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Factors Affecting Adoption of Climate Change Adaptation Strategies by Smallholder Farmers in Mountain and Low-land Agro-ecological zones of Eastern Uganda

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Abstract

Several challenges confront farmers in tropical rural areas, but climate change can only be overcome by adopting climate change resilience strategies. This study assessed the factors affecting the adoption of strategies to enhance climate change resilience in the Muyembe sub-county, Bulambuli district, Uganda. We used questionnaires, interviews, focused group discussions, and field observations to collect the required data, which was analysed using basic descriptive statistics and a logistic regression model. The results indicate that the dominant climate change resilience strategies adopted in the study were soil/water conservation (65%), drought-resistant crop varieties (59.4%), and irrigation (55.6). In addition, the logistic regression indicated that gender and family size were the most important factors influencing the adoption of climate change resilience strategies with coefficients -0.86 and P<0.05, and0.18 and P<0.05, respectively. On the other hand, financial constraints and adulteration of farm inputs were the dominant barriers to adoption most farmers with 93.4% and 74%, respectively. We concluded that many farmers remain locked in indigenous practices that have made them vulnerable to climate change effects characterized by low yields, crop failure, low incomes, poverty, and food insecurity. We recommended that government should support the adaptation strategies to climate change by the smallholder farmers technically by providing both ground and surface water irrigation facilities and financially by providing agricultural loans as well as focusing on promoting awareness and advancing education on climate change to farmers through knowledge and skill sharing platforms such as training, conferences, and seminars.

Keywords: agro-ecological zone, early warning, soil/water conservation, farm insurance, resilience, Eastern Uganda.

1. Introduction

Agriculture being the economic backbone of many developing countries has been severely hit by climate change (Mugagga, 2017). The impact has been worse in tropical regions where majorly individual household farms have either been submerged under extreme unpredicted and unexpected floods or been burnt to wilts arising out of unpredicted prolonged drought. Such events have limited the expected productivity from agricultural activities as these unexpected extreme climatic events have persisted in the tropical region. Moreover, agricultural activities are prone to numerous risks and uncertainties, including abiotic factors (such as water, light, radiation, temperature, humidity, or soil) or biotic factors (including pests and diseases). The condition has come with a food shortage, poverty, and generally low living standards (Taruvinga *et al.*, 2016).

Farmers in the tropical world have adopted climate change resilience strategies to minimize associated farm losses that result in a decline in national and individual incomes and livelihoods (Bannayan *et al*., 2016; Oranu *et al.*, 2018; Muklhlis & Perdana, 2022). The Intergovernmental Panel on Climate Change (IPCC, 2014) defines resilience as the ability of a system and its parts to anticipate, absorb, accommodate or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration or improvement of its essential basic structures and functions. However, the changing climate also influences the emergence and re-emergence of vector-borne diseases. Therefore, the management of agricultural systems and natural resources requires improvement to ensure that farming communities and practices are sufficiently resilient and sustainable to cope with the impacts of climate change. The improvements include the early and rapid identification of disease vectors and pathogens, also reducing over-dependence on nature (Mburu *et al.,* 2015).

Various parts of the world have designed region-specific policies as resilience response to climate change (Amare *et al*., 2017; Oranu *et al.*, 2018; Kemal *et al*., 2022; Gyima *et al*., 2020). However, the implementation seems to be less commensurate with the efforts and, in most cases, it has been hampered by institutional, political, geographical, and ecological or socio-economic factors. For example, in east African countries, Uganda heavily hinges on subsistence farming where farmers depend on natural rainfalls (Mburu *et al*., 2015). Unfortunately, by nature, rains in this part of the world have become unreliable and sometimes inadequate, causing agricultural ecosystem degradation that comes with poverty and food shortage (Mugagga *et al*., 2019).

Uganda is one of the tropical countries that have witnessed unpredicted prolonged drought spells intercepted by extremely prolonged torrential rains. These have not only come with landslides but also floods especially in the low-land areas and lake basins where gardens have been submerged by excess water, especially from rising lake waters in the lake Kyoga and Victoria basins. Short- and long-term effects have manifested through crop gardens, livestock farms, and settlement loss. However, the government of Uganda, through its departments such as the ministry of agriculture, animal industry and fisheries and line parastatals like NARO (National agricultural research organization), and NAADs (National agricultural advisory services) with the FAO support, has advised farmers to cope up with climate change resilience strategies based on region-specific agricultural activities. For instance, the government has developed and given farmers better animal and seed varieties/breeds under the OWC (Operation Wealth Creation) program. Farmers now have valley dams and demonstration farms to see, imitate, and practice. Additionally, political structures like DAOs (District Agricultural Officers), DVOs (District Veterinary Officers), and others have brought agricultural extension services to the grassroots level to train farmers in climate-smart agricultural practices. The practices include soil and water conservation, mixed farming, early/late planting strategies, and crossbreeding technologies.

Despite all these efforts by the government of Uganda to save the farmers from the effects of climate change vagaries, the adoption rate of these climate-smart technologies and strategies by smallholder farmers in rural areas has remained low. Most farmers in Muyembe sub-county have not embraced these strategies, save for very few farmers in the mountain and lowland agro-ecological zones. Some attempted to drop the practices, but only a few have persisted. Factors underscoring these efforts of adopting strategies to enhance resilience to climate change are unknown and documented in the Muyembe sub-county.

This study, therefore, sought to examine the possible factors affecting the adoption of resilience strategies to climate change by farmers in both mountain and lowland agro-ecological zones in Muyembe sub-county, Bulambuli district in eastern Uganda. The purpose of studying these two different agro-ecological zones was to compare and establish whether spatial environmental differences could account for the differences in adoption levels. This study was accomplished by first examining the prevalent region-specific and agro-ecological zone-specific climate change resilience strategies used in the Muyembe sub-county. Then, we identified the factors that have influenced smallholder farmers' decisions and those that have prevented them from adopting climate change resilience strategies in both mountain and lowland agro-ecological zones in Muyembe sub-county. Finally, we postulated that the two most important variables influencing the adoption of techniques for climate change resilience in the Muyembe sub-county were the size of the farm and educational attainment levels.

2. Research Methods

2.1. Study area

The study was conducted in Muyembe sub-county in Bulambuli District located in Eastern Uganda, stretching between 33.5° – 36° E and 2° – 5° N (Figure 1). Muyembe sub-county covers a surface area of approximately 710.96 km2 and comprises six (6) parishes, namely Bufukhula, Bulako, Bungwanyi, Bufumbula, Buyaka, and Nabongo. It lies at an approximate altitude ranging between 1089 m - 2247 m above sea level. The population of Bulambuli District was 28209 while that of Muyembe sub-county was 9560 people based on the 2014 Uganda National Housing and Population Census. A big part of the sub-county lies in an agro-ecological mountain zone (between 1862-2247 MASL), with a smaller part in the lowland agro-ecological zone (between 1089-1861m ASL). Bulambuli and Muyembe sub-county in particular, has a montane climate with a bimodal rainfall pattern, with the first rain season from April to June and the second rainfall season from October to December with two dry periods of July to September and January to March. It has a mean annual rainfall of 1280 mm, and depending on altitude and season, the mean temperature varies from 10 °C to over 22 °C (Turyahabwe *et al*., 2021). The soils are generally volcanic, although some parts are comprised of ferralisols and vertisols. Coffee and banana crop gardens and other annual crop gardens dominate the upper slopes of the study area, while rice gardens and other annual crop gardens of cabbages, beans, maize, sorghum, sunflower and soybeans dominate the lowland region. Single and mixed cropping are the dominant cropping systems. Animal grazing dominates the lowland areas where pasture and wetlands are grazing points. Both agro-ecological zones of the study area possess some woodlots.

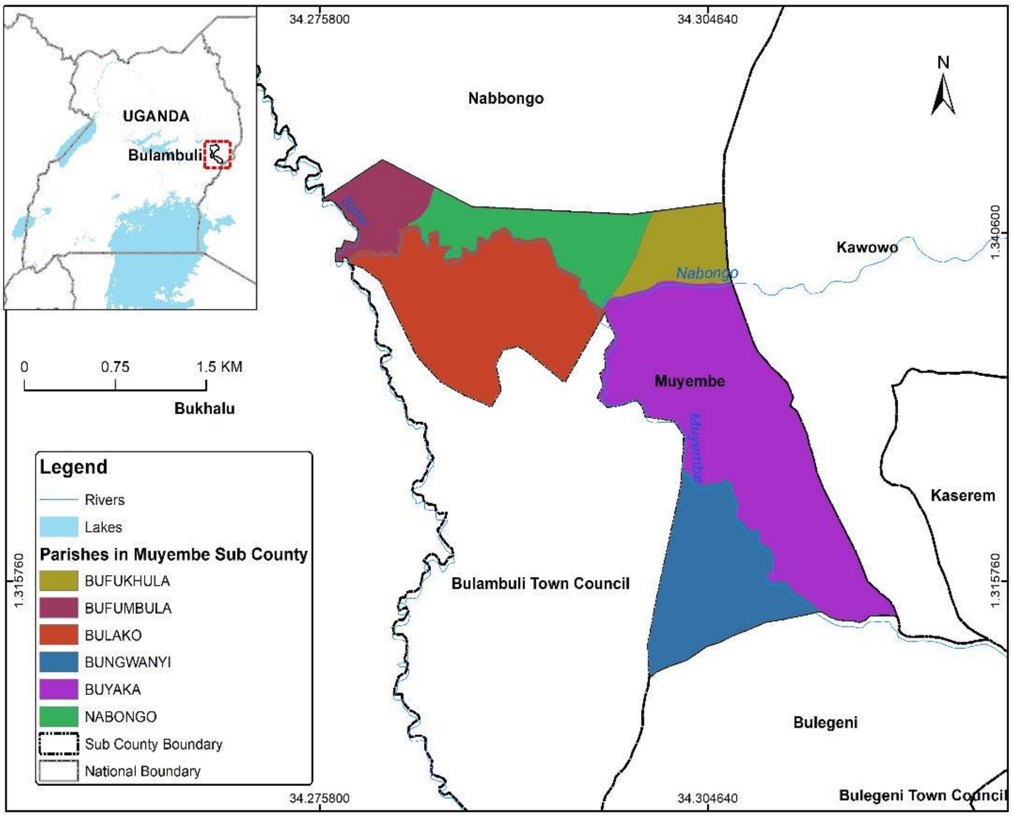

Figure 1. Muyembe Sub-County in Eastern Uganda and Study Clusters (Parishes).

2.2. Data collection

First, we applied purposive sampling to select Bulambuli district from the eastern part of Uganda. The key reasons were that the district is characterized by two different agro-ecological zones (mountain and lowland) where adaptation strategies differ due to spatial differences, high population growth with limited and eroded farmland, prevalence of food insecurity and widespread poverty. A stratified sampling technique was also used to select five parishes out of six (Figure 1), taking 100 respondents from each giving 500. Selection of respondents in each parish was done randomly. We collected primary data using structured interviews, focus group discussions, and questionnaires. Three focus group discussions were carried out in each agro-ecological area (low land and high land) with between 5 - 10 people where gender balance was considered. These included farmers, extension workers, e.g., (OWEC, NAADs, and NARO officers), and elders. Similarly, key informant interviews were conducted with one district agriculture officer, five parish chiefs, and one community development officer. Questionnaires comprise open- and close-ended interviews and discussions targeting obtaining information about the demographic characteristics. The attributes are age, sex, level of education, farmers' annual incomes, accessibility to extension services, history of climate change, nature of adaptation strategies, and factors that influence farmers' adoption of these strategies as well as those that have limited adoption of such adaptation strategies in the area of study. Field observation was conducted throughout the whole course of the research in order to ensure the validity of the information obtained through discussion, interview, and questionnaire. Trained data collectors who were university graduate students administered the questionnaires. The researchers played the supervisory role.

The sample size was determined using Equation 1 by Yamane (1967). Where n = sample size, N = the total number of people involved in subsistence farming, e = margin of error. By using the Equation 1 with a confidence level of 90% and marginal error of 10%, a computation from a population of 9560 (UBOS, 2016) for Nabongo yielded 99.9 farmers as sample size that we took for each parish making a total of 500 respondents. We raised the margin of error to 10% to downscale the sample size owing to the financial limitations and the time needed to finish the study. The categories of respondents included smallholder farmers and Key Informants.

$$n = N1 + N(e2) \text{ ....} \quad (1)$$

2.3. Data analysis

We analysed the data obtained from questionnaires, discussions, interviews, and field observations using qualitative and quantitative methods. Inferences and simple descriptive statistics like percentages, graphs, and totals generated were presented in tables to depict existing phenomenal relationships. The study adopted a logistic regression model since the outcome was binary in nature (adopters verse non-adopters). The chance of an outcome based on the characteristics of the adopter verses non-adopters since the chance was in the form of a ratio. The model took the direction of logarithm of the chance as denoted by Equation 2. Where π indicates the probability of an event (e.g., adoption for this case), and βi are the regression coefficients associated with the reference group and the xi explanatory variables.

$$log(\frac{\pi}{(1-\pi)} = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots \beta_m x_m \text{.....................................} \quad (2)$$

3. Results and Discussion

3.1. Climate change adaptation strategies used by farmers in Muyembe sub-county, eastern Uganda

Several strategies to enhance climate change resilience are under use in the study area (Figure 2). The strategies include drought-resistant crop varieties strategy, crop diversification/switching strategy, soil and water conservation strategies, Irrigation strategy, Agroforestry strategy, Agro-climatic information dissemination and early warning strategy, Crop farm insurance strategy, and early and late planting strategy.

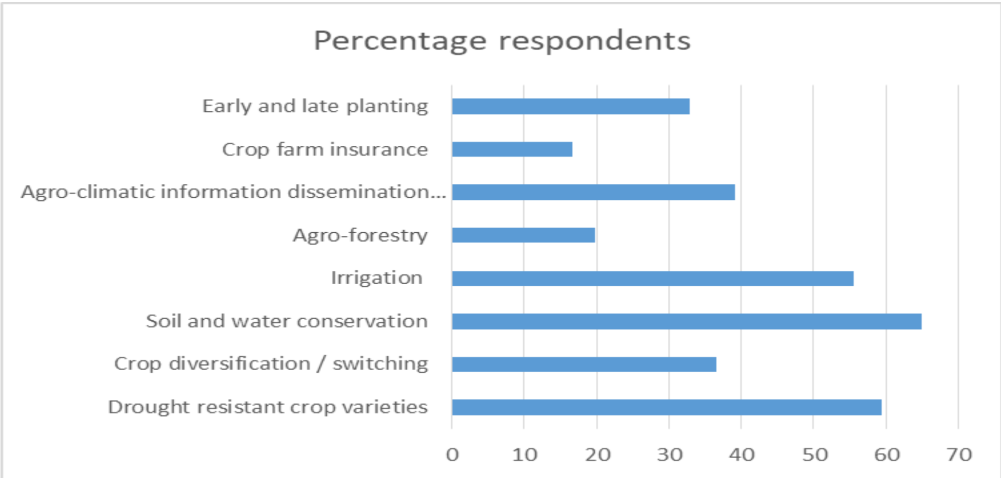

Figure 2. Climate Change Adaptations Used in The Study Area and Their Frequency of Occurrence.

Drought-resistant crop varieties strategy

In response to changing climate patterns, farmers have in Muyembe sub-county adopted new crop varieties of rice, maize, and banana. 59.4% of the respondents (Figure 2) indicated that these new varieties yield at least twice more than indigenous ones, even under limited soil fertility enhancement. The maize varieties included MM3, Longe 7H, and Longe 10H, which are disease, weed, and drought resistant, fast maturing (<90 Days), and high yielding (up to 3600 Kg per acre). Nerica and NP3, NamChe-1, 2, 3, and TXD3 06 are rice varieties that withstood limited soil moisture during drought. Dessert bananas, specifically Musa acuminate, NARO-Ban1-4 developed by National Banana Research program, are the banana varieties introduced for high yield and drought resistance. All these new crop varieties were seen as new sources of income and game changers to the people who tried them, indicating that they are profitable and guarantee food availability.

Crop diversification/switching strategy

Some respondents (36.5%) noted that, for the past five years, many farmers in the mountain agro-ecological zone had abandoned maize to concentrate on rice, most of them opting for upland rice (Figure 2). Where onions have failed, farmers have resorted to planting coffee in mountain zone or sometimes cotton in the lowland zone. Root crops such as cassava, Potatoes, and Irish potatoes are grown under crop rotation together with maize to reduce climate change vulnerability, especially new trends of rainfall patterns.

Soil and water conservation strategies

These dominated farmers' strategies with a 65% response rate (Figure 2). They ranged from not tilled, intercropping/mixed, and channelization to mulching. Farmers grow pearl millet not for food but for soil health. When the millet starts flowering, the crop is rolled flat and left to decompose, fixing nitrogen, adding fertility, and retaining moisture. This strategy is followed by planting rice; hence no need for weeding and fertilizer application. Coffee–banana intercropping is proving to be effective in addressing increasing temperatures affecting coffee compared to mono cropping. Of emphasis in the area is mulching in banana plantations to increase soil water conservation amidst a drought. Valley dams and other low-cost water harvesting techniques (tiny basins and semi-circular bunds) help to gather and store excess water.

Irrigation strategy

As the majority felt prolonged drought, farmers resorted to using both local and improved irrigation techniques. 55.6% of the local farmers use low-cost irrigation systems, including drip irrigation (Figure 2). Very few of the 55.6% of farmers applied improved irrigation systems ranging from overhead irrigation to drainage pipe/canal systems. These irrigation systems help to supplement the unreliable and little rainfall received in the area.

Agroforestry strategy

Few smallholder farmers (19.8%) have strategized by adapting to agroforestry, where tree crops such as guavas, jackfruits, mangoes, and oranges, both local and hybrid varieties have been planted as the crops that can withstand adverse climatic conditions (Figure 1). These fruit trees help to build resilience and increase environmental health through rainfall formation enhancement, soil particle binding effect, increase in infiltration, wind breaking, and increase in income source diversification for farmers.

Agro-climatic information dissemination and early warning strategy

A weather station exists at the Bulambuli district headquarters to inform farmers about the finer resolution of weather forecasts so that farmers know what and when to plant based on micro weather forecasts. Information dissemination of drought-related early warning to farmers is a district agricultural extension workers mandate. Some respondents (196 people) indicated that some farmers sought this information to decide whether and when planting seasons were to start.

Crop farm insurance strategy

Agricultural insurance scheme packages aimed at saving farmers from losses incurred from climate change remain unpopular with only a 66.6% response rate (Figure 2). These strategies aim to enable farmers to re-invest in inputs and technologies, especially at worst years of climatic extremes (both prolonged rains/flood time and prolonged drought.

The early and late planting strategy

It was revealed that farmers adjusted the planting time/calendar based on prevailing agro-climatic warnings/information and experience. For example, farmers grew crops early at the start of the first rains or anticipation that rains were about to come based on the prevailing weather conditions. With this technique, there is hope that as the rains came, they would find freshly planted crops and continue growing (early planting). On the other hand, other farmers waited to plant in the middle of the short rainy season because they were not sure whether the rains would not stop soon (late planting). All these aim at reducing the possible effects of climate change.

3.2. Factors influencing the adoption of climate change resilience strategies in Muyembe sub-county

These factors are of two categories, i.e., socio-economic factors and other factors. Socio-economic factors further have sub-categories to show how the factors influenced farmers/respondents in each sub-category in question to adopt resilience strategies to climate change. Table 1 shows that the most important factors influencing adoption of strategies to enhance climate change resilience are gender 60%, social capital (56%) and farm size (52.5%). On the other hand, the least important factors were the farmers' family size, age, and education level, with 30.5%, 41.1%, and 45%, respectively.

Table 1. Socio-Economic Factors Are Affecting the Adoption of Climate Change Resilience Strategies in Muyembe Sub-County.

Factor	Category	Total respondents per factor category	**Number of adopters of different Climate Change Adaptations**										
			Drought resistant crops	Agroforestry	Climate information	Farm Insurance	Soil and water conservation	Early/late planting	Irrigation	Crop diversification	Total Adopters	%Age adopters of total respondents	%Age non-adopters of total respondents
Age (years)	20-39	50	04	02	00	02	05	00	04	00	17	34	66
	40-59	350	67	07	35	32	35	35	56	35	302	86	14
	60-79	80	08	03	00	00	14	00	09	00	34	43	57
	80+	20	00	00	00	00	16	00	00	4	20	100	00
Education level	Uneducated	80	02	04	00	00	00	00	00	06	12	15	85
	Primary	280	10	00	00	03	53	22	00	35	123	44	56
	Secondary	100	23	2	16	5	24	3	12	00	88	88	12
	Tertiary	40	11	6	4	-	10	1	4	00	36	90	10
Farmer's income (Million shillings)	<10	310	9	00	00	00	22	00	00	00	31	10	90
	10-20	170	20	2	17	2	28	-	21	-	102	60	40
	21-40	10	1	00	00	1	3	00	4		9	90	10
	41+	10	00	00	1	1	00	00	2	00	4	40	60
Farm size (acres)	<3	100	00	00	1	00	5	00	00	6	12	12	88
	3-5	200	16	00	12	00	46	00	16	6	96	48	52
	6-8	160	27	5	16	13	32	5	16	00	114	71	29
	9+	40	8	1	4	4	6	2	6	2	33	83	17
Family size(members)	<5	90	5	6	00	00	10	5	9	3	39	43	57
	5-10	100	3	00	00	00	5	00	3	1	12	12	88
	11-15	210	40	00	21	00	25	00	17	00	103	49	51
	16+	100	8	00	00	00	6	00	4	00	18	18	82
Gender	Males	140	25	4	00	8	61	00	8	00	106	76	24
	Females	360	22	00	14	00	6	11	00	17	70	19	81
Social capital	Belonging to group	208	50	10	20	10	40	10	30	10	145	70	30
	Single individual	292	6	00	00	00	24	24	20	9	82	28	72

Age and Adoption of Climate change Adaptations

The age group 20-39 adopted most of the soil and water conservation strategy (5 adopters), while they were not interested in early/late planting (zero adopters). The age group 40-49 adopted all the strategies, mostly irrigation and planting of drought resistant crop varieties, with 56 and 67 adopters, respectively. For those aged 60-79, the most adopted adaptation was soil and water conservation practices with 14 adopters but neglected crop diversification, early/late planting, farm insurance and climate information with 0 adopters. Finally, the elderly group (80+) only maintained crop and soil conservation practices through traditional methods like mulching and digging trenches in banana plantations and the use of contour ploughing along slopes of mountain Elgon.

Education and adoption of Climate change Adaptations

Farmers with non-formal education largely adopted crop diversification (6 adopters), and agroforestry (4 adopters). Conversely, those that had attained a secondary school level of education dominated the adoption by adopting all strategies save for crop diversification. In the same way, those that had attained tertiary education level adopted strategies to enhance climate change resilience in larger numbers. This stresses the fact that the higher the level of education attained by farmers, the higher the rate of adoption of climate change strategies. For example, the tertiary and secondary level farmers highly adopted drought-resistant crops with 11 and 23 adopters, respectively. In addition, soil and water conservation strategies have 23 and 10 adopters, respectively.

Farmer's income and climate Change Adaptations

Farmers with an annual income of below 10 million Uganda shillings mainly adopted soil and water conservation. 22 adopters that earned 10-20 million, mainly preferred soil and water conservation 28 adopters and irrigation 21 adopters, those that earned 21-40 million annually largely practiced irrigation (9 adopters) and soil and water conservation (3 adopters). Farmers earning 41 million and above mainly practiced irrigation 2 adopters (50%). It is noticeable that richer farmers did not practice soil and water conservation while poor farmers did not practice irrigation. Farmers' incomes determined how much the farmer could invest in the farms and the resilience strategy a farmer could adopt. The poor farmers with <10m annually found it hard to adopt to expensive resilience strategies such as farm insurance and agroforestry where 0% adopters were found. Conversely, despite small numbers, the rich farmers (with >41m) adopted the most expensive resilience strategies like irrigation, farm insurance and agroforestry to guarantee no loss of crop farms in case of drought and heavy rains. The middle-income earners (21-40M) adopted all the strategies but mostly irrigation and growing drought resistant.

Farm Size and Climate Change Adaptation

Farm size determined yield and incomes and paved the way for adopting alternative resilience strategies to climate change. However, people with farmland size< 3 acres had limited options of adoption- were limited to only three resilience strategies, including diversification of crops, soil and water conservation, and seeking agro-climatological information. Conversely, people with farm sizes > 9 acres adopted various resilience strategies to climate change, with irrigation and drought-resistant crops dominating adoption alternatives (8 and 6 adopters respectively).

Family Size and Climate Change Adaptations

Households with family sizes below five people mainly preferred soil and water conservation practices (25.6%) and irrigation (23.1%). Those that had 5 to 10 family members also largely adopted soil conservation (41.7%) and irrigation (25%). those with 11-15 members and 16 and above largely practiced drought-resistant crop growing. Drought-resistant crops, soil and water conservation and irrigation were preferred across households with varying sizes. Farm insurance was not preferred across family sizes. Smaller family size with <5 members allowed for more land and a variety of resilience strategies, that is, six strategies, while despite providing enough labour force on farm, larger families with>16 members were associated with less adoption to climate change resilience strategies that's, only 3 strategies including drought-resistant crops, irrigation and soil/water conservation. A similar case was with the sizes between 11-15 members.

Gender and Climate Change Adaptations

The results in Table 1 reveal that males mainly preferred irrigation and soil and water conservation. Females, on the other hand, mainly adopted drought-resistant crops and crop diversification. Nevertheless, both male and female-headed households did not adopt climate change information sharing and early/late planting. There were more female adopters compared to male counterparts. It is worth noting that much as each of the sexes adopted five resilience strategies, females found irrigation harder and failed to adopt it, as was the case with agroforestry and farm insurance, with zero adopters in each case. Females liked more planting drought-resistant crops and seeking for agro-climatological information before planting the crops. On the other hand, males adopted all other resilience strategies save for early/late planting and crop diversification with zero adopters. Males found more yields with irrigation and soil/water conservation strategies.

Social Capital and Climate Change Adaptations

Those who were members of social organizations mainly adopted drought-resistant crop varieties at a rate of 29.4% and irrigation at 17.6% adoption. In comparison, those who did not belong to any organization mainly adopted soil and water conservation and early planting, both of which were 29.3%. Membership in social organizations increased the likelihood of a farmer adopting a variety of adaptations. The grouped farmers easily accessed farm inputs and agricultural loans and found it easy to pool resources towards adaptation to climate change resilience (social capital).

The government of Uganda has set aside money for people organized in groups that carry out one similar activity (special duty), locally known as the emyooga fund. These funds have been utilized in adopting to climate change resilience strategies and benefiting only people in groups as opposed to single individual farmers.

Some farmers have come together, pooled resources, and sought financial and agricultural extension assistance against food insecurity from local authorities, government, and No-government organizations, to help fight climate change in form farm in-puts. This constitutes socio-economic capital. Other farmers have done so individually. This study revealed that there were more adopters in groups compared to individual farmers. Farmers in groups adopted all the resilience strategies, while individual farmers adopted only five resilience strategies

Other factors influencing adoption of climate change adaption by farmers

Environmental factors like soil depth and steep slope angle of agro-ecological mountain zone favours specific resilience strategies such as contour banding, where grass bands are planted across the mountain slopes to conserve soil and increase water retention other than erosion in times of heavy rains. Agroforestry is also practiced to protect the land from landslides. This strategy is suitable in this agro-ecological zone. Irrigation is hard as carrying water upslope by farmers is tiresome and expensive but only employed drip irrigation. Farmers in the lowland agro-ecological zone found mulching a better option for water/soil conservation. Farmers irrigate their crops by channelling river water to farms. Farmers in the lowland agro-ecological zone, through early planting, planted fast-maturing crops, where crops like tomatoes; cabbages are grown based on the forecast of weather conditions with the hope that harvesting of the crops is done before heavy rains set in.

The government of Uganda, through the ministry of agriculture, animal industry, fisheries, and line-parastatals, including the national agricultural research organization and operation wealth creation, has launched campaigns to distribute improved crop seeds and tree seedlings. Also, by providing extension services to farmers struggling to cope with climate change. Choices of which crops, seeds, and tree seedlings to be delivered and planted in specific geographical areas rests upon these parastatals' technical teams. Unfortunately, some corrupt officials have chosen to distribute drought-resilient seeds and tree crop seedlings, e.g., mangoes, and oranges, to individual farmers who have given the bribes and/or facilitated their transport to farms. The implication is that some adopters have also been corrupt farmers.

In Muyembe sub-county, only places that have been accessible by technical agricultural extension teams have accessed these improved drought-resistant crop varieties, tree seedlings, accessed agricultural extension services and hence adoption. In this case, non-adoption has not been by choice but by inaccessibility of farmers' residences.

The flourishing of a demonstration farm established at Buginyanya (on Mount Elgon) has encouraged farmers to practice what they have learnt in relation to adoption of strategies to enhance climate change resilience. Farmers have learnt best practices, such as which crops do better in mountain and lowland agro-ecological zones. A research Centre at Buginyanya demonstration farm helps to produce and distribute banana species that are drought resistant and fast maturing for planting by farmers to lessen climate change vulnerability.

The study adopted a logistic regression model since the outcome was binary (adopters verses non-adopters) to isolate the most important factors that affected adoption of climate change adaptation. In this model the chance of an outcome were based on the characteristics of the adopter verses non-adopters. We run the logistic regression model to determine which strategy to climate change resilience had a higher chance of being adopted by farmers in the study area compare to non-adoption. The results are presented in the Table 2.

The results of the logistic regression brought to light that, gender and family size were the most important factors that influenced adoption of strategies to climate change resilience (Table 2). At the same time, gender had a significant negative influence on adoption of climate change resilience strategies with coefficient -0.86 and $P<0.05$, family size had a significant positive influence on adoption rates with coefficient0.18 and $P<0.05$ (Table 2).

On the other hand, the most important strategies to climate change resilience that had higher chances of being adopted as opposed to non-adoption included Agroforestry, agro-climatic information dissemination, farm insurance, soil, water conservation practices, and early/late planting. In the case of agroforestry, the odds of adoption for adopters were 1.93 times greater than for non-adopters, and this was significant (p=0.0590.1). That of agro-climatic information dissemination was 2.66 times, farm insurance at 2.33 times, soil and water conservation practices at 2.39 times, early/late planting at 1.88times higher in adopters as compared to non-adopters and these were all significant at P<0.05 (Table 2).

Table 2. Summary of variables used in the logistic regression model.

Variables	Coefficients	Odds Ratio	Std. Err.	z	P>z
Gender	-0.86	1.427	0.99	-0.20	0.04**
Family size	0.18	1.20	0.97	0.23	0.021**
Social capital	0.02	0.91	0.01	0.51	0.56
agecat1	-0.08	0.93	0.84	-0.08	0.933
educlevel1	0.01	1.00	0.24	0.14	0.67
farmeincome1	0.10	1.00	0.01	0.01	0.78
Drought resistant crops	-0.06	0.94	0.05	-1.03	0.303
Agro forestry	0.66	1.93	0.14	0.44	0.059*
Climate information	0.98	2.66	0.11	1.14	0.006**
Farm insurance	0.84	2.33	0.13	1.55	0.021**
Soil and water conservation	0.87	2.39	0.03	2.60	0.008**
Early-late planting	0.63	1.88	0.07	1.00	0.019**
Irrigation	-0.06	0.94	0.05	-1.01	0.312
crop diversification	-0.09	0.92	0.05	-1.46	0.144
_cons	0.45	1.56	9.44	0.07	0.041**

*Significant at P<0.1, **Significant at P< 0.05

3.3. Barriers to adoption of climate change adaptation by smallholder farmers in Muyembe sub-county

The study revealed that a number of factors hindered adoption of strategies to climate change resilience by smallholder farmers in Muyembe sub-county (Table 3). It was reported by 289 respondents that, extension workers at both district and national levels have remained too few to cover the entire farming community. As a result, majority of the farmers have not had sufficient and or any training on how best they can resist effects of climate change. Some farmers have not even recognized the causes and effects of climate change and which resilience strategies they can use. This status of climate change ignorance has barred majority farmers from adoption of such strategies.

Table 3. Barrier/limiting factors limiting adoption of climate change resilience strategies by smallholder farmers in Muyembe sub-county.

Factor	Number of respondents (N=500)	Percentage
Limited training on appropriate method	289	57.8
Financial constraints	467	93.4
Ignorance on potential effects of climate change	221	44.2
Adulteration of inputs like seeds	326	74
Land tenure system	260	52

Effecting adoption of resilience strategies comes at accost of farm in-puts like seeds, irrigation equipment, tractors and fertilizers. At the national and district levels, there has been budgetary stress on financial resources to agriculture although agriculture remains the sole employer of population. The majority of the respondents (93.4%) revealed that this has not only limited but has also led to rationing and selective distribution of farm in-puts and for this reason, very few have accessed and adopted improved drought-resistant seeds, irrigation farming etc.

The study revealed that high demand for farm inputs like fertilizers and improved seed varieties had met the same scarcity. This condition has attracted middlemen who have produced adulterated in-puts especially seeds that they have sold to farmers and, as a result, failed to perform to the expectation of the farmers. Farmers that adopting such strategies were reported by 74% of the respondents. Most farmers have fallen victim of climate change effects due to their ignorance about the possible causes, effects, and resilience strategies. Some farmers indicated that the changes would be short-lived and, so there was no need for panic, weather elements would finally stabilize. Others have attributed climate change to misfortune, and witchcraft (rainmaking) and believe that if rainmakers are appeased, rains would come or persistent rains could be stopped. This does not only present some degree of backwardness but also strengthens their rigidity to adapt to changes in climate change resilience strategies.

Most farmers use rented or leased lands where property owners dictate how their lands must be used. Some farmers are barred by their property owners from adopting agroforestry practices since these take longer seasons than rented time. Other farmers have deliberately stayed away from soil and water conservation techniques, as they know they are using the land for a short time. Others found establishing drainage/irrigation structures on lands that did not belong to them as a waste of resources since they were going to leave the structures in the lands for property owners.

3.3. Discussion

Climate change resilience strategies adopted in Muyembe sub-county

Results of the current study indicated that farmers in Muyembe sub-county used mixed farming adaptation strategies to reduce the consequences of climate change. This result is in consonance with earlier studies by Amare *et al*. (2017) and Lemma (2016). These studies observed that mixed farming adaptation practice was the dominant adaptation strategy to reduce climate change-related problems in the drier areas of Ethiopia—implementing mixed cropping aimed at minimizing the effects of moisture stress on crops and reducing the risk of losing it all at once in case of prolonged drought or heavy rains. A similar study done by Irham *et al.*, (2022) in Indonesia also notes that mixed farming as a common adaptation strategy among vegetable farmers.

Early and late planting (changing sowing period) adaptation strategy was practiced in North West Ethiopia as indicated by Mequannt *et al*. (2020) and Oranu *et al.*, (2018). In the current study the changes in the season corresponded to changes in the climatic conditions. The reasoning in these two studies was so similar that, early rains called for farmers to plant early, while late rains called for farmers patience in planting, violation of this rhythm would lead to losses to climate change.

Whereas in Ethiopian farmers grew drought resistant barley varieties as reported by Mequannt *et al*. (2020), in farmers in Muyembe sub-county grew drought resistant rice, banana and maize varieties. These were chosen as wonder crops for they are fast maturing and have a high potential of yielding at least double the indigenous crops. Mburu *et al*. (2015) and Oranu *et al.*, (2018) also indicated that growing drought-tolerant crop varieties was one of the most common and vital adaptation strategies in practice on small-scale farms in Kenya. The difference in crops is attributable to heterogeneity of geographical regions and agro-ecological settings.

Farmers in Muyembe sub-county constructed trenches, mulched tomato and banana plantations to conserve soil and water as one of the most important adaptation strategies. These were practiced with biological measures such as planting contour bands across the mountain slopes to regulate erosion rates in the mountain agro-ecological zone. This is in agreement with Mugagga (2017) and Debela (2017) who indicated that farmers used physical and biological management practices to conserve soil and water as an adaptation strategy to climate change in different parts of Ethiopia.

Although the accessibility of water for irrigation was hard in Muyembe sub-county, irrigation was one of the most dominant climate change resilience strategies adopted by farmers who used drip irrigation as the major irrigation technique. This aimed at reducing the reliability of rains. It was more so by farmers of short-season crops like cabbages and tomatoes especially in the lowland agro-ecological zone. This technique is not peculiar to our study area but was also reported by Mburu *et al.* (2015), who noted that irrigation was used by a small number of farmers in Kenya as an adaptation strategy to overcome the direct and indirect effects of climate change. He further noted that this adaptation strategy helped protect farmers against losses due to dynamism in temperature and rainfall.

Factors influencing adoption of Climate change resilience strategies in Muyembe Sub-County

The study results indicate that, the higher the income level of farmers, the higher the rate of adoption. In addition, farmers with higher incomes adopted the expensive strategies as compared to farmers who earned less. This is similar to Abid *et al*. (2014) who noted that, there was a significant relationship between farmers' income and adoption so much so that increased in income of farmer's income increased farmers' probability to adopt a climate change adaptation strategy. The farmers with higher annual incomes can meet the expenses required to adopt strategies for climate change resilience more than those who earn less.

The education level of the head of the household is also hypothesized to be positively related to awareness of climate change. Highly educated farmers laboured to seek for agro-climatic information as compared to their counterparts. Therefore, education highly influences adoption of strategies for climate change resilience. Farmers in these categories have known the power of access to meteorological information for resilience. This does not differ from Mequannt *et al.* (2020), Kemal *et al.* (2022), and Gyimah *et al.* (2020) who observed that farmers with access to climate information appeared to have a higher probability to adopt adaptation strategy compared to farmers without access to climate information. This is because access to climate information increases farmers' awareness and knowledge of the changing patterns of rainfall and temperature as well as the possible response strategies to climate change.

The age of the head of the household represents experience in farming and studies have indicated that experienced farmers are more likely to perceive climate change (Maddison, 2006; Irham *et al.*, 2022; Kemal *et al.*, 2020). This coincided with the results of the current study where mature farmers aged 40-79 adopted more resilience strategies compared to farmers 20-39. However, despite the experience, the very old farmers (80+ years) adopted fewest number of resilience strategies. This is attributable to reduced energy and vigour to carry out agriculture.

Access to information on climate change through extension agents or other sources creates awareness and favourable conditions for adopting suitable farming practices under climate change (Maddison, 2006; Kemal *et al.*, 2020). In our study area, only places accessible by technical agricultural extension teams have accessed this climate change information, improved drought-resistant crop varieties, tree seedlings, and accessed agricultural extension services hence adoption.

Farmer-to-farmer extension and the number of relatives in the Got (village) represent social capital, which plays a significant role (Isham, 2002; Saptutyningsih *et al.*, 2020) in information exchange, and hence, it is hypothesized that social capital is associated with the perception of climate change. In the current study, there were more adopters in groups compared to individual farmers. This group has helped them come together, pool resources, and seek financial and agricultural extension assistance from local authorities, government and No-government organizations, which tasked to fight climate change in form of farm in-puts. This is why farmers in groups adopted all the resilience strategies while individual farmers adopted only five.

The agro-ecological setting of an area based on environmental factors influences farmers' perception and adoption of climate change resilience. For example, a study by Diggs (1991) revealed that farmers living in drier areas with more frequent droughts are more likely to adopt the strategies for climate change resilience compared to farmers living in a relatively wetter area with less frequent droughts. In the current study, farmers in lowland agro-ecological zones adopted more diverse strategies for climate change resilience than those in the Mountain agro-ecological zone. This is because prolonged heavy rains (flooding), very hot temperatures (drought) severely affected the gardens, so controlling and conserving soil, and water from hill-slopes was the only answer. This therefore does not differ from the hypothesis by Belay *et al.* (2005) that farmers living in lowland areas are more likely to perceive climate change as compared to midland and highlands. Those at highland agro-ecological zone emphasized agroforestry and contour ploughing as opposed to mulching in lowland zone.

Barriers to adoption of climate change resilience strategies in Muyembe sub-county

In Muyembe sub-county, various barriers hinder the farmer's ability to adopt strategies for climate change resilience. These include limited training on appropriate strategies, financial constraints, ignorance of farmers on potential effects of climate change, adulteration of inputs like seeds and effects of land tenure system. This study is in consonance with the results obtained by Abid *et al.* (2014) and Mugagga (2017), who concluded that lack of information about potential of climate change, lack of knowledge about appropriate adaptation option, lack of credit services and money were the major constraints to hinder farmers' willingness to adopt adaptation strategies in response to climate change effects.

4. Conclusion

Given that climate change effects have severely affected farming in Uganda, adaption to techniques for enhancing climate change resilience is inevitable. As a result, some farmers in the Muyembe sub-county have tried implementing resilience methods, such as conserving soil and water, looking for agro-climatic information, irrigation, farm insurance, agroforestry, crop switching, early/late planting, and raising drought-resistant crop varieties. Age, education level, farm size, family size, farmer income, sex, and other characteristics have all had an impact on the adoption of these by farmers in the sub-county. However, many farmers are still stuck in traditional methods that have left them open to the repercussions of climate change, which include low yields, crop failure, low earnings, poverty, and food insecurity. We discovered that these farmers' sensitivity and vulnerability were due to a number of uncontrollable circumstances, including but not limited to their lack of knowledge about climate change, low financial resources and land tenure, and tainted farm inputs. Therefore, we recommended that as a matter of policy, more support from crucial governmental organizations and non-governmental organizations (NGOs) be availed to the farmers. This can be both technically and financially by providing irrigation facilities for both ground and surface water, as well as by concentrating on raising awareness and advancing education on climate change among farmers through knowledge- and skill-sharing platforms like training, conferences, and seminars. In order to improve the ability of farmers in the study area to adapt, the government should invest in providing the Bulambuli District with adequate technical staff in the field of climate science. It should also import more adaptive technologies from other nations with comparable socioeconomic and environmental settings.

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References

Abid, M., Scheffran, J., Schneider, U.A., Ashfaq, M. (2014). Farmer's perceptions of and adaptation strategies to climate change and their determinants; the case of Punjab province, Pakistan. *Earth Systems Dynam*. 5, 1359–1406

Amare, A. and Simane, B. (2017). Determinants of Smallholder Farmers' Decision to Adopt Adaptation Options to Climate Change and Variability in the Muger Sub Basin of the Upper Blue Nile Basin of Ethiopia. *Agriculture & Food Security*, 6, 64. https://doi.org/10.1186/s40066-017-0144-2

Bannayan, M., Paymard, P. and Ashraf, B. (2016). Vulnerability of Maize Production under Future Climate Change: Possible Adaptation Strategies. *Journal of the Science of Food and Agriculture*, 96, 4465-4474. https://doi.org/10.1002/jsfa.7659

Belay, K., Beyene, F.&Manig, W. (2005). Coping with drought among pastoral and agro-pastoral communities in eastern Ethiopia. *Journal of Rural Development* 28,185–210

Debela, B., (2017). Gender and climate change: determinants of female farmer's adaptation strategies to climate change; A survey study in AtsbiWomberta, Ethiopia. *J. Citizen.Moral*. 1 (1), 14–40

Diggs, D. M. (1991). Drought experience and perception of climatic change among Great Plains farmers. Great Plains Research: *A Journal of Natural and Social Sciences*1, 114–132

Gyimah, A., Bagbohouna, M., Sanogo, N. and Gibba, A. (2020). Climate Change Adaptation among Smallholder Farmers: Evidence from Ghana. *Atmospheric and Climate Sciences*, **10**, 614-638. doi : 10.4236/acs.2020.104032.

IPCC. (2014). Climate Change 2014 : Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp

Irham Irham, Irma Audiah Fachrista, Masyhuri Masyhuri, Any Suryantini. (2022). Climate Change Adaptation Strategies by Indonesian Vegetable Farmers : Comparative Study of Organic and Conventional Farmers. *The Scientific World Journal*, vol. 2022, Article ID 3590769, 13 pages, 2022. https://doi.org/10.1155/2022/3590769

Isham, J. (2002). The effect of social on fertiliser adoption: evidence from rural Tanzania. *Journal of African Economies* 11,39–60

Kemal, A., Mohammed, A. and Lelamo, L. (2022). Pastoralists' Adaptation Strategies to Climate Change and Determinant Factors in Korahey Zone, Ethiopia. *American Journal of Climate Change*, **11**, 79-102. doi : 10.4236/ajcc.2022.112005.

Lemma, W.A. (2016). Analysis of Smallholder Farmers' Perceptions of Climate Change and Adaptation Strategies to Climate Change: The Case of Western Amhara Region, Ethiopia. *PhD Thesis*, University of South Africa, Cape Town.

Maddison, D. (2006). The Perception of and Adaptation to Climate Change in Africa. *CEEPA Discussion Paper No.10. Pretoria, South Africa*: Centre for Environmental Economics and Policy in Africa

Mburu, B.K., Kungu, J.B., Muriuki, J.N. (2015). Climate change adaptation strategies by small-scale farmers in Yatta District, Kenya. Afr. *J. Environ. Sci. Technol*. 9 (9),712–722

Mequannt M, Fikadu Y, Mebrahtu H, Filmon T. (2020). Farmers' choices and factors affecting adoption of climate change adaptation strategies: evidence from northwestern Ethiopia. *Heliyon*. https://doi.org/10.1016/j.heliyon.2020.e03867

Mugagga, F. (2017). Perceptions and response actions of smallholder coffee farmers to climate variability in montane ecosystems. *Environment and Ecology Research*, 5, 357-366. https://doi.org/10.13189/eer.2017.050505

Mugagga, F., Elepu, J., Nimusiima, A. and Bamutaze, Y. (2019). Institutional Determinants to Climate Variability Adaptation by Smallholder Irish Potato Farmers in Rubanda District, South Western Uganda. *American Journal of Climate Change*, 8, 77-93. doi: 10.4236/ajcc.2019.81005

Mukhlis M, Perdana R. (2022). A Critical Analysis of the Challenges of Collaborative Governance in Climate Change Adaptation Policies in Bandar Lampung City, Indonesia. *Sustainability*. 14(7):4077. https://doi.org/10.3390/su14074077

Oranu, C., Achike, A., Zenebe, A. and Teklehaimanot, A. (2018). Comparative Evaluation of Farmers' Perception and Adaptation Strategies to Climate Change and Variability in Bako Tibe, Ethiopia and Abeokuta, Nigeria. *American Journal of Climate Change*, **7**, 611-623. doi : 10.4236/ajcc.2018.74038.

Saptutyningsih, E., Diswandi, D., & Jaung, W. (2020). Does social capital matter in climate change adaptation? A lesson from agricultural sector in Yogyakarta, Indonesia. *Land use policy*, *95*, 104189.

Taruvinga, A., Visser, M. and Zhou, L. (2016). Determinants of Rural Farmers' Adoption of Climate Change Adaptation Strategies: Evidence from the Amatole District Municipality, Eastern Cape Province, South Africa. *International Journal of Environmental Science and Development*, 7, 687-692. https://doi.org/10.18178/ijesd.2016.7.9.863

Turyahabwe, R., Mulabbi, A., Asaba, J., &Olowo, M. (2021). Ecological Responses of Macroinvertebrates to an In-Stream Ecosystem Restoration Technique in a Tropical Stream in Eastern Uganda. East African *Journal of Environment and Natural Resources*, 3(1), 129-144.

Uganda Bureau of Statistics. (2016). The National Population and Housing Census 2014 – *Main Report*, Kampala, Uganda