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Determinants of smallholder farmers' adaptation strategies to the effects of climate change: Evidence from northern Uganda

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Abstract

Background: Climate change poses a threat to the sustainability of food production among small-scale rural communities in Sub-Saharan Africa that are dependent on rain-fed agriculture. Understanding farmers' adaptations and the determinants of their adaptation strategies is crucial in designing realistic strategies and policies for agricultural development and food security. The main objectives of this study were to identify the adaptation strategies used by smallholder farmers to counter the perceived negative effects of climate change in northern Uganda, and factors influencing the use of specific adaptation strategies. A cross-sectional survey research design was employed to collect data from 395 randomly selected smallholder farmers' household heads across two districts by the administration of a semi-structured questionnaire. Binary logistic regression was used to analyze the factors influencing farmers' adaptation to climate change.

Results: The three most widely practiced adaptation strategies were planting of different crop varieties, planting drought-resistant varieties, and fallowing. Results of the binary logit regression model revealed that marital status of household head, access to credit, access to extension services, and farm income influenced farmers' adoption of planting drought-resistant varieties as an adaptation strategy while access to credit, annual farm income, and time taken to market influenced adoption of planting improved seeds. Gender of household head and farm income had a positive influence on farmers' adoption of fertilizer and pesticide use. Farming experience, farm income, and access to extension services and credit influenced farmers' adoption of tree planting. Household size, farming experience, and time taken to market had positive influence on the use of fallowing, while size of land cultivated significantly influenced farmers' planting of different crop varieties as an adaptation strategy.

Conclusion: Findings of the study suggest there are several factors that work together to influence adoption of specific adaptation strategies by smallholder farmers. This therefore calls for more effort from government to strengthen the provision of agricultural extension services by improving its climate information system, providing recommended agricultural inputs and training farmers on best agronomic practices to enhance their holistic adaptation to the effect of climate change.

Keywords: Adaptation options, Adaptive capacity, Coping strategies, Climate variability, Smallholder agriculture

Background

The consensus by policymakers, practitioners, and researchers today is that adaptation to climate change is not happening at the desired pace [1]. Frequent floods, land degradation, and droughts are some of the

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indications of climate change leading to agricultural productivity losses [2]. The Intergovernmental Panel on Climate Change (IPCC) defines human adaptation as "the process of adjusting to actual or expected climate variability and its effects to moderate harm or exploit beneficial opportunities" [3]. The process of adjustment to actual or expected climate is normally affected by several factors (herein referred to as barriers). Barriers are the factors and conditions that may hinder or prevent this adjustment to climate change and its effects and are categorized into financial, technical, socio-cultural, and political economic [4, 5].

Inadequate capacity to adapt to the effects of climate change has resulted in global food insecurity which remains a worldwide concern for the next 50 years and beyond [6]. This appalling situation is partly because of the elusive conceptualization of food security yet its indicators are oriented to one or more of its dimensions of availability, access, utilization, and stability [7]. Although agroecological approaches offer some promise for improving yields, achieving food security needs policy, and investment reforms on multiple fronts, including human resources, agricultural research, rural infrastructure, water resources, and farm- and community-based agricultural and natural resource management. [8].

Sub-Saharan Africa has been identified as one of the regions most vulnerable to the negative impacts of climate change compared to other regions [9–12]. This is because of their low level of adaptation capacity and poverty [13, 14]. In developing countries, the adaptation of the agricultural sector to the present changing climate is necessary for ensuring the livelihoods of the poor communities [15, 16]. This initiative can be made possible through the participation of multiple stakeholders, such as policymakers, extension agents, Non-Governmental Organizations (NGOs), researchers, and the local farming communities. However, the adaptation to climate change is mostly location specific, and the adaption strategies employed by farmers depend on the local institutions, and various socioeconomic and environmental factors, e.g., education level, gender, age, farming experience, and wealth of household head, family size, farm size, access and availability of markets, access to extension and credit, access to climate information, and favorable agricultural policies in place [15, 17–19].

Uganda is one of the countries in Africa that is heavily burdened by the effects of climate change, and those who are most vulnerable are the smallholder farmers who constitute the majority (85%) of the farming community [1]. More than half of the rural households are dependent on agriculture for their livelihoods, and nearly half of those rural households that depend on agriculture usually experience one or more of the several forms of food insecurity resulting from the decline in household food production and diversity due to climate change [20]. The Uganda Bureau of Statistics (UBOS) defines smallholder farmers as those who usually cultivate less than one hectare of land in a cropping season, practice labor intensive farming using rudimentary technology especially the hand hoes, own a few heads of cattle, and produce mainly for family consumption, with a limited surplus for the market. Family labor is their main source of labor and is particularly undertaken by women and children. Besides, they lack efficient means of transport to take the surplus produced to the market centers forcing them to sell at the farm gate at low prices [21]. Along the agricultural value chain, smallholder farmers in Uganda face a multitude of constraints, such as inadequate knowledge and skills for value addition, inadequate financial capacities to purchase, and use the right inputs which limit their ability to increase productivity and access the markets.

Materials and methods

Study area

This study was conducted in Apac and Amuru districts of Northern Uganda (Fig. 1). We selected these two districts because they are characterized by different agro-climatic conditions and predominant production systems. Apac district is located in the cattle corridor that stretches from southwestern to northeastern Uganda. The cattle corridor is dominated by pastoral rangelands and has semi-arid characteristics. On the other hand, Amuru district is located outside the cattle corridor. The two districts cover a total area of 7,534 km^2. The farming system in both districts is predominantly annual cropping and livestock rearing [29]. Farming in the two districts is largely small scale, with Apac practicing both small-scale livestock rearing and crop farming [30], while Amuru is predominantly inhabited by crop farmers with a few families keeping domestic livestock at subsistence level [31]. Apac district lies between longitudes 32° E and 34° E and latitudes 2° N and 3° N (Fig. 1), and its southern boundary is bordered by Lake Kwania and the river Nile. Apac District has a unimodal season and receives a total annual rainfall of 1,330 mm which falls predominantly from April to November with peaks in April and August. The dry season is from December to March and the average monthly minimum and maximum temperatures are 17 °C and 29 °C, respectively [24]. Amuru district lies between longitudes 30° E and 32° E and 2° N and 4° N (Fig. 1). The district is endowed with vast fertile soils that support farming [32]. Amuru experiences dry and wet periods throughout the year and receives a mean annual rainfall of 1,434 mm [25]. The wettest period extends from April to October, with its peaks in May, August, and October, while the dry season is from the end of November to end

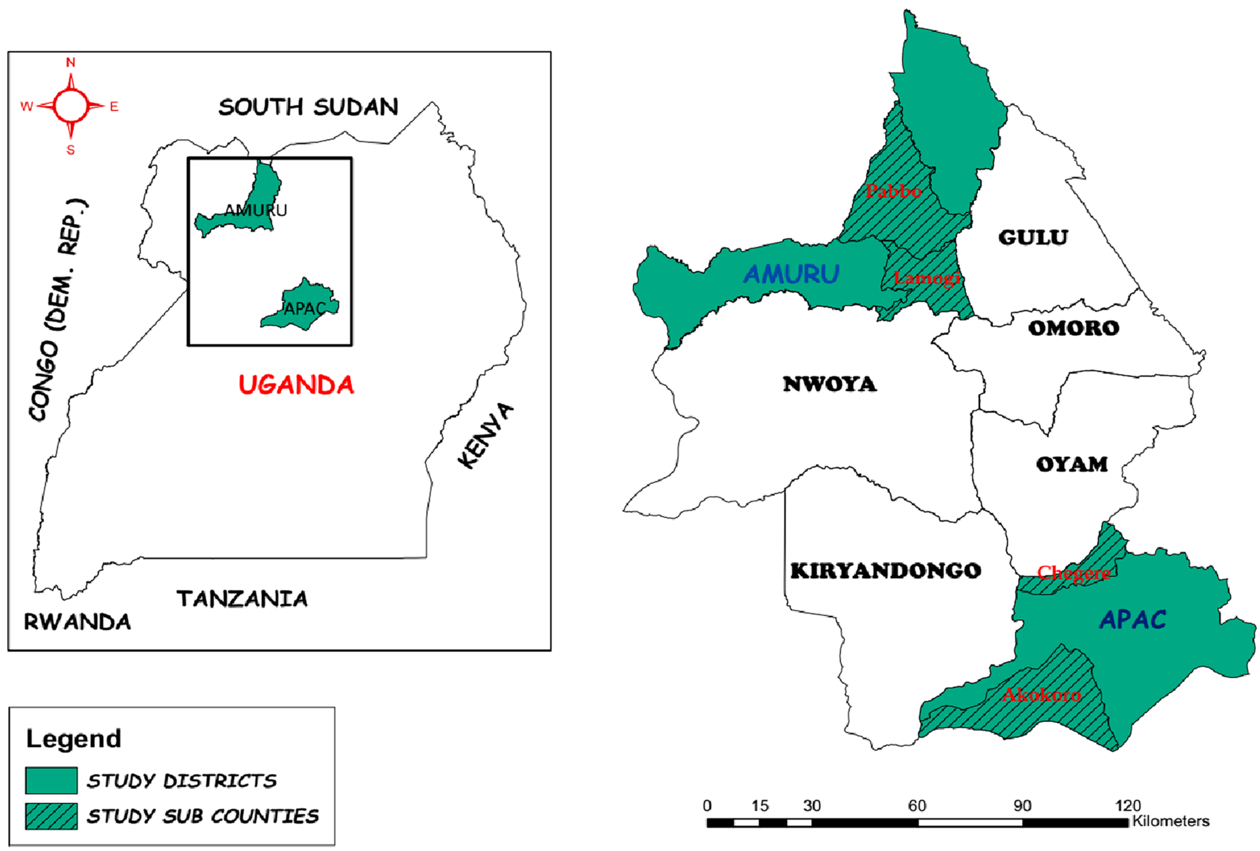

Fig. 1 Location of the study areas (Apac and Amuru districts) in Uganda. The map was created by the authors using ArcGIS version 10.3.1

of March. Average maximum and minimum temperatures in Amuru are 30.5 °C and 16.8 °C [33], respectively.

Sampling design and sample size

The target population of smallholder farmers was selected using a multistage sampling technique. First, the two districts were purposively selected based on the limited researched information regarding the adaptation of smallholder farmers to the effects of climate change, and the highly agrarian nature of their population and location in the cattle corridor. From each district, two sub-counties—Paboo and Lamogi (in Amuru) and Akokoro and Chegere (in Apac district)—were randomly selected. In each of the selected sub-counties, two parishes were randomly selected totaling to eight parishes. From each of the parishes, one village was randomly selected making a total of eight villages for the entire study. Finally, 395 households [34] were randomly and proportionally selected from the eight villages, 260 for Apac and 135 for Amuru districts. A cross-sectional survey (conducted from December 2018 to May 2019) was employed to collect primary data from farming household heads. The survey was piloted at Paicho sub-county in Gulu district with 20 farmers (13 males and 7 females). The surveys were carried out by trained data enumerators. The primary data obtained included data on the socio-economic characteristics of the farmers, such as gender, age, marital status, land owned, land cultivated, education level, farming experience, annual farm income, distance to the nearest market, time taken to the nearest market, access to extension services, access to credit facilities, and farmer group membership. During the interview, individual farmers/household heads were also asked what climate change adaptation strategies they implement to counter the impacts of climate change on their farming activities.

Econometric analyses

In mitigating the effects of climate change, farmers usually adapt a number of strategies with the decision to use a given strategy being guided by the Utility Maximization Theory. The theory postulates that economic units (farmers) make decisions guided by the expected benefit that they expect to obtain from such a decision, amidst a set of constraints [35–37]. Consequently, a given climate change adaptation strategy would be used only if the expected net benefits from its use surpasses the expected net benefits from non-use. The choice of each of the adaptation strategy available to farmers is thus a binary decision. Given this binary nature, a Binary logistic regression (BLR) model was employed to identify the factors that determine the smallholder farmers' adaptations to climate change. The model was applied separately to each of the seven adaptation strategies identified among farmers in the study area. The advantage of the BLR is that it permits analysis of dichotomous decisions, such as when a farmer adapts the practice to counter the effects of climate change or not, allowing the determination of choice probabilities for the different categories [38].

Let Y be our binary outcome variable adaptation strategy. We define Y as specified in Eq. (1):

$$Y_i = \begin{cases} 1 \text{ if the } i\text{th farmer uses a given adaptation strategy} \\ 0 \text{ otherwise} \end{cases} \quad (1)$$

In this case Y_i is a latent variable with probabilities p for $y_i^* = 1$ and $1 - p$ for $y_i^* = 0$. $\mathrm{Y_i}$ is a dichotomous dependent variable, i.e., 1 if a farmer has adapted and 0 otherwise to climate change. In this study, seven dichotomous choice variables of adaptation strategies were considered (Table 2), and, as such seven separate binary logistic models, were estimated.

The binary dependent variables were regressed against the X variables as specified in Eq. (2):

$$Y_i^* = \alpha + X_I' + u_i, \quad (2)$$

where X_i' represents a vector of explanatory variable which influences a given adaptation practice. These variables are described in Table 1. α is the constant term, β is a vector of parameters to be estimated associated with farm specific attributes, while u_i is the error term. The conditional probability is estimated from specification given in Eq. (3):

$$\Pr(z_i = 1|x) = F\left(x_i'\delta\right), \quad (3)$$

where $F(.)$ is the cumulative logistic density function that applies to the binary logit model.

Prior to the logit regression, we checked for multicollinearity among the explanatory (independent) variables using a correlation test. Variables that were strongly correlated to each other (correlation coefficient above 0.5) were dropped from the regression analyses. Thus, age and distance to the nearest market were removed due

Table 1 Description, definition, and values of variables used in the logistic regression

Variable	Definition	Value and unit of measurement	
Dependent variables			
Adaptation strategy	Adaptation options	Dummy, 0 = not using the adaptation strategy 1 = using the adaptation strategy	
	Adaptation strategies considered in this study included planting of drought-resistant varieties, use of improved seeds, use of chemical fertilizers, use of pesticides, fallowing the garden, and planting different crop varieties		
Variable	**Definition**	**Value and unit of measurement**	**Apriori expectation (Citation)**
Independent variables			
Gender	Gender of the household head	Dummy variable, 0 = Female 1 = male	± [15, 40, 41]
Household size	Number of family members	Categorical, 1 = 1–5, 2 = 6–10, 3 = 11–15, 4 = 16–20, 5 = 21–25	+ [42–44]
Marital status	Marital status of the household head	Dummy variable, 1 = married, 0 = not married	± [4, 45, 46]
Farming experience	Number of years of farming by household	Continuous variable (years),	± [15, 40, 47]
Extension services	Access to extension services	Dummy variable, 1 = access to extension services 0 = otherwise	+ [15, 42–44, 48]
Farmland size owned	Size of farm land owned by the household	Continuous variable (in acres)	+ [15, 40, 42, 43, 49]
Land cultivated	Size of cultivated farmland by the household	Continuous variable (in acres)	− [50]
Credit	Access to credit services	Dummy variable, 1 = access to credit and 0 = otherwise	± [40, 43, 50, 51]
Time to market	Time taken to the nearest market	Continuous variable (minutes)	± [15, 50, 52]
Income	Average annual household income (2018)	Continuous variable (UGX)	+ [40, 47, 48, 53,]
Farmer group membership	Belongs to a farmer's group	Dummy variable, 0 = No, 1 = Yes	± [40, 50, 52]

UGX is Ugandan Shillings ($ 1 = 3,700 UGX)

Table 2 Descriptive statistics of sampled farm households

Variable	Mean	Std. Dev	Min	Max
Gender (1 = Male, 0 = Female)	0.54	0.50	0	1
Household size	6.79	3.63	1	24
Marital status (1 = married, 0 = otherwise)	0.82	0.39	0	1
Farming Experience (Years)	18.80	13.62	1	65
Access to Extension (1 = yes, 0 = No)	0.19	0.39	0	1
Land Owned (Acres)	7.94	32.76	0	600
Land cultivated (Acres)	2.90	1.07	0.5	7
Access to credit (1 = yes, 0 = No)	0.63	0.48	0	1
Time taken to market (Hours)	0.98	0.97	0	6
Farm income (UGX)	821,704.80	717,340.90	10,000	5,000,000
Group membership (1 = yes, 0 = No)	0.48	0.50	0	1

In case of dummies, the mean refers to mean proportions (in percentage)

to their strong collinearity with farming experience and time taken to the nearest market, respectively. Similarly, the education variable was also dropped since the dummies for primary level and secondary level were strongly correlated.

Definition of variables

The dependent variables in this study are the adaptation strategies adopted by farmers (1 if adapted, 0 otherwise, Table 1). The independent (explanatory) variables were chosen based on previous studies [39–41] and they included household characteristics: gender, household size, marital status, farming experience, access to extension services, farmland size owned, land size cultivated, access to credit, time taken to the nearest market, household income, and farmer group membership (Table 1). Among adaptation strategies that were considered in this study, planting of different crop varieties here meant farmers planted multiple crop varieties in one planting season as a way of ensuring that some of the planted crops survive the climate change effects. The planting of drought-resistant crop varieties is where farmers planted crop varieties that are specially designed or adapted to thrive amidst droughts and the famers despite experiencing drought would still have good harvest from such a garden.

Results and discussion

Descriptive analysis of respondents

Table 2 presents the summary of socioeconomic characteristics of households surveyed in the study area. It showed that more agricultural households were headed by male (54% of the household heads) which reflects the patriarchal cultural practices in Africa whereby women are looked at as "inferior" and are not allowed to talk on behalf of the household heads [54]. The average household size was seven individuals which is above the national average of five [32]. Household size is a proxy to labor availability that enables farmers to take labor adaptive measures on their farm. Female heads of households were often divorced or widowed. Over 82% (majority) of the household heads were married and they had an average of 18.80 years of farming experience (Table 2). Several studies have shown that farmers with more years of farming experience perceive climate change adaptation strategies better than those with less experience in farming practices [55]. The surveyed households also owned on average 7.9 acres of land, although they only cultivated an average of 2.9 acres. The majority (63%) of the farmers had access to funding (microcredit) from various registered microfinance institutions, including banks and village savings and loan associations. Only 48% of the household heads belonged to a farmer organization (a village association, cooperative, or a communal union of farmers), and only 19% of the household heads received agricultural extension services. The household heads took on average 0.98 h to travel either from their households to the market or vice versa. Households earned on average of UGX 822,000 (USD 222) income from all the farming activities per year.

Adaptation strategies of smallholder farmers to climate change

The results revealed seven adaptation strategies commonly used by smallholder farmers in both Amuru and Apac districts to mitigate the effects of climate change on their farming activities (Table 3). All the adaptation strategies reported focused on reducing the effects of drought which seem to be a more frequent problem to farmers in the study area [56, 57] compared to floods. Planting different crop varieties was the most widely practiced (96% overall) adaptation strategy by farmers in both districts.

Table 3 Adaptation strategies used by smallholder farmers to mitigate the effects of climate change and the proportion of respondents that practiced them in Amuru and Apac districts

Adaptation strategy	Overall		Amuru		Apac	
	Freq	%	Freq	%	Freq	%
Planting drought-resistant varieties	314	79.5	105	80.8	209	78.9
Use of improved seeds	228	57.9	55	42.3	173	65.3
Use of chemical fertilizers	93	23.6	23	17.7	70	26.4
Intensive use of pesticides	247	62.5	75	57.7	172	64.9
Fallowing the garden	263	66.6	88	67.7	175	66.0
Use of different crop varieties	379	96.4	128	98.5	251	94.7
Practicing tree planting	152	38.5	42	32.3	110	41.5

At the specific study district level, Amuru and Apac had 99% and 95% of its farmers, respectively, adopting the planting of different crop varieties that can tolerate the effects of climate change to improve crop productivity. This finding corroborates a study conducted by FAO in developing countries which revealed that planting different crop varieties enhances achievement of a sustainable agricultural growth for food security amidst climate change [58].

Planting drought-resistant crop varieties was the second most (80%) adopted strategy by farmers in both districts with Amuru having 81% and Apac 79% of its farmers adopting the planting of drought-resistant varieties. Fallowing was the third most adopted strategy (67%) by both districts with 68% of farmers in Amuru and 66% in Apac adopting fallowing. Other adaptation strategies in this study included intensive use of insecticides (63%) for pest control, use of improved seeds (58%), and tree planting (39%) probably to reduce soil erosion and improve water catchment which is in line with the findings of a study conducted in the central rift valley of Ethiopia revealing that increased planting of trees by farmers in the area was mainly to provide natural shade for farmers' crops during the long dry periods [15]. The use of chemical fertilizers (24%) was the least adopted adaptation strategy by farmers. This could probably be attributed to the limited technological skills and financial capacity of smallholder farmers to adequately use chemical fertilizers [15].

Determinants of farmers' adaptation strategies to the effects of climatic change

The binary logistic regression analysis was used to assess the determinants of farmer's adaptation strategies to the effects of climate change. Post-estimation results showed that the Wald Chi was significant for all the adaptation strategies, while the Pearson Chi-square goodness of fit was not significant for all the adaptation, which indicates that our data fits well with the model. In the following sections, the regression results are described and compared to literature. The results of the binary logistic regression (Table 4) showed that some of the explanatory variables influenced the adoption of specific adaptation strategies by smallholder farmers to the effects of climate change.

Gender responsiveness on adaptation

The results revealed that gender of household head had a positive and significant influence on the application of chemical fertilizers and intensive use of pesticides as adaptation strategies to the effects of climate change. Male household heads were 0.78 times more likely to use chemical fertilizers ($p = 0.011$) and 0.66 times more likely to use pesticides ($p = 0.008$) as adaptation strategies to the effects of climate change than their female counterparts. This finding is consistent with a study conducted in Ghana which found that male household heads were more likely to adopt climate-related practices than female household heads [40]. This could be because female household heads are less likely to meet the investment demands for such adaptation practices since they usually have limited access and control to productive and financial resources than their male counter parts [42, 59]. Females also have lower capacities to diversify their sources of income due to heavy domestic responsibilities than their male counter parts [60, 61].

Household size

The results of the study indicated that household size had a significant ($p = 0.018$) effect on adoption of fallowing as an adaptation strategy. This implies that a unit increase in household size reduces the likelihood to use fallowing as an adaptation strategy by 0.087. This finding is in line with a study conducted by Ndamani and Watanabe [40] in the Lawra district of Ghana and by FAO in developing countries [58] which showed that the likelihood of

Table 4 Binary logit model parameter estimates on determinants of adaptation strategies to the effects of climate change

Explanatory variables	Drought resistant varieties		Improved Seeds		Fertilizer use		Pesticide use		Fallowing		Different varieties		Tree planting	
	Coef. (SE)	P > z	Coef. (SE)	P > z	Coef. (SE)	P > z	Coef. (SE)	P > z	Coef. (SE)	P > z	Coef. (SE)	P > z	Coef. (SE)	P > z
Gender of household head	0.562 (0.316)	0.075	− 0.356 (0.248)	0.151	0.778 (0.306)	**0.011**	0.656 (0.246)	**0.008**	0.385 (0.261)	0.140	− 0.044 (0.584)	0.939	0.014 (0.264)	0.956
Household size	-0.025 (0.039)	0.521	− 0.030 (0.034)	0.377	− 0.018 (0.038)	0.641	− 0.041 (0.038)	0.272	− 0.087 (0.037)	**0.018**	− 0.108 (0.068)	0.115	− 0.028 (0.034)	0.415
Marital status	0.913 (0.379)	**0.016**	0.200 (0.324)	0.536	− 0.406 (0.402)	0.313	− 0.406 (0.334)	0.224	0.257 (0.331)	0.437	− 0.546 (0.865)	0.528	0.108 (0.338)	0.748
Farming Experience (Years)	0.015 (0.011)	0.167	0.004 (0.009)	0.652	− 0.004 (0.012)	0.752	0.002 (0.010)	0.873	0.032 (0.010)	**0.001**	− 0.003 (0.023)	0.908	0.024 (0.010)	**0.012**
Access to Extension	1.644 (0.529)	**0.002**	0.296 (0.319)	0.354	0.573 (0.322)	0.075	− 0.041 (0.315)	0.896	0.175 (0.339)	0.605	− 0.981 (0.642)	0.127	0.686 (0.293)	**0.019**
Land Owned (Acres)	0.010 (0.015)	0.507	− 0.011 (0.010)	0.253	0.001 (0.003)	0.917	0.001 (0.003)	0.841	0.041 (0.039)	0.290	0.016 (0.019)	0.419	− 0.002 (0.003)	0.519
Land cultivated (Acres)	0.323 (0.159)	**0.043**	− 0.124 (0.126)	0.328	0.165 (0.145)	0.255	0.138 (0.131)	0.291	0.121 (0.146)	0.409	0.822 (0.286)	**0.004**	0.150 (0.126)	0.235
Access to credit	− 0.686 (0.317)	**0.030**	0.585 (0.252)	**0.020**	0.323 (0.286)	0.259	0.315 (0.254)	0.215	− 0.484 (0.266)	0.069	− 0.686 (0.664)	0.302	0.626 (0.271)	**0.021**
Time taken to market (Hours)	0.068 (0.154)	0.657	0.365 (0.146)	**0.012**	0.150 (0.137)	0.276	0.066 (0.135)	0.623	0.292 (0.145)	**0.044**	− 0.114 (0.279)	0.681	0.130 (0.115)	0.259
Farm income (UGX)	− 0.038 (0.174)	0.829	0.325 (0.157)	**0.038**	0.572 (0.204)	**0.005**	0.508 (0.162)	**0.002**	0.247 (0.152)	0.105	− 0.259 (0.308)	0.400	0.385 (0.169)	**0.022**
Group membership	0.225 (0.296)	0.447	− 0.168 (0.241)	0.486	0.002 (0.274)	0.994	0.084 (0.241)	0.729	0.118 (0.251)	0.637	0.295 (0.491)	0.548	0.005 (0.249)	0.983
Constant	-0.668 (2.226)	0.764	− 3.703 (2.074)	0.074	− 8.248 (2.781)	0.003	− 5.370 (2.126)	0.012	− 3.936 (2.074)	0.058	6.450 (4.606)	0.161	− 7.167 (2.283)	0.002
Log likelihood	− 162.752		− 226.272		− 173.344		− 219.111		− 206.671		− 52.515		− 214.903	
Wald chi2	33.18	0.000	21.04	0.033	33.95	0.000	25.93	0.007	0.039	0.003	22	0.024	34.63	0
GOF Pearson chi2	327.98	0.711	354.74	0.306	369.48	0.147	359.09	0.264	361.66	0.234	311.26	0.875	356.48	0.297

Coeff Coefficient, SE Standard Error in parentheses, GOF Goodness of fit test adapting to climate change was higher with large household size than with small households probably due to higher availability of labor.

Marital status

This study found that marital status of the household head had a significant ($p=0.016$) influence on adopting planting of drought-resistant crop varieties as an adaptation strategy in response to the effects of climate change and households with married heads were 0.913 times more likely to adopt planting of drought-resistant crop varieties than their unmarried counter parts (Table 4). This particular finding is in agreement with a study conducted in southern Ethiopia [43] which indicated that marital status is highly related to household decision making. A number of previous studies [62–64] also showed that households with married heads are more likely to adopt improved crop varieties since they seem to have distinct agricultural contacts, including extension agents and agro-input dealers compared to their unmarried counter parts who rely mostly on other farmers as their source of agricultural information.

Years of farming experience

The study results showed that farming experience of household heads had a significant effect on adopting fallowing ($p=0.001$) and tree planting ($p=0.012$) as adaptation strategies to the effects of climate change, and farmers with more years of experience were 0.032 and 0.024 times more likely to adopt fallowing and planting of trees, respectively, than those with fewer years of farming experience. This is in agreement with a study conducted in Dejen District, Nile Basin of Ethiopia [47] which established that as one becomes more experienced in farming, the probability of adopting improved farming practices increases. This could be because experienced farmers have a wealth of indigenous knowledge and information about changes in climatic conditions and the best agronomic practices to adopt [65].

Access to extension services

Household heads that received extension services were found to be 1.644 times more likely to plant drought-resistant crop varieties ($p=0.002$) and 0.686 times more likely to plant trees ($p=0.019$) as adaptation strategies to the effects of climate change than their counter parts who did not have access to extension services. These findings are in agreement with previous studies [65–67] which showed that access to information through agricultural extension increases the likelihood of uptake of adaptation to climate change as farmers get exposed to new information and technical skills. Therefore, the provision of timely information and frequent support of farmers by extension services should be strengthened to allow farmers to adapt to the effects of climate change. In the present study, planting of different crop varieties was the least favored adaptation strategy used by farmers who had access to agricultural extension services. This could be because planting of different crop varieties is labor intensive [50], making it less favored by smallholder farmers who mainly use rudimentary farm tools and equipment to farm on small pieces of land for their livelihoods.

Size of land cultivated

The results of study showed that household heads that cultivated large pieces of land were 0.323 times more likely to plant drought-resistant varieties ($p=0.043$) and 0.822 times more likely to plant different crop varieties ($p=0.004$) as adaptation options to the effects of climate change than their counter parts who cultivated smaller farm sizes. This result is in agreement with a study by Daberkow and McBride [68] in the United States which showed that given the uncertainty and the fixed production and information costs, there is a critical limit on farm size that prevents smallholder farmers from adapting to newly introduced farming technologies. This could be because large farm size allows for adopting newly introduced farming practices without running sort of land to practice the usual farming practices. The results of this study also corroborate with Amare and Simane [50] in the Muger River sub-basin of the Blue Nile basin of Ethiopia which showed that size of land cultivated by a household tends to influence adoption of farming practices.

Access to credit

The study showed that household heads that had access to credit were 0.686 times less likely ($p=0.030$) to plant drought-resistant varieties, 0.585 times more likely ($p=0.020$) to plant improved seeds, and 0.626 times more likely ($p=0.022$) to plant trees than those who did not have access to credit (Table 4). With increased access to credit/cash flows, farmers are able to invest in more costly but better rewarding farming practices which could reduce the negative impact of climate change on food production. This finding is consistent with findings of previous studies in the Nile Basin of Ethiopia [17] and in Sekyedumase district, Ghana [39], respectively, which indicated a positive correlation between adoption of climate change adaptation practices and access to credit. These findings, as well as our study, suggest the important role of increased institutional support in promoting adaptation practices to mitigate the negative impact of climate change on smallholder farming communities.

Time taken to market

Households heads that took a shorter time to reach the market were 0.365 times less likely ($p=0.012$) to plant improved seeds and 0.292 times less likely ($p=0.044$) to leave part of their land to fallow than their counterparts who took longer to reach the market. In this study, time taken to the market is a proxy of the road distance to the market, the means of transport used, and the cost of transportation to the market. The probable explanation for this particular finding could be that farmers who move longer distances to markets usually acquire inputs from urban areas where improved seeds are sold as might be the case for these particular farmers who often come from rural areas to the town ones in a while. Similarly, since time to the market is a proxy for how far a farm is located from the urban areas, farmers who stay far away from urban areas are the ones who usually have more land that can be fallowed. An additional explanation could be that because of increased access of middlemen in the trade sector who travel to buy produce right from the farm gate, coupled with the difficulties in transportation of farm produce by individual farmers from their farm to the markets, farmers who are far from the market have difficulties in accessing agricultural extension services that should prompt them to plant improved seeds and fallow their gardens as a means of improving their productivity amidst climate change. However, these findings are not in agreement with other studies, such as one by Maddison [69] which reported a decrease in the tendency of farmers to adopt climate change strategies as markets get further away from their homes. This study also does not corroborate with a study conducted in the Muger sub-basin of the Upper Blue Nile Basin of Ethiopia [50] which contended that adoption to different technologies thrive in areas with well-developed rural infrastructures, such as access roads which make it easy for farmers to take their farm products to nearby markets. Also, According to Vorley et al. [53], proximity to market is a means of sharing and exchanging information with other farmers and service providers; therefore, farmers nearer to markets are more likely to adopt innovations brought on board. Accessibility to markets also increases the incentive of farmers to produce surplus food and cash crops that can easily be taken to the market and thereby enhances their income and capabilities to adapt to the effects of climate change [70].

Household farm income

Household heads with a higher annual farm income were 0.325 times more likely ($p=0.038$) to plant improved seeds, 0.572 times more likely ($p=0.005$) to use fertilizers, 0.508 times more likely ($p=0.002$) to use pesticides, and 0.385 times more likely ($p=0.022$) to plant trees as adaptation strategies to the effects of climate change than their counter parts with low farm income. This finding is in agreement with previous studies [14, 71] which showed that wealthier farmers are more likely to employ adaptation strategies by changing agronomic practices to mitigate the effects of climate change than poor farmers. Furthermore, the findings of Nhemachena and Hassan [65] also indicated that per capita income has a positive influence on farmer' decision to take-up adaptation measures.

Conclusions

In this study, we assessed the factors that influence the adaptation strategies to the effects of climate change by smallholder farmers in Northern Uganda. Using 395 smallholder farmer household heads across two districts in northern Uganda as the study sample size, we found that the three most widely practiced adaptation strategies to the effects of climatic change by smallholder farmers were planting of different crop varieties followed by planting drought-resistant crop varieties, and land fallowing. This is interesting because if access to weather information by farmers could be improved, a large number of smallholder farmers could be protected against the adverse effects of droughts and floods. However, a relatively small percentage (24%) of the household heads interviewed were found to use chemical fertilizers, probably because of the high cost of chemical fertilizers. The study also revealed a number of factors that influence the adoption of different specific adaptation strategies by smallholder farmers' household heads to the effects of climate change. Using the binary logit regression analysis, the study established that gender of household head, household size, marital status of household head, years of farming experience, size of land cultivated, time taken to market, farm income, access to agricultural extension services, and credit facilities significantly influenced the adoption of adaptation strategies by smallholder farmers in northern Uganda. In light of the above, the study recommends that government and development partners should focus on awareness creation of farmers on better production techniques and climate change adaptation strategies through mass media and agricultural extension, and creating affordable credit schemes through innovative approaches, such as Savings and Credit Cooperatives Societies (SACCOS) and Village Savings and Loan Associations (VSLA) to enhance adaptive capacity of smallholder farmers in northern Uganda.

Abbreviations
ADB: African Development Bank; HHs: Households; HHHs: Household heads; GUREC: Gulu University Research Ethics Committee; IPCC: Intergovernmental Panel on Climate Change; NGO: Non-Governmental Organization; UNCST: Uganda National Council of Science and Technology.

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Authors' contributions
FA, GMM, MN, and IOU participated in designing the study; FA and DMO participated in collecting field data. FA, GMM and DMO participated in analyzing and presenting the data. FA, GMM, MN, SPA, and IOU wrote the initial drafts of the manuscript. All the authors read and approved the final manuscript.

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Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate
This study was approved by the Gulu University Research Ethics Committee (GUREC: GUREC-022–19). Permission to conduct this study was later granted by the Uganda National Council of Science and Technology (UNCST) and the Chief administrative officers of the districts of study. Written informed consent and assent were obtained from the adult participants and persons under the age of 18, respectively.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no conflict of interests.

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Appendix
See Tables 5, 6, 7, 8, 9, 10 and 11.

Table 5 The results for binary regression analysis for determinants of drought-resistant varieties as adaptation strategy

Explanatory variables	Coef	Std. Err	z	P>z	[95% Conf	Interval]
Male	− 0.562	0.316	− 1.780	0.075	− 1.181	0.057
HH size	− 0.025	0.039	− 0.640	0.521	− 0.102	0.052
Married	0.913	0.379	2.410	0.016	0.170	1.655
Experience	0.015	0.011	1.380	0.167	− 0.006	0.037
Extension	1.644	0.529	3.110	0.002	0.607	2.682
Land owned	0.010	0.015	0.660	0.507	− 0.020	0.040
Land Cultivated	0.323	0.159	2.030	0.043	0.011	0.635
Credit	− 0.686	0.317	− 2.170	0.030	− 1.306	− 0.065
Time taken	0.068	0.154	0.440	0.657	− 0.233	0.370
log_farmY	− 0.038	0.174	− 0.220	0.829	− 0.378	0.303
Group	0.225	0.296	0.760	0.447	− 0.355	0.805
_cons	0.456	2.188	0.210	0.835	− 3.832	4.745

Table 6 The results for binary regression analysis for determinants of use of improved seeds as adaptation strategy

Explanatory variables	Coef	Std. Err	z	P > z	[95% Conf Interval]	
Male	0.356	0.248	1.430	0.151	− 0.130	0.843
HH size	− 0.030	0.034	− 0.880	0.377	− 0.098	0.037
Married	0.200	0.324	0.620	0.536	− 0.434	0.834
Experience	0.004	0.009	0.450	0.652	− 0.014	0.022
Extension	0.296	0.319	0.930	0.354	− 0.330	0.922
Land owned	− 0.011	0.010	− 1.140	0.253	− 0.030	0.008
Land Cultivated	− 0.124	0.126	− 0.980	0.328	− 0.371	0.124
Credit	0.585	0.252	2.320	0.020	0.091	1.079
Time taken	0.365	0.146	2.500	0.012	0.079	0.651
log_farmY	0.325	0.157	2.080	0.038	0.018	0.632
Group	− 0.168	0.241	− 0.700	0.486	− 0.641	0.305
_cons	− 4.415	2.007	− 2.200	0.028	− 8.350	− 0.481

Table 7 The results for binary regression analysis for determinants of use of chemical fertilizer as adaptation strategy

Explanatory variables	Coef	Robust Std. Err	z	P > z	[95% Conf Interval]	
Male	0.778	0.306	2.540	0.011	0.177	1.379
HH size	− 0.018	0.038	− 0.470	0.641	− 0.092	0.057
Married	− 0.406	0.402	− 1.010	0.313	− 1.194	0.382
Experience	− 0.004	0.012	− 0.320	0.752	− 0.028	0.020
Extension	0.573	0.322	1.780	0.075	− 0.058	1.204
Land owned	0.000	0.003	0.100	0.917	− 0.005	0.006
Land Cultivated	0.165	0.145	1.140	0.255	− 0.119	0.448
Credit	0.323	0.286	1.130	0.259	− 0.237	0.884
Time taken	0.150	0.137	1.090	0.276	− 0.120	0.419
log_farmY	0.572	0.204	2.810	0.005	0.173	0.971
Group	0.002	0.274	0.010	0.994	− 0.536	0.540
_cons	− 9.804	2.661	− 3.680	0.000	− 15.020	− 4.589

Table 8 The results for binary regression analysis for determinants of use of agricultural pesticides as adaptation strategy

Explanatory variables	Coef	Robust Std. Err	z	P > z	[95% Conf Interval]	
Male	0.656	0.246	2.660	0.008	0.173	1.139
HH size	− 0.041	0.038	− 1.100	0.272	− 0.115	0.032
Married	− 0.406	0.334	− 1.220	0.224	− 1.061	0.248
Experience	0.002	0.010	0.160	0.873	− 0.017	0.020
Extension	− 0.041	0.315	− 0.130	0.896	− 0.659	0.577
Land owned	0.001	0.003	0.200	0.841	− 0.005	0.006
Land Cultivated	0.138	0.131	1.060	0.291	− 0.118	0.395
Credit	0.315	0.254	1.240	0.215	− 0.184	0.814
Time taken	0.066	0.135	0.490	0.623	− 0.198	0.331
log_farmY	0.508	0.162	3.130	0.002	0.190	0.826
Group	0.084	0.241	0.350	0.729	− 0.388	0.556
_cons	− 6.682	2.078	− 3.210	0.001	− 10.755	− 2.608

Table 9 The results for binary regression analysis for determinants of use of fallowing as adaptation strategy

Explanatory variable	Coef	Robust Std. Err	z	P > z	[95% Conf Interval]	
Male	− 0.385	0.261	− 1.480	0.140	− 0.897	0.126
HH size	− 0.087	0.037	− 2.360	0.018	− 0.159	− 0.015
Married	0.257	0.331	0.780	0.437	− 0.392	0.906
Experience	0.032	0.010	3.220	0.001	0.013	0.052
Extension	0.175	0.339	0.520	0.605	− 0.488	0.839
Land owned	0.041	0.039	1.060	0.290	− 0.035	0.118
Land Cultivated	0.121	0.146	0.830	0.409	− 0.166	0.408
Credit	− 0.484	0.266	− 1.820	0.069	− 1.005	0.038
Time taken	0.292	0.145	2.020	0.044	0.008	0.576
log_farmY	0.247	0.152	1.620	0.105	− 0.052	0.546
Group	0.118	0.251	0.470	0.637	− 0.373	0.610
_cons	− 3.165	2.008	− 1.580	0.115	− 7.101	0.770

Table 10 The results for binary regression analysis for determinants of use of different varieties as adaptation strategy

Explanatory variables	Coef	Robust Std. Err	z	P > z	[95% Conf Interval]	
Male	0.044	0.584	0.080	0.939	− 1.099	1.188
HH size	− 0.108	0.068	− 1.580	0.115	− 0.242	0.026
Married	− 0.546	0.865	− 0.630	0.528	− 2.241	1.150
Experience	− 0.003	0.023	− 0.120	0.908	− 0.047	0.042
Extension	− 0.981	0.642	− 1.530	0.127	− 2.239	0.278
Land owned	0.016	0.019	0.810	0.419	− 0.022	0.053
Land Cultivated	0.822	0.286	2.870	0.004	0.261	1.382
Credit	− 0.686	0.664	− 1.030	0.302	− 1.987	0.616
Time taken	− 0.114	0.279	− 0.410	0.681	− 0.660	0.431
log_farmY	− 0.259	0.308	− 0.840	0.400	− 0.862	0.344
Group	0.295	0.491	0.600	0.548	− 0.667	1.257
_cons	6.361	4.200	1.510	0.130	− 1.872	14.594

Table 11 The results for binary regression analysis for determinants of use of tree planting as adaptation strategy

Explanatory variables	Coef	Robust Std. Err	z	P > z	[95% Conf Interval]	
Male	− 0.014	0.264	− 0.050	0.956	− 0.532	0.503
HH size	− 0.028	0.034	− 0.820	0.415	− 0.094	0.039
Married	0.108	0.338	0.320	0.748	− 0.553	0.770
Experience	0.024	0.010	2.520	0.012	0.005	0.043
Extension	0.686	0.293	2.340	0.019	0.111	1.260
Land owned	− 0.002	0.003	− 0.650	0.519	− 0.007	0.003
Land Cultivated	0.150	0.126	1.190	0.235	− 0.097	0.397
Credit	0.626	0.271	2.310	0.021	0.094	1.157
Time taken	0.130	0.115	1.130	0.259	− 0.096	0.356
log_farmY	0.385	0.169	2.280	0.022	0.054	0.716
Group	0.005	0.249	0.020	0.983	− 0.483	0.494
_cons	− 7.138	2.180	− 3.270	0.001	− 11.410	− 2.865

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