% in the TS sub zone observed that indeed climate change is occurring as shown are shown in Table 3.

The responses from farmers across the entire agro-ecological zone regarding their knowledge of rainfall and temperature for a period of ten years are summarized in Table 3. It was observed that a majority of respondents witnessed a rise in temperature and a decline in rain water during the period under review. Specifically, in the BCMS sub-zone, 55.7% of farmers noted an increase in temperature, while 61.5% reported a reduction in rainfall over the past decade. Conversely, in the TS sub-zone, 57.8% of respondents observed a rise in temperature, with 59.9% noting a decrease in rainfall over the same period. A smaller percentage of respondents from both sub-zones reported either constant (TS: 6.3%, BCMS: 5.2%) or fluctuating (TS: 21.4%, BCMS: 9.9%) patterns in both temperature and rainfall.

We noted that farmer's knowledge on rainfall trends slightly differed from other studies conducted in other regions of the country such as those by [31] and [32]

Table 3 Farmers' perception on the past climate change conditions

Climatic Parameter	Farmers' response	Response rates	
		BCMS sub zone	TS sub zone
		%	%
Ever noticed climate change?	Yes	85.9	93.8
	No	14.1	6.3
	Increasing	26	15.6
Rainfall trend over the previous years	Decreasing	61.5	59.9
	Constant	4.7	8.3
	Fluctuating	7.8	16.1
	Increasing	55.7	57.8
Temperature trends over the previous years	Decreasing	29.2	14.6
	Constant	5.2	6.3
	Fluctuating	9.9	21.4

Source: Field data analysis

who noted farmers' perceptions of increasing temperature and rainfall, albeit with shorter rainfall seasons or altered onset and cessation dates, impacting farmers' calendars. However, the perceptions of farmers in this study align closely with those of other studies conducted across Africa, including [17] in Uganda, [4, 19] for Ethiopia & [33] for Ghana. These studies collectively indicated that farmers point to increase in temperature and a decrease in rainfall within the three past decades or so, with some aligning closely with observed climate data [25].

Level of adaptation to climate by subzone and socioeconomic characteristics

We present and discuss an analysis of the extent to which smallholder farmers with diverse socioeconomic characteristics have adapted to the challenges posed by climate change, focusing specifically on the number of adaptation strategies adopted. We explored whether this adaptation level varies among farmers of different socioeconomic characteristics and spatially across different sub-zones of the Kyoga plains agro ecological zone as depicted in Fig. 4. We began by identifying the most common adaptation methods through a review of existing literature and subsequent validation during pre-survey reconnaissance. Consequently, the primary adaptation strategies prevalent in the area emerged, including the utilization of fast-yielding varieties, adjustment of planting dates, mulching, soil conservation practices, tree planting, and diversification of farming activities. The other adaptation strategies were irrigation, and crop intercropping. Farmers were then asked to indicate the number of adaptation strategies they employed from this list. These responses were aggregated into three categories: 5–7 strategies, representing the highest level of adaptation; 3–4 strategies, denoting a moderate level; and 1–2 strategies, indicating a low level. Subsequently, these categories were cross-tabulated with the various socioeconomic characteristics of farmers across different sub-zones within the agro-ecological zone to discern variations in adaptation levels.

In the BCMS sub zone, majority of the farmers who adopted 5–7 adaptation measures (27.3%), were in the 40–49 and 50–59 age groups while most of those who adopted 3–4 adaptation strategies (27.1%) and those who adopted 1–2 adaptation strategies (27.0%), were in the 30–39. In the TS sub zone, majority of farmers who adopted 5–7 strategies (24.6%) were in the 50–59 age group, those who adopted 3–4 strategies (35%) were in the 40–49 age group and those who adopted 1–2 strategies (34%), were in the 30–39 age group. Descriptively this implies that in both sub regions, the level of adaption varied with the age of the farmer as the majority of those

who had the highest level of adaptation (5–7 strategies) were in the higher age groups and vice versa.

In the BCMS sub zone, the highest percentage of farmers with 5–7 adaption strategies (45.5%) were those with 20–30 years of experience. The majority of those in the second category, 3–4 adaptation strategies (40.7%) were those with less than 20 years of experience and the majority of those in the last category of adaptation, 1–2 strategies, (40.5%) were those with 50 and above years of experience. In the TS sub zone on the other hand, most of the farmers at all the adaptation levels, 5–7 adaptation strategies (40.4%), 3–4 strategies (50.0%), and 1–2 adaptation level (40.0%) had 20–30 years of experience. In both sub zones, increase of adaptation level with age ended at 30 years of experience. This probably shows that beyond a certain level of experience, it's difficult to make farmers learn new innovations perhaps because they become risk averse or they feel they know enough and so cannot easily take in new advice, where it exists [34] noted that farming experience has a significant positive impact on farmers' ability to adapt to climate extremes.

With regard to education, in the BCMS sub zone, the majority of farmers at all levels of adaptation, 5–7 strategies (50.0%), 3–4 strategies (64%) and 1–2 strategies (50.5%) were those at the level of primary education. Similarly, in the TS sub zone, most of the farmers at all the adaptation levels, 5–7 (54.4%), 3–4 (50.0%) and 1–2 (48.6%) were at primary level education. This likely suggests that education is crucial in enabling farmers to value innovation for adaptation. However, once a certain level is reached, many farmers tend to shift their focus to non-farm sources of income. The BCMS sub zone, a high number of male famers had the highest level of adaptation, 5–7 (68.2%), while the majority of those in the second category 3–4 (61.0%) and third category, 1–2 (58.6%) were females. Similarly, in the TS sub zone, most of the farmers at all the adaptation levels, 5–7 (91.2%), 3–4 (76.0%) and 1–2 (57.1%) were males. This implies that gender determines the level of adaptation since at a higher adaptation levels there are more males than females probably because they have more resources given their gender biased position in society.

The majority of farmers in the BCMS sub zone at all levels of adaptation, 5–7 (59.1%), 3–4 strategies (54.2%) and 1–2 strategies, (45.5), had 2–4 acres of land. In the same way, most of the farmers in the TS sub zone at all the adaptation levels, 5–7 (61.1%), 3–4 (61.1%) and 1–2 (57.1%), had 2–4 acres of land. This probably implies that the level of adaptation rises with the rise in size of land owned but only up to 2–4 acres of land and beyond this, the farmers perhaps shift their attention to non-farm sources of income hence not paying much attention to increased adaptation.

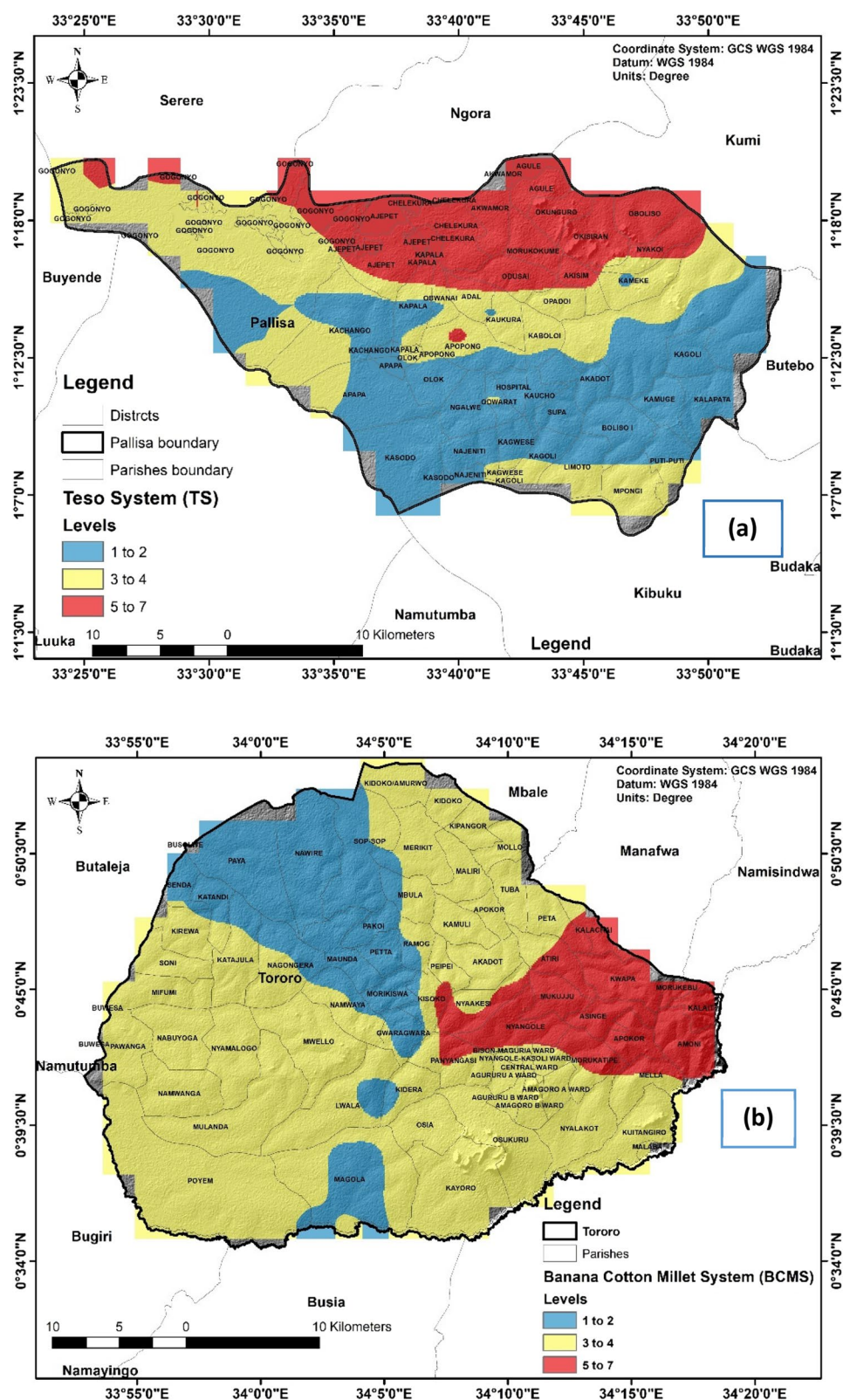


Fig. 4 The spatial interpolation of adaptation levels by subzones (a) TS and (b) BCMS

Most farmers at the highest level of adaption, 5–7 strategies (36.4%) in the BCMS sub zone, were those earning 101,000–200,000 shillings per month. Most of those in the adaptation level, 3–4, (66.7%) and most those at the lowest level of adaptation, 1–2 strategies (79.4%) were those earning 10,000–100,000= . In the TS sub zone, most of the farmers who adopted 5–7 (52.8%), 3–4 (70.2%) and 1–2 (77.1%) adaptation strategies were those earning 10,000–100,000= per month. Looking at the scenario from both sub zones jointly, it can be noted that the level of adaptation rises with the level of income at least up to the 200,000= mark.

In the BCMS sub zone, most of the farmers all levels of adaptation, 5–7 strategies (86.4%), 3–4 strategies (79.7%), and 1–2 strategies (68.5%) were those who belonged to a social group. Similarly, in the TS sub zone, most of the farmers at all the levels of adaptation, 5–7 (61.4%), 3–4 (66.0%) and 1–2 (51.4%) were those who belonged to a social group. This implies that belonging to a group highly influences adaptation probably due to peer to peer farmer education.

Just like in the case of social network, most of the farmers at all the adaptation levels, 5–7 (77.3%), 3–4 (84.7%) and 1–2 (88.3%) in the BCMS sub zone had access to climate change information. Similarly, in the TS sub zone, majority of the farmers at all adaptation levels, 5–7 (96.5%), 3–4 (98.0%) and 1–2 (94.3%), had access to climate information. This implies that the level of adaptation is positively related to access to climate information.

The majority of farmers in the BCMS sub zone at the 5–7 level of adaptation (72.7%) were those who had access to information services while at the 3–4 level, most of the farmers (56.9%), had no access to information services. Majority of those at the 1–2 level (55.0%) also had access to information services. In the TS sub zone on the other hand most of the farmers at all the levels of adaptation, 5–7 (54.4%), 3–4 (55.6%) and 1–2 (57.1%), had access to information services. This shows an increase in the level of adaptation with increase in access to information services implying that access to information services is key to achieving a high level of adaptation.

The highest percentage of farmers at all the levels of adaptation, 5–7 (72.7%), 3–4 (59.3%) and 1–2 (51.8%) in the BCMS sub zone were those who had access to credit. In the same way, most of the farmers in the TS sub zone at first two levels adaptation, 5–7 (56.1%) and 3–4 (56.0%) while those at 1–2 (57.1%), had no access to credit. This suggests that access to credit significantly enhances a farmer's ability to adapt to changing conditions support this notion with their study in northern Ethiopia, where they found that improving farmers' access to credit increased the likelihood of adopting crop diversification strategies by 10.6%. This finding indicates

that access to credit enables poor farmers to make more productive investments, thereby improving their resilience and capacity to adapt to climate change.

In the BCMS sub zone most of the farmers at the 5–7 level of adaptation (54.5%), had 5–9 house hold members, majority of those at the 3–4 level of adaptation (52.5%) had less than 5 household members and most of those in the 1–2 level (51.8%) had less than 5 household members. In the TS sub zone, most of the farmers at the 5–7 level of adaptation, (31.6%) had less than five household members, those at 3–4 (37.8%) had 5–9 household members and those at 1–2 (40.0%), adaptation level had less than five household members.

Determinants of variation in the level of adaptation to climate change among small holder farmers

In this section, we only looked at and discussed variables that were statistically significant at the 10% level or lower as seen Table 4. The findings demonstrated a strong negative relationship between female gender and the use of three or four adjustment techniques in the TS subzone. However, in the BCMS subzone, the connection was favorable but not statistically significant. Female farmers were much less likely than male farmers to select 3–4 adaptation methods in the TS subzone, compared to the base category of 1–2 strategies. Similarly, female farmers in the TS subzone were much less likely to use 5–7 adaptation strategies compared to the base group's 1–2 strategies, with a negative and significant connection found.

This validated our hypothesis that male farmers had more opportunity to exercise higher levels of adaptation than female farmers, which was consistent with previous research [4, 30].

Membership in a group exhibited a significant positive association with the adaptation levels of 3 to 4 strategies in both the TS (0.081) and BCMS (0.070) subzones, compared to the reference category of 1 to 2 strategies. Furthermore, there was a positive link between group membership and the practice of 5–7 adaptation techniques in both subzones, albeit this relationship was only statistically significant at 10% in the BCMS subzone. This spatial variance indicated disparities in the extent of coping to climate extremes between farmers in groups and those not in groups across the Kyoga Agro-ecological zone, which is consistent with earlier findings [5, 48].

Income was significantly linked with the use of 3–4 (0.70) and 5–7 (0.013) adaption strategies in the BCMS subzone when compared to the base category of 1–2 techniques. However, in the TS subzone, the association, albeit positive, was not significant. This indicated that greater income levels were associated with a higher level of adaptation, supporting our hypothesis of variance in adaption levels among farmers of various income levels

Table 4 Determinants of adaptation levels among smallholder farmers (Base outcome was 1–2 strategies)

Adaptation levels (Base outcome = 1–2 strategies)	BCMS sub zone			TS sub zone		
	Coef	RRR	P>z	Coef	RRR	P>z
3—4 strategies						
c.a1age#c.aii_farm_exp	0	1.0	0.115	0	1	0.944
Sex (RC: male)						
Female	0.24	1.3	0.554	−1.4	0.25	0.004
Monthly income	0	1.0	0.07	0	1	0.622
Belonging to a group (RC: No)						
Yes	1.08	3	0.07	1.03	2.8	0.081
Access to extension workers (RC: 1)						
No	0.87	2.4	0.036	0.54	1.71	0.274
Access to loans (RC: 1)						
No	0.62	1.9	0.264	−0.35	0.71	0.548
Education level (RC = No formal education)						
Primary education	0.97	2.6	0.059	0.97	2.63	0.17
Secondary education	−0.32	0.7	0.682	0.3	1.34	0.718
Higher	0.21	1.2	0.848	0.61	1.84	0.655
No of farming equipment	0.25	1.3	0.246	−0.46	0.63	0.056
Constant	0.96	0	0	0.65	1.91	0.515
5—7 strategies						
c.a1age#c.aii_farm_exp	0	1	0.013	0	1	0.406
Sex (RC: male)						
Female	−0.66	0.5	0.247	−2.46	0.09	0
Annual income	0	1	0.013	0	1	0.687
Belonging to a group (RC: 0)						
Yes	1.58	4.9	0.084	0.6	1.82	0.361
Utilizing extension services(RC: 1)						
No	0.15	1.2	0.826	0.89	2.43	0.103
Credit/loans (RC: 1)						
No	0.69	2	0.384	−0.32	0.73	0.62
Education (RC = No formal education)						
Primary	2.4	11	0.03	2.89	18.03	0.018
Secondary	2.83	17	0.014	2.54	12.71	0.052
Higher	1.92	6.8	0.189	3.56	35.3	0.037
No of farming equipment	0.42	1.5	0.138	−0.31	0.73	0.231
Constant	−6.77	0	0	−2.25	0.1	0.123

Source: Field data analysis

RC Reference category, LR Likelihood Ratio, 1=yes, 0=No, RRR Relative Risk Ratio, P>z = P-value

across subzones. This study contradicted that of [34] who discovered a strong negative influence of income on climate change adaption in Ethiopia.

Education was positively and significantly linked with the practice of 5—7 adaption methods in both the BCMS and TS subzones, as opposed to the base category of 1—2 strategies. Primary education was highly associated to the practice of 5—7 techniques in both subzones, with secondary education also showing a tight relationship. However, there was regional variance in the extent of adaptation among farmers with higher education levels

within the Kyoga plains Agro-ecological Zone. The association between adaptability and higher education was positive in both subzones, although it was more significant in the TS subzone than in the BCMS subzone. Thus, adaptability increased with education level, but this variation was uniquely associated to higher education across the studied zones, as previously reported by [49].

The absence of access to information services was found to have a positive and significant association with the use of 3 to 4 adaptation strategies in the BCMS subzone, though not in the TS subzone. This suggests that

farmers in the BCMS area lacking access to information services were still capable of implementing three to four adaptation measures. This discrepancy in adaptation levels among farmers without access to information services challenges the commonly held belief that such services facilitate greater practice of climate change adaptation strategies. This finding contrasts with the assertion by [50] that training provided by extension workers can enhance farmers' readiness to confront climate change challenges.

Conclusion and recommendations

Our study underscore the pressing need for tailored interventions to address the challenges of climate induced drought faced by the smallholder farmers in the Kyoga plains Agro-ecological zone of Uganda. Farmers are already grappling with adverse climate impacts, including rising temperatures and decreasing rainfall, which have significantly affected agricultural production. To combat these challenges, farmers are employing various adaptation strategies, but their ability to do so is hindered by predictors such as limited availability of information and gender disparities, while positively influenced by group membership, income, and education. Support farmers operating on small pieces of land < 2 acres in coping to climate extremes through targeted interventions including a comprehensive support for indigenous adaptation strategies, with a specific focus on addressing gender disparities coping styles. Additionally, enhancing the effectiveness of information services and improving their delivery methods are crucial steps. Furthermore, the study highlights the importance of designing location-specific adaptation strategies tailored to the socio-economic characteristics of farmers in each subzone, rather than adopting a one-size-fits-all approach. This approach is vital for mitigating the impacts of climate change and improving the livelihoods of farmers in the Kyoga plains Agro-ecological zone. Further research can be focused on modelling the future climate scenarios for Kyoga plains since farmers would incorporate prepare for the either worse, similar or ameliorated climate conditions as predicted in the study.

Supplementary Information

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Supplementary Material 1.

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Authors' contributions

CO – Conceptualization, investigation, writing original manuscript, data curation, funding; P.I.M—Supervision, Conceptualization, review of draft and final manuscript; GO—Conceptualization, Visualization, writing original manuscript, review of draft and final manuscript, & Y.K – Writing original manuscript, formatting, review of draft and final manuscript and visualization.

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Data availability

Data cannot be shared openly but will be available on request from the corresponding author.

Declarations

Ethics approval and consent to participate

The study was approved by the Higher Degrees Research Committee of the School of Forestry, Environmental and Geographical Studies of Makerere University during the doctoral study of the first author. The ethical considerations of participant consent, confidentiality, academic integrity and avoidance of harm. We strictly adhered to these ethical concerns issued by the committee through the following ways;—(i) To maintain peace and harmony with respondents, the first author carried out field visits through the local administrative structures such as the Local Council leaders and technical persons. The meetings with the leaders acted as amicable grounds to discuss the goal and objectives of the study. With their consent and permission, we were then guided to the targeted study areas which were the hotspots of the climate change extremes. Informed consent was obtained from all participants. Participants that voluntarily consented to participate in the study were considered all through the process of data collection. In the consent forms, we disclosed the risks associated with the interview process to respondents including sitting for several minutes close to an hour, cognitive strain, psychological distress during the interview to ensure harmony and safety of our participants. All respondents were at the liberty to skip questions or withdraw from the interview without any consequence. During reporting, we didn't mention direct names, position and any information about the respondent that would result into exposure of the respondents.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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