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Potential Climate Change Adaptation and Coping Practices for Agricultural Productivity in the Mountain Areas of South Western Uganda

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Authors' contributions

This work was carried out in collaboration with all authors. Author AZ initiated the research and conducted it. Authors MMT and JGMM designed the study and supervised the research. Authors MM, PA, AA, GG and YB managed the literature searches and reviewed the manuscript drafts and participated in the data collection. Author LK analysed the soil properties in relation to the field analyses. Author EA provided the technical input in the overall research project. All authors read and approved the final manuscript.

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ABSTRACT

Agricultural productivity in Rwenzori mountain area is declining and undermining food security in the region. This trend has been accelerated in recent years due to rapid changes in climatic conditions. Climate change adaptation and coping practices are critical to identifying vulnerable

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entities and developing practical, well targeted adaptation practices and policies to improve agriculture productivity. However, it is currently poorly understood and not clear how to categorise and implement climate change adaptation practices. Little information is available on their potential impact and viability. This study was conducted to establish the viability and effectiveness of climate change coping and adaptation practices at different landscape positions in Rwenzori mountain areas of south western Uganda. Household data were collected at three landscape positions on farm households and soil samples were collected from 0-15 cm and 15-30 cm depth under major crops (banana, coffee, cotton and maize). Major adaptation practices were categorized using a developed field ranking approach. Data analysis was done using Genstat software discovery version 13 for soil and yield information and SPSS version 17.0 for socio-economic data. All climate change adaptation practices identified in the study area were at different landscape positions but their responses differed significantly between locations ($P>0.05$). The relationship between landscape position and climate change adaptation practices, largely depending on the type of livelihood emphasized in each location and the predominant crop enterprises grown.

Keywords: Climate change adaptation practices; landscape position; soil properties.

1. INTRODUCTION

Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer) which may be due to natural internal processes or external forcings due to persistent anthropogenic changes in the composition of the atmosphere or in land uses [1]. The importance of climate change adaptation for agricultural productivity is increasingly emphasized by scientists, governments, international research centers, and it has emerged as one of the most important environmental and international development challenges of the twenty-first century [2,3]. Climate change adaptation has increasingly become a global discourse widely recognized as a fundamental and necessary response to the threats posed by climatic changes that occur due to atmospheric concentration of carbon dioxide. The gas has risen steeply and foretells major changes in the Earth's climate in the decades to come as well as major policy decisions to be made sooner than later [4,5].

Global climate change is one of the greatest environmental challenges facing the world including Uganda in the Sub-Saharan Africa. Uganda, like other countries, is vulnerable to the adverse impacts of climate change and variability because their economies are tightly bound to climate [6-9]. Over generations, climate adaptation especially in arid environments has strongly been adopted for livelihoods and farmers have developed coping practices over time to buffer against the uncertainties and induced changes in climate which intend to trigger seasonal variations in the farm communities.

Generally, adaptation to climate change takes place through adjustments to reduce vulnerability or enhance resilience in response to observed or expected changes in climate and associated extreme weather events [10]. Examples of adaptation practices on a broad scale are categorized into proactive and reactive adaptation measures such as crop and livelihood diversification, seasonal climate forecasting, community-based disaster risk reduction, famine early warning systems, insurance, water storage, supplementary irrigation, emergency response, disaster recovery, and migration among communities [11].

It has long been recognized that climate variability hampers implementation of climate change adaptation practices and this has an impact on agriculture production [12-15], although the extent and nature of this impact is still uncertain. The effects of climate variation in Sub-Saharan Africa to agricultural production particularly in tropical areas manifest through floods, droughts, erratic rains and extreme events resulting into famine and food insecurity [16].

Climate change is a central development challenge that threatens to undermine progress and set adaptation efforts from scientists and policy makers to reduce the subsequent negative impacts [17,18]. Studies indicate that such changes affect agriculture and food production around the world, severely in some regions [19-22].

In Uganda, Rwenzori mountain areas are among the highlands mostly affected by climate effects due to increased mean temperature. This has already been manifested as a result of loss for over 80% glaciated surface area since 1900 [23-25]. Other drivers of changes observed on the region are anthropogenic such as land degradation from poor farming practices and soil erosion [26,27]. This has affected crop productivity among others, threatening food security and as a consequence of a decrease in crop and livestock productivity [28,29].

The contribution of sustainable land and water management (SLWM) practices that are commonly being promoted in the region are focused on tackling land degradation and less on communities' potential to adapt and cope to the effects of climate change and resilience to the farming community [30]. Studies have indicated that certain sustainable land and water management practices have the potential to increase soil carbon, a property that would be crucial in helping communities to adapt, become more resilient to changes in climate as they influence soil temperature and moisture content [31,32], which directly affect carbon dioxide fluxes from the soil surface [33,34], hence affecting soil carbon levels. These findings are particularly relevant to Uganda's mountain areas and other regions because agriculture is the largest economic activity and its management is likely to be a key component of adaptation to climate change which is an integral component of the country's policy development planning [35]. The big question this paper poses to the global climate change research community is the potential to practice viable adaptation and coping practices in the changing climatic condition to future agriculture production in mountain areas. This paper presents the data and evidence from a study conducted in 2011-2014 on how farmers in mountain areas of Rwenzori highlands adapt to such extreme changes.

Without viable climate change adaptation and coping practices, it is anticipated that adverse impacts of climate change on agriculture sector will exacerbate poverty [36]. Rwenzori Mountain is traditionally known for its snow at the peak which used to regulate the micro climate with in the area; earlier studies conducted in the region indicate that the snow is gradually melting due to climate change and other anthropogenic related factors [37,38,24]. However, the magnitude of the impact of how farmers cope and practice adaption to climate change impacts is not well documented to direct policy formulation and planning [10]. Therefore, this study assesses the viability of climate change adaptation practices employed by small scale farmers to improve agricultural productivity in mountain areas. Uncertainties about the detail of viable and effective adaptation practices remain a major consideration in studies of regional climate change and adaptation to boost agricultural productivity [39]. What is lacking are viable adaptation practices tested and implemented to support farmers in mountain areas to increase crop yield and address food security. This will help to support institutional arrangements, policies and mechanisms for improving the practices of agricultural sector actors to address what is working where, how and why it is practiced in specific geographic location along the mountain slopes. It is this knowledge gap that this study thought to fill.

1.1 Effects of Climate Variation for Agricultural Productivity

Climate variations and changes can have significant impacts on agricultural production, forcing farmers to adopt new practices in response to altered conditions. These temporal and spatial variations in climate have a direct influence on the variability of available soil moisture [40]. Higher temperatures, changes in precipitation, and increased climate variability can affect agriculture, forestry, and rural areas [41,42]. Other impacts are also on livelihoods and food production which affects food availability and nutrient access aspects of food security and market access for farmers to obtain agriculture inputs [43].

Several studies indicate that climate change is already taking place worldwide and that the climate system is likely to experience changes, regardless of whether emission reductions are successfully undertaken [44,45]. According to [27], Rwenzori region will be one of the few areas in Uganda which is going to experience drastic climatic changes in the near future as shown in Table 1.

1.2 Analysis of Weather Trends and Time Series for Climatic Changes in Kasese

Since 1980-2009, the average surface temperature across Kasese and the contiguous districts in the region of the country has risen to maximum of 30-32ºC (Fig. 1). This average temperature has risen more quickly since the late 1960s shifting weather patterns and causing more extreme climate events which are already affecting society, institutions and ecosystems. The equation in Fig. 1 (y= 0.0451x + 23.372), illustrates a change in mean temperature over time and R^2 = 0.7332 also represents 73.3% of the total variation in *y* a linear relationship between *x* and *y* (as described by the regression equation). Therefore, there is a strong positive correlation between Y and X implying that significant climatic changes are occurring.

Temperatures in Kasese district have been increasing slowly but steadily over the last thirty years as shown by the positive relationship in the two temperature equations; however rainfall has remained constant over the period with maximum peaks being registered in 1997 and 1998 where Uganda experienced the el'nino rains country wide. The lowlands of the district experienced remarkable flooding like in Karusandara subcounty of the study area.

1.3 Choice of Adaptation Practices by Farmers

Various factors determine and enhance the choice of specific coping and adaptation practices by farmers like land management practices, influence of household size, availability of farm inputs to farmers, and adoption of agricultural technologies. For instance, land management practices are adopted as climate change adaptation practices and this can be attributed to prevalence of land degradation as a result of climate change risks. However, these practices are not measures to control land degradation but for effective coping and adaptation practices which often involves modification of the slope, like terracing and preventing runoff water through infiltration ditches, benches, hedgerows, among others [46]. In the studies of [47], certain land management practices are attributed to having the potential to increase soil carbon, a property that would be crucial in helping communities become more resilient and adapt to changes in climate as they influence soil temperature and moisture content which is a key determinant for crop productivity. This is also similar with findings of other Authors [31,32,48], that sustainable land and water management practices directly influence and affect carbon dioxide fluxes from the soil surface which also affect soil carbon levels [33,34].

Household size influence the choice of climate change adaptation practices that can be seen from two dimensions; the first assumption is that, households with many members may be forced to divert part of the labour force to off-farm activities in an attempt to earn income in order to ease the consumption pressure imposed by a large family [49]. The other assumption is that large family size is normally associated with a higher labour endowment, which would enable a household to accomplish various agricultural tasks which is in line with findings of [50]. Availability of farm inputs to farmers such as fertilizer inputs and credit to purchase facilities increases the likelihood of climate change adaptation like using improved crop varieties, soil conservation, planting trees and agroforestry and adoption of irrigation facilities. Research on adoption of agricultural technologies indicates that there is a positive relationship between the level of adoption and the availability of farm inputs [51,49]. Likewise, this study also had an assumption that there is a positive relationship between availability of farm inputs, access to credit to purchase inputs and adaptation techniques of climate change. Studies on adoption of agricultural technologies and climate change adaptation also indicate that land size has both negative and positive effects on adoption, showing that the effect of land size on technology adoption and climate change adaptation is inconclusive [52]. However, land size is associated with greater wealth and it may be attributed as a factor to increase adaptation to climate change.

Table 1. Comparison of baseline and future temperatures of three different regions in Uganda

	March to May		June to August		September to November	
	1961-1990	**2012-2044**	**1961-1990**	**2012-2044**	**1961-1990**	**2012 -2044**
Rwenzori Highlands	26.7ºC	36ºC	25ºC	33.1ºC	26ºC	34.6ºC
Cattle Corridor	26ºC	28ºC	29ºC	31.3ºC	28ºC	30.5ºC
Northern Region	31ºC	33ºC	32ºC	34ºC	31ºC	37ºC

Source: Nandozi et al. 2012 [27]

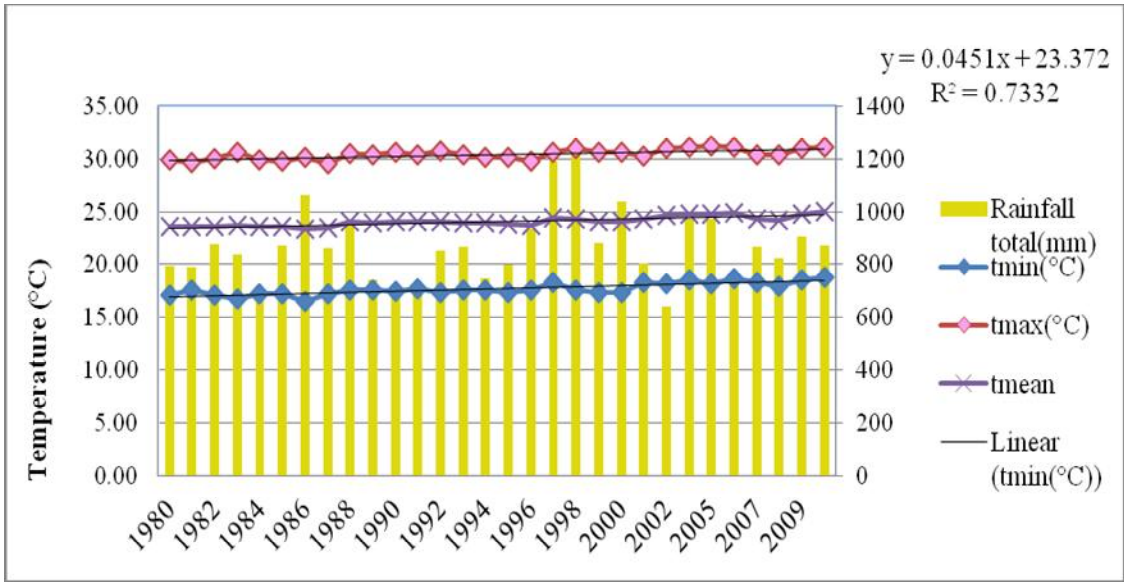

Fig. 1. Temperature trends for Kasese district

During present study, there was a set hypothesis that different households living in different landscape positions (upper, middle and lower) practice climate change adaptation according to where they live and use different adaptation practices. This is due to the fact that climatic conditions, soil and other factors vary across different landscapes and agro-ecologies which influence households in making adaptation choices and their decisions to adapt. However, analysis of the relationships in climatic variables like temperature and rainfall with choice of adaptation practices requires time series data on how farmers have behaved over time in response to changing climatic conditions. Therefore it was assumed that climatic conditions vary in respective landscape positions.

2. RESEARCH METHODOLOGY

This study was carried out in Kasese district of mountain Rwenzori area located in the south western region of Uganda astride the equator and directly to the northern Channel of Lake Edward and Lake George which it shares with Bushenyi district in the south. The district lies between latitudes 0º 12'S and 0º 26'N; longitudes 29º 42'E and 30º 18'E. It also shares borders with the newly established Kamwenge district in the east (curbed out of former Kabarole district), Bundibugyo and Kabarole districts in the north and northeast. To the west lies the Democratic Republic of Congo (DRC) (Fig. 2).

2.1 Identification of Coping and Adaptation Practices on Farm for Climate Change

Climate change coping and adaptation practices were identified through field interviews and on-farm field observations. The primary reason for using the observation method was to check for the accuracy of the information obtained from the interview survey methods [53]. The sample size from the total population of 18,538 households in the study area was calculated using the formula proposed by [54].

$$n = \frac{N}{1 + N(\alpha)^2}$$

Where

- n = Sample size
- N = Total number of households in the study area
- α = Marginal of error set at 10%

With the above formula, the sample size derived was 99.46 (approximated to 100), and a proportionate stratified random sampling based on the equal proportions of each landscape position contributed to the total number of households that were selected for the study. Therefore, the unit of analysis was the rural farm house hold which operates as the ultimate decision making unit in farming and livelihood process.

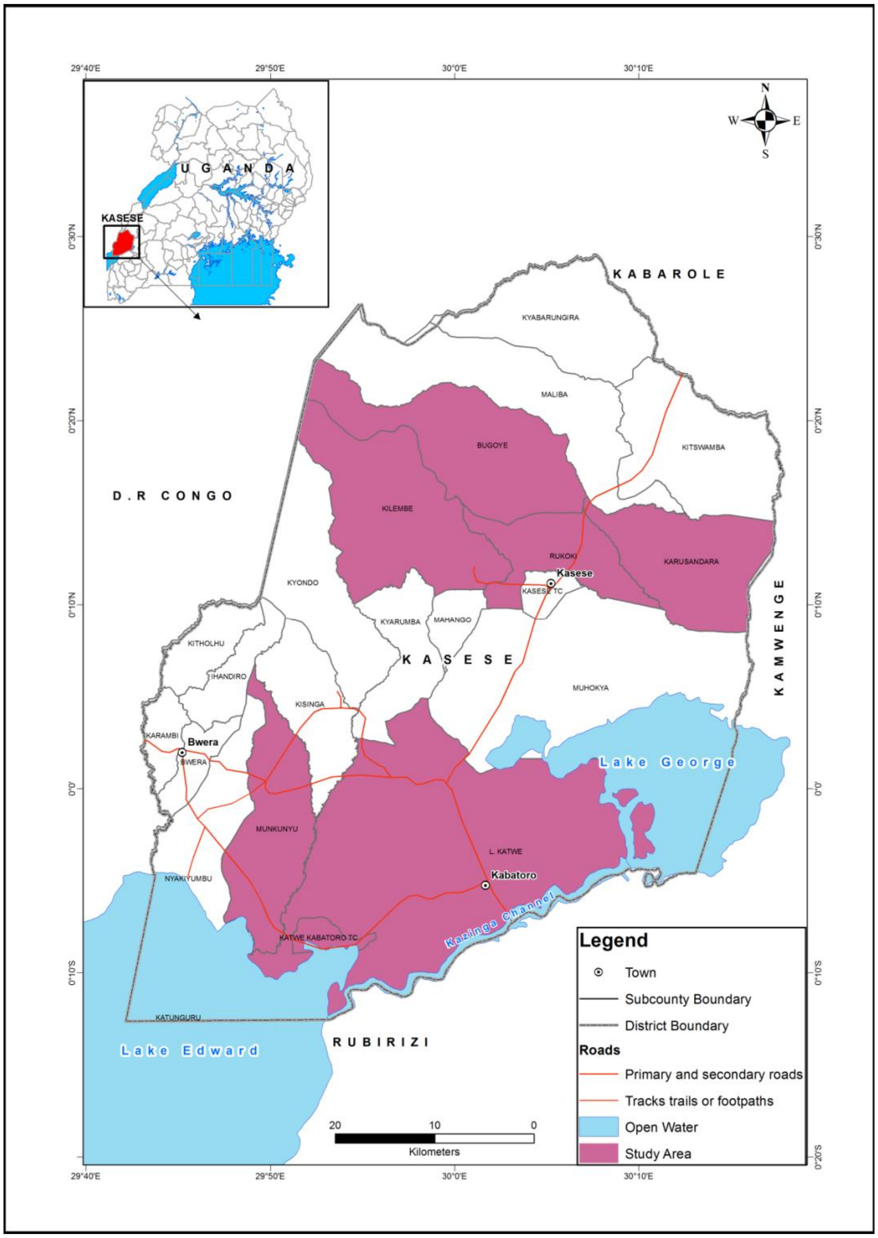

Fig. 2. Study area in Kasese mountain of Rwenzori region

2.2 Field Based Ranking Approach

The exploration of climate change adaptation processes begins with a quantitative categorisation of observed on-farm coping and adaptation practices. Since adaptation itself is a complex, multidimensional process, a field based ranking approach as proposed by [55] was adopted to measure climate change adaptation practices with major factors respondents consider important as parameters for categorising adaptation practices in the study area of south western Uganda. In the field interviews, the respondents were asked to rank the factors considered more important for climate change adaptation. The responses were assigned weights from 4-0, where (4) was highly most important factor cited per each adaptation practice, (3) was the second most important factor, (2) was important, (1) was moderately important and (0) was coded as not important in adoption of climate change adaptation practices.

The direct link of factors which support local livelihoods to practice climate change adaptation practices required using weights because they are easier to assign for the respondents [55]. A further advantage of this approach is that, it allows the researcher to assign specific codes of adaptation determinants at the household level. Therefore, it is expected to be a robust measure for individual, autonomous adaptation practices as presented in the preceding discussion.

A reconnaissance study was conducted in the months from December 2011 to April 2012 during the production season, were on-farm climate change coping and adaptation practices were assessed. Following this assessment, soil samples and crop yield data for major crops were collected from 30 farms of households with on-farm climate change adaptation practices and farms without on-farm adaptation practices at all the three landscape positions (upper, middle and lower slopes).

Soil samples were collected from 0-15 cm and 15-30 cm depth. Soil health indicators are a composite set of measurable physical, chemical and biological attributes which relate to functional soil processes and can be used to evaluate soil health status, as affected by farm management practices and climate change drivers. The soil layer 0-30 cm was considered because it is the major agricultural layer (Tenywa, 1998). Soil pH, Soil organic matter (SOM), total nitrogen (N), extractable phosphorus (P), % carbon and exchangeable potassium (K) parameters were determined using the laboratory standard procedures described by [56].

2.3 Data Analysis

Data collected from respondents using semi-structured questionnaires were coded, cleaned, and entered into SPSS software version 17.0 for descriptive statistics and the soil and yield data was analysed using Genstat and ANOVA discovery version 13. In this study many factors were assumed to be influencing use of different adaptation practices at different landscape positions. This necessitated a test of different identified variables to attest relationships with climate change coping and adaptation using non-parametric chi-square test of association. The chi-square test was also used to determine the relationship between factors influencing adoption of different adaptation practices.

3. RESULTS AND DISCUSSION

3.1 On-farm Climate Change Adaptation Practices against Climate Change Impacts

From on-farm observations and field interviews, nearly all climate change adaptation practices identified in the study area were at different landscape positions (Table 2) and their performances differed significantly between locations ($P>0.05$). The relationship between landscape position and climate change adaptation practices, largely depending on the type of livelihood emphasized in each location and the predominant crop enterprises grown where the respondents live.

From expanding land, changing planting dates, use of high yielding crops and intercropping (31%) was in mid-slopes with majorly in maize-cotton cropping systems and 46% SLWM (stones, terracing, agroforestry, cover cropping, grass bunds, mulch) under banaana-coffee. Migration and off-farm activities were in the lower slopes (11%) under very low productive low lands. These findings are in line with results reported by [57] in the Nile basin of Ethiopia and [30] in south western Uganda who found that climate change adaptation is influenced by agro-ecological settings. Variation in climate change adaptation practices across landscape positions is due to differences in climatic conditions and soil types as reported by [58-62,55].

3.2 Field Based Ranking Approach of Major Climate Change Adaptation Practices

Prioritizing beneficial factors to foster climate change adaptation practices is an imperative step in mitigating climate sensitive risks in agriculture production. From (Table 3), use of crop varieties like maize (Longe4H, Longe6H); Banana (FIA 21, FIA 17) and other indigenous varieties were the most important climate change adaptation practices (11 score) used by the respondents. Planting trees and agroforestry was the second most important practice (10 score) and furrow irrigation (10 score). Using the chi-square test of association, the determining factors of adoption and climate change adaptation practices employed on farm [Chi-square calculated (126.78) > Chi-square tabulated (25) $P>0.05$] which indicated that, there was a significant association between factors for adoption of practices and implementation of adaptation practices on-farm.

Vulnerability was the most important factor for adoption of a given climate change adaptation practice as indicated at (22 score) followed by obtaining farm crop yield output (17 score), maximizing economic returns (11 score), on-farm and social cultural factors scored the least (3 score). This is due to uncertain climatic changes prone to agriculture a major source of livelihood, this makes the farming communities regard vulnerability as central and a major driving factor for adoption of adaptation practices. The adaptation practices employed on farm was statistically significant ($P > 0.05$), basing on the chi-square test of association as presented in (Table 3). This test revealed a significant relationship between factors for adoption of various adaptation practices in the study area.

3.3 Viability Assessment and Performance of Adaptation Practices at Different Landscape Positions and Soil Property Variation

Generally, climate change adaptation practices increased the yield for all the major crops grown at the respective landscape positions in the study area of mountain Rwenzori ($P<0.05$), (Figs. 3A, B, C, D and E). Farmers tended to grow different crops at different landscape position. For example, banana and coffee was the only crop located in the upper landscape position (Figs. 3A and B), maize cotton were found in mid-slopes (Figs. 3C and D) while banana-cotton was located in the lower landscape position (Fig. 3E and F). As shown below, 19% and 27% increment were registered where agroforestry and tree planting are employed under banana and coffee cropping systems respectively in the upper landscape position (Figs. 3A and B).

Figs. (3C) and (D) illustrates that in the mid-slope, changing planting dates significantly improved maize yield compared to no adaptation conditions; while crop varieties and furrow irrigation improved cotton yield significantly ($P<0.05$). Change in crop varieties reduced maize yield compared to the control (without adaptation practices). Maize yield (Fig. 3C) and cotton yield (Fig. 3D) under changing planting dates, use of crop varieties and furrow irrigation as climate change adaptation practices in the mid-slope landscape position.

In the lower slope, intercropping and use of improved varieties increased cotton and banana yield (Figs. 3E and F). Under intercropping in the cotton production, 500% increment in the yield was registered while 400% increment was observed under use of crop varieties in cotton production. In the banana production, intercropping led to 78% and use of crop varieties contributed to 22% compared to where there was no climate change adaptation and coping practices at the same landscape positions (Fig. 3A). This finding is in agreement with simulation findings reported by [63-66].

In this study all farms had high OM, %C, %N and available P content a major determining factor for crop productivity [67]. Similar findings were observed under high yielding crop varieties of maize production in Czech Republic [68]. The influence of high yielding maize crop varieties, furrow irrigation and intercropping led to an increment in crop yield.

In Eastern and Southern Africa, a general relationship can be observed between annual rainfall and national average maize yields [69]. Conventional drought resistant varieties of banana, maize and cotton have yielded significant dividend. Breeding for resistance to adverse climatic factors with efficient on-farm management practices can support crop productivity. Significant increases in maize yield of up to 144 kg ha^{-1} yr^{-1} under drought stress conditions where reported [70]. In this study, the influence of crop varieties on yield productivity was variable and dependent on the geographical location. The study showed an increase in the yield between 800 - 1000 kg ha^{-1} yr^{-1} in the middle slope.

3.4 Selected Soil Properties under Adaptation Practices / or Strategy for Different Crops and Landscape Positions

Available phosphorus (Av. P) was generally higher than the critical value (>15 mg kg^{-1}) (Table 4) across the landscape positions (Fig. 4). Generally, land without adaptation practices had relatively low Av. P content compared to that with climate change adaptation practices. Av. P was also higher at 15-30 cm soil depth in the mid-slope and lower slope compared to 0-15 cm soil depth on farm lands where adaptation practices were not employed.

Total nitrogen (TN) variation within landscape position, soil depth and presence or absence of adaptation practices is given in Fig. 5. TN content was generally higher were adaptation practices were employed except in the middle slope. There was not significant variations ($P<0.05$) in the upper slopes and lower slopes in the entire layers of 0-15 cm and 15- 30 cm of soil depth.

Potassium was generally higher than the critical value (0.15 and 0.22 cmol kg^{-1}) across all the landscape positions, soil depth (Fig. 6). Land with adaptation practices had high K content compared to farm lands where there was no adaptation practice. In the lower slope, K content was relatively higher where there was adaptation practices compared to farm lands without adaptation practices in the lower slope positions of mountain Rwenzori mountain study area.

Table 2. Coping and adaptation practices in the study area

Landscape position	Coping and adaptation practices	Altitude (m asl)	Percent (%)
Upper slope position	SLWM (stones, terracing, agroforestry, grass bunds, cover cropping, mulch)	1400-1450	46 %
Mid slope position	Expanding land, high yielding crops and intercropping, changing planting dates,	1400-1450	31%
	Fertilizers, irrigation, new crops and changing field location	1100-1200	12%
Very low productive low lands	Migration and off-farm activities	900-1000	11%
Total			100%

Table 3. Field based ranking index approach of major climate change adaptation practices and factors for their adoption in the study area

Adaptation practices	Factors for adoption				
	Economic returns	Yield output	Vulnerability level	Socio cultural	Total
Changing planting dates	1	3	4	0	8
Planting trees / agroforestry	4	3	3	0	10
Soil conservation (mulching, cover crop, terracing)	0	4	3	0	7
Crop varieties (early maturing and drought resistant like Longe4H, Longe6H, FIA 21, FIA 17 and indigenous varieties,)	3	4	4	0	11
Migration and off farm activities	0	0	4	3	7
Fallow Irrigation	3	3	4	0	10
Sub total	11	17	22	3	53
Chi cal			126.8		
Df			15		
Critical Value			0.05		
Chi-square tabulated			24.996		
Chi- probability			9.04632E-20		
Chi cal>Chi tab					

Table 4. Critical levels uses to analyse soil physico-chemical characteristics

	pH	OM (%)	N (%)	Av. P (mg kg^{-1})	K (cmol kg^{-1})	Na (cmol kg^{-1})	Mg (cmol kg^{-1})	Ca (cmol kg^{-1})
Critical values	5.5	3.0	0.20	15	0.22	<1.0	0.5	4.0

Source: Okalebo et al. 2002 [56]

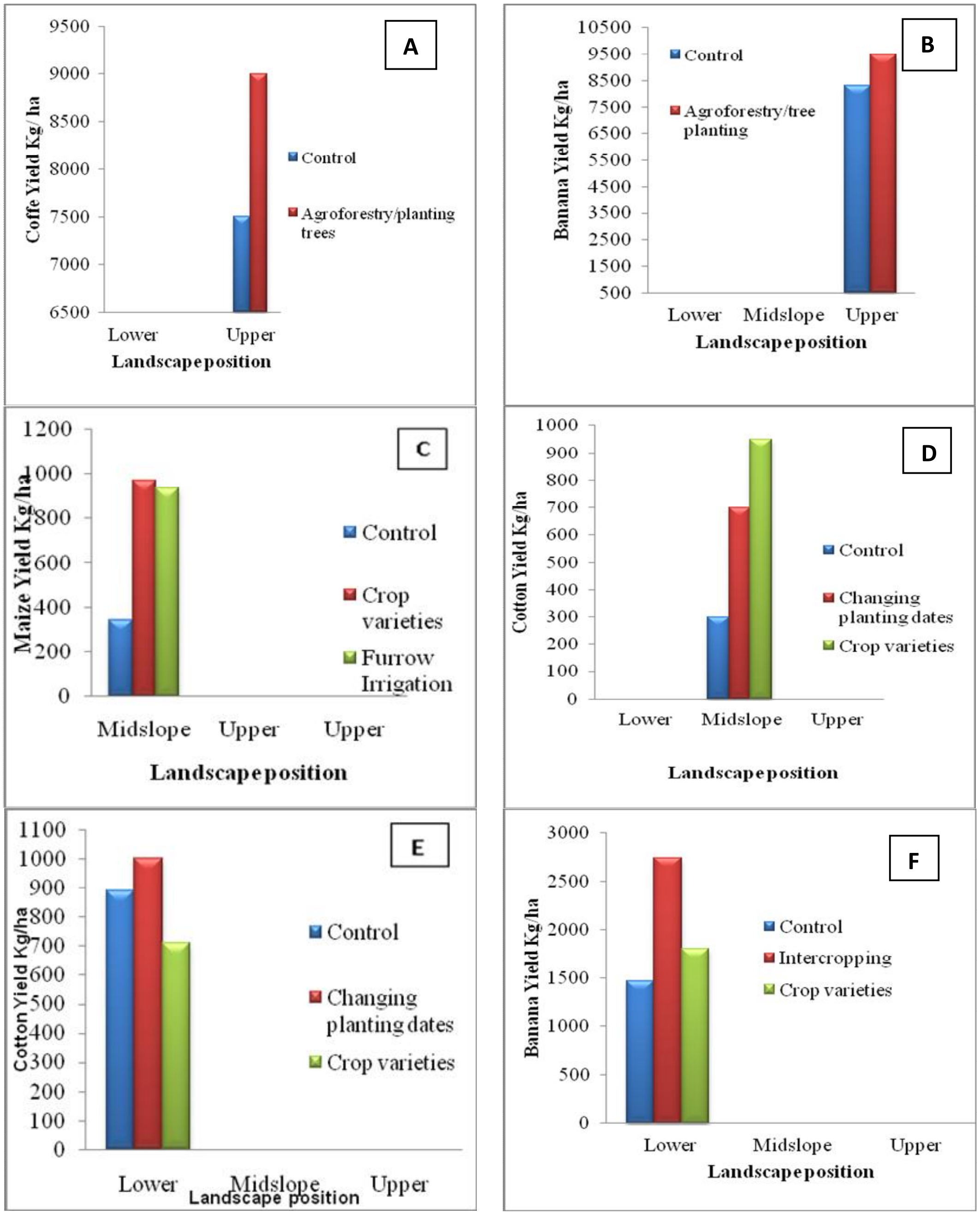

Fig. 3. A banana yield and B coffee yield under agroforestry practice in the upper landscape position, C is the maize yield and D cotton yield under changing planting dates, crop varieties and furrow irrigation adaptation practice in the mid-slope landscape position. E is cotton yield and F banana yield under intercropping, crop varieties and changing planting dates climate change adaptation practices in the lower landscape position

Soil organic matter (SOM) was relatively high in the top soil (0-15 cm) across the landscape positions were there was adaptation practices. Low SOM content was observed in the mid-slope were adaptation practices where not employed (Fig. 7).

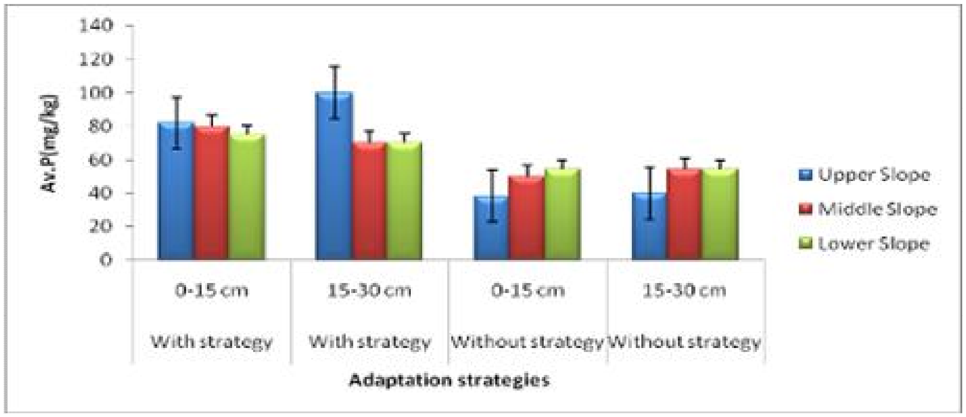

Fig. 4. Available Phosphorus (Av.P) variation across landscape position, soil depth and climate change adaptation practices

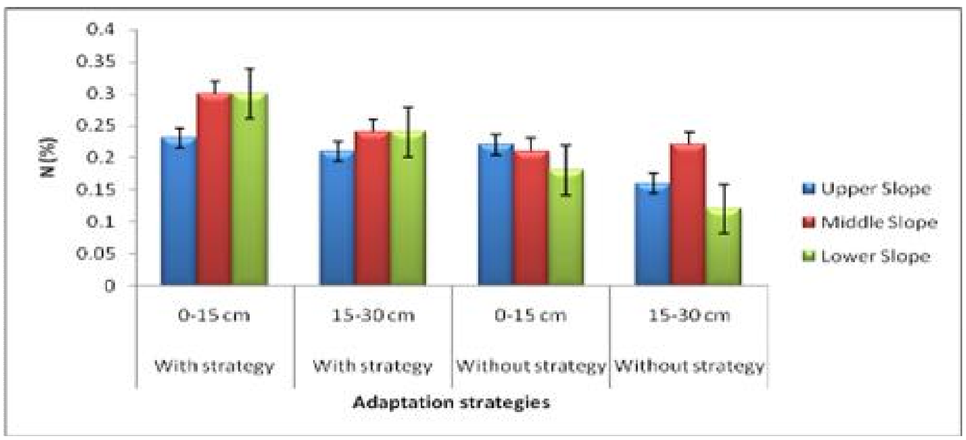

Fig. 5. Total nitrogen variation across landscape position, soil depth and adaptation practices

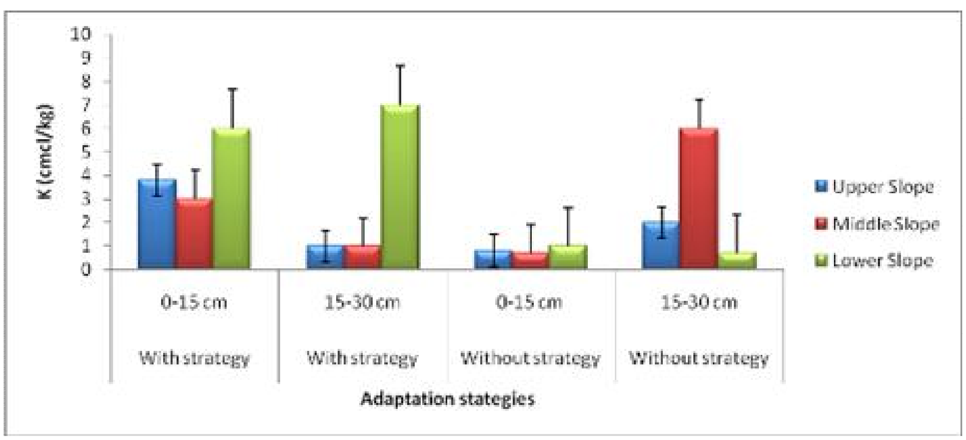

Fig. 6. Potassium variation across landscape position, soil depth and adaptation practices

Soil pH was neutral in all landscape positions and varied between 6.0 -7.0 where adaptation practices were employed and where there were no adaptation strategy/practices. Though in the lower slope, the soil was alkaline (8.0-9.0) were there was adaptation practices (Fig. 8).

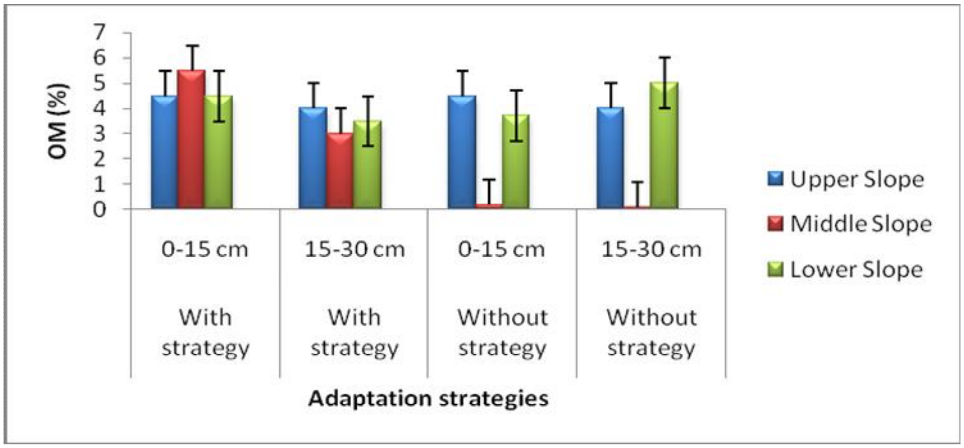

Fig. 7. % OM variation across landscape position, soil depth and adaptation practices

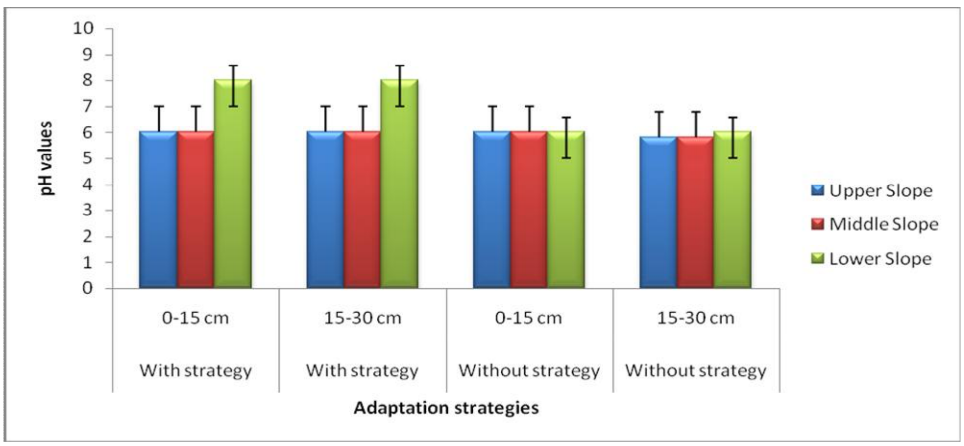

Fig. 8. Soil pH variation across landscape position, soil depth and adaptation practices

Generally carbon varied with soil depth in (0-15 cm and 15-30 cm) and where presence or absence of climate change adaptation practices. In the upper slope, there was variation in the top soil (0-15 cm), at all slopes were adaptation practices existed and were they did not exist. In the mid-slope, there was effect on % C were adaptation practices were implemented and it varied significantly (P>0.05) to where climate change adaptation practices where not employed. There was also a variation in the lower slopes were adaptation practices are found and where they are not employed in all the respective soil depth (Fig. 9).

Soil depth had no effect on the Mg content along the landscape position and it was relatively high where adaptation practices were employed. The lower slope had significantly more Mg content than upper and mid-slope only where there was coping and adaptation practices (Fig. 10).

Generally, calcium varied according to soil depth and landscape position with adaptation practices. The upper slope position had no significant variation in Ca content given the soil pH which was neutral (6.0-6.8) while it was observed that in the lower slope, soils were alkaline (8.5-9.0) and with sodium of >1.0 cmol kg^{-1} (Fig. 11).

Sodium varied relatively high in the lower slope compared to upper and mid-slope positions. The lower slope had more Na content were there was coping and adaptation practices (Fig. 12).

3.5 Implication of Climate Change on Soil Properties and Climate Change Adaptation Practices

With climate change impacts, rainfall levels and distribution are expected to decline in many places and occur in more intense events, erratic and evaporation and transpiration rates are projected to increase. These changes will reduce and affect the availability of soil moisture for plant growth and crop productivity. Several climatic factors influence soil temperature and moisture content which is a key determinant for crop productivity. Therefore climate change adaptation can buffer against such impacts for example; it induces soil physico-chemical properties through microbial activity which tends to increase the quantity of plant nutrients cycling through soil organisms [31,32,48].

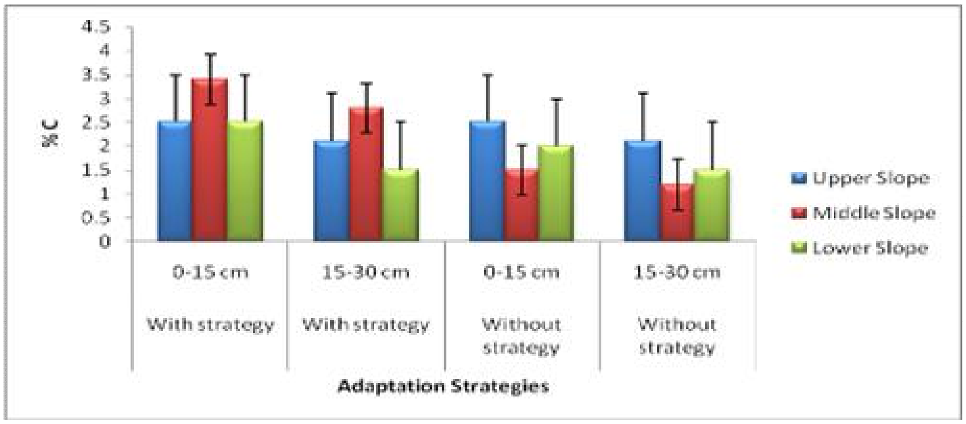

Fig. 9. Carbon variation across landscape position, soil depth and adaptation practices

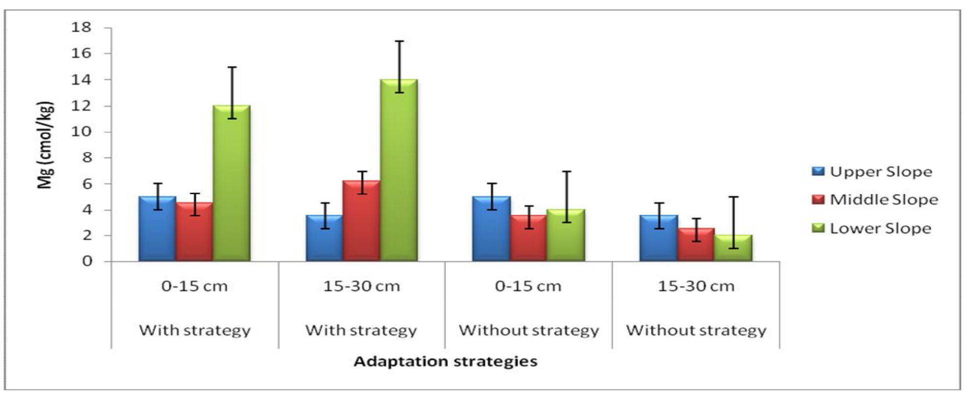

Fig. 10. Magnesium variation across landscape position, soil depth and adaptation practices

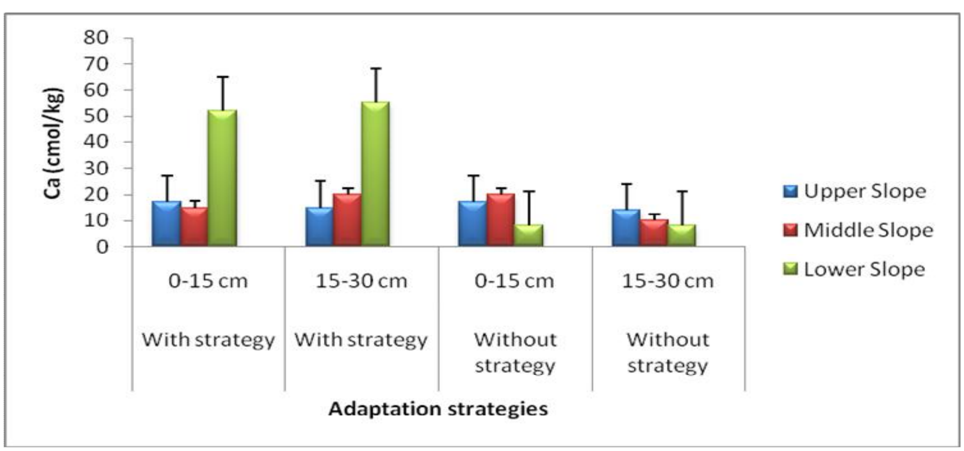

Fig. 11. Calcium variation across landscape position, soil depth and adaptation practices

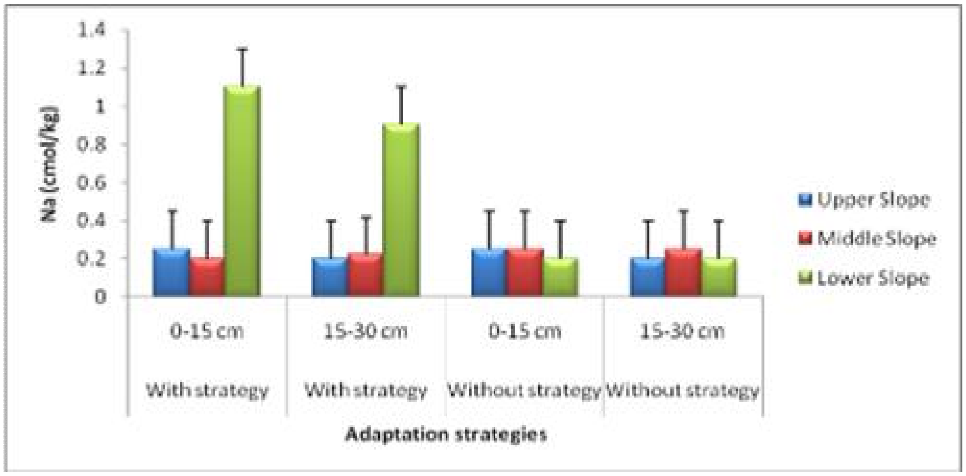

Fig. 12. Sodium variation across landscape position, soil depth and adaptation practices

The higher temperatures will also increase the rate of soil organic matter decomposition, especially near the soil surface, which will affect the soil's potential capacity to sequester carbon and retain water [71]. Climate change adaptation practices like agroforestry, mulching and intercropping replenish soil fertility and enhances integrated nutrient management for example; through biomass transfer system of leguminous mulches [72]. Leguminous tree fallows of several species under such cropping systems and adaptation can accumulate significant amounts of nitrogen in their leaves in the short duration (from 6 months to 2 years) which increases soil organic matter [73]. Similar studies by [74], indicate that agroforestry is more efficient for climate change adaptation because of its greater stimulation of soil organisms and nutrient additions under banana-coffee farming system.

Other climate change adaptation strategies like improved fallows and intercropping can also contribute to the control of crop pests, weeds (including Striga hermontheca) and provide wood for energy and for staking climbing crops like climbing bean. Such technologies also reduce climate change risks of soil acidification and salinization hence improving crop productivity and soil pH modification [75]. Salinization is one of the progressive causes of soil degradation that threatens to limit plant growth and reduce crop yields on productive agricultural lands [76]. However, high levels of soil salinity can also be tolerated if salt-tolerant (halophytic) plants are grown in such areas. Recent data show that globally about 11 percent of irrigated land is salt-affected and about 53 percent of the global groundwater is also saline [77].

Adaptation practices can also improve soil structure, build up soil organic matter and its carbon (C) stocks, thus contributing to C sequestration [78]. Mulching is a simple climate change adaptation techniques that buffers soil temperature and helps the soil-crop system reduce evaporation and the mineralization of organic matter and in the long production season it also counteracts the nutrient loss.

4. CONCLUSION

We investigated the viability of potential adaptation practices which could offset climate change impacts for Uganda's agriculture in the mountain areas of Rwenzori. In light of the above results, the use of high yielding crops, including; maize (Longe4H and Longe6H), Banana (FIA 21 and FIA 17), indigenous varieties, intercropping and changing planting dates were the major climate change adaptation practices in the mid-slopes of Rwenzori mountain areas. Other sustainable land and water management practices (stones, terracing, agroforestry, cover cropping, grass bunds, mulch) also increase soil moisture availability a key parameter for soil fertility. While migration and off-farm activities were in the lower slopes dominated by pastoralists and salt mining was the major off farm activity for livelihood with low agricultural activities. Fertilizer use, furrow irrigation, new crops and changing field location was found in different landscape positions were the major adaptation practices in the mid-slopes. Use of crop varieties like; Longe4H, Longe6H for maize crop and FIA 21, FIA 17 for banaana crop and other indigenous varieties, were the most important climate change coping and adaptation practices used by the households in the study area. Planting trees and agroforestry was ranked the second most important and furrow irrigation.

From the determining factors of adoption and climate change adaptation practices employed on farm, the findings revealed that, there was a significant association (p>0.05) between factors for adoption and adaptation practices. Vulnerability was the most important factor for adoption of any given climate change adaptation practice/or strategy followed by obtaining crop yield output, maximizing economic returns on farm and social cultural aspects. In the study area, farm communities are dependant on agriculture for livelihood as the mainstay for households in Rwenzori mountain areas though vulnerable to climate change. Therefore, coping and adaptation practices are adopted to buffer against climate change risks and impacts which affect crop productivity and minimize the seasonal yield output.

The study also reveals that, where climate change coping and adaptation practices are being implemented, key soil properties (NPK) at all the landscape positions varied with the crop yield output of the major crops grown in the Rwenzori Mountain study area compared to were adaptation practices are not employed. However, it was noted that, all landscape positions (upper slope, mid-slope and lower slope positions) in the Rwenzori Mountain study area had different climate change adaptation practices, various crops grown and varying crop yield output with respective adaptation practices at a specific landscape position. Finally, climate change adaptation and coping practices are location specific in Rwenzori Mountain areas and households employ coping and climate change adaptation according to where they live and viability of any adaptation practice is dependent on various benefits that accrue to it like; yield output, performance for a given season, vulnerability to climate change shocks, economic returns and its cost effectiveness associated with social cultural factors. Investment in further research should be conducted to provide empirical evidences scalability of the practices.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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