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## Farmers' adaptation to climate change and crop yield: a case of Amuru and Apac districts of Northern Uganda

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### ABSTRACT

With increasing incidences of the negative impacts of climate change to smallholder farming, an understanding of the effects of farmers' adaptation options to climate change on crop yield is critical in designing practical measures and policies for increasing food production and food security. This study assessed the effects of smallholder farmers climate change adaptation intensity on crop yield with focus on maize, groundnuts and beans in Apac and Amuru districts, northern Uganda. Cross-sectional survey design was employed for data collection. Data were analysed using both descriptive and econometric approaches. Results showed that the most common climate change adaptation strategies used by smallholders related to varietal adjustments including planting different crop varieties each time, drought-resistant varieties, early maturing varieties, improved seeds and changing the time of planting. Yield comparisons between adapters and non-adapters for the three major crops showed that adapters realized significantly higher yields than non-adapters for most of the climate change adaptation strategies. This study suggests that farmers who used more adaptation strategies realized higher yields than the non-adapters. Our findings call for increased efforts by stakeholders to strengthen agricultural extension services and coverage to enhance smallholder farmers capacity to adapt to the effects of climate change.

### KEYWORDS

Adaptation capacity; adaptation intensity; adapters; non-adapters; varietal adjustments

## Introduction

There are growing concerns from many studies (Bandara & Cai, 2014; Kahsay & Hansen, 2016; Roudier et al., 2011) showing that least developed countries are experiencing an increasingly negative impact of climate change on the agricultural sector. Manifestations of climate change are seen in different ways including prolonged and frequent droughts, rising temperatures, erratic and heavier rains (Akinagbe & Irohibe, 2015; Chepkoech et al., 2018), which impact greatly on the agricultural sector particularly in sub-Saharan Africa (SSA), where farming is mainly rain-fed and largely undertaken by

smallholders. These smallholders are particularly hit harder because they usually do not have agricultural techniques such as greenhouses and irrigation facilities to improve crop yield (Amikuzino & Donkoh, 2012) that can cushion them from the adverse effects of climate change. With rainfall patterns becoming highly unpredictable, coupled with anticipated increased occurrence of droughts, and floods in the near future (IPCC, 2007; Roudier et al., 2011; World Bank, 2010), smallholder farmers are expected to be highly impacted. With agriculture being the backbone of most SSA countries, climate change is expected to highly affect these economies.

Uganda for instance is one of the least developed countries in the SSA region and is known to be vulnerable to climate change (Wichern et al., 2019). This vulnerability is because the agricultural system of the country is predominantly dependent on a rain-fed smallholder system for rural livelihood (Wichern et al., 2019); yet agriculture is the backbone of the economy, and the livelihoods of many people depend on it (Mubiru et al., 2012). The impact of climate change on smallholder farming is usually manifested as negative effects on the production of common grains and pulses such as maize, millet, rice, beans and pea (Adhikari et al., 2015; Al-Bakri et al., 2011). Any slight variability in rainfall may therefore be reflected in crop yield which may result in adverse physical, environmental and socio-economic impacts.

The impact of climate change on agricultural production is sensitive at local, regional, national as well as global levels (Parker et al., 2019). The climatic condition in Northern Uganda was described by Nimusiima et al. (2013) as highly variable with erratic and unpredictable rainfall, variability in onset and cessation of rain seasons and increasing variability trends in drought and floods. This has resulted to reduced crop yields and/or total crop failure (Roberts & Mattoo, 2018). Therefore, this pathetic situation calls for an imminent need for the adaptation of farmers to the effects of climate change if they are to maintain agriculture as their major source of livelihood.

Several studies conducted in Uganda have focused on farmers' perception of climate change (Osbahe et al., 2011), its effects on agricultural production (Okonya et al., 2013) and adaptation strategies developed by farmers to the effects of climate change (Atube et al., 2021; Hisali et al., 2011), but none of these studies specifically focused on whether farmer adaptation intensity to the effects of climate change affects crop yield with specific attention on maize, rice and beans. Although a study by Onzima et al. (2019) in Northern Uganda looked at the effect of adaption on bean yields, it only focused on two climate change adaptation strategies (varietal adaptation and adjusting planting calendar). Yet a number of studies (Ajak et al., 2018; Atube et al., 2021; Mubiru et al., 2018) show that smallholder farmers in Uganda most commonly practice planting different crop varieties, planting drought-resistant crop varieties, land fallowing, mulching, intercropping and planting of food security crops as adaptation

strategies to climate change. Consequently, it is important to understand how adaptation intensity (the number of climate change adaptation strategies adopted by a farmer) would impact on the yield of common crops cultivated by smallholder farmers.

In this study, we used Amuru and Apac districts in Northern Uganda as our areas of focus because they are both characterized by different agro-climatic conditions and predominant agricultural production systems. Since the population in these two districts predominantly depend on agriculture for their daily livelihoods, they are among the districts in Uganda that are most vulnerable to the impacts of climate change due to such existing development challenges as high population growth, increasing poverty levels among low-income earners and low household incomes among others (Mubiru et al., 2015). This study was aimed at assessing the effects of adaptation of smallholder farmers on crop yields with a particular focus on maize, groundnuts and beans in Apac and Amuru districts, northern Uganda. Although there are several other crops cultivated by smallholder farmers in the region, these three crops were identified as the most common in this study.

## Materials and methods

### Study area

This study was conducted in Apac and Amuru districts of Northern Uganda. The selection of these two districts was informed by their location. Apac district is located in the 'cattle corridor', an area stretching from the southwest bordering Tanzania to the northeast of the country bordering Kenya and Southern Sudan (Mulumba & Kakudidi, 2010). The cattle corridor is dominated by pastoral rangelands and has semi-arid characteristics. On the other hand, Amuru district is located outside the cattle corridor. The two districts cover a total area of 7,534 km<sup>2</sup>. The farming system in both districts is predominantly annual cropping and livestock rearing (Odogwu et al., 2016). Farming in the two districts is largely small-scale, with Apac practicing both small-scale livestock rearing and crop farming (Auma, 2016) while Amuru is predominantly inhabited by crop farmers with a few families keeping domestic livestock at subsistence level (Angwech et al., 2015; Atube et al., 2021). Apac district lies between longitudes 32° E and 34° E and latitudes 2° N and 3° N and its southern boundary is bordered by Lake Kwana and the river

Nile. Apac District has bimodal seasons and receives a total annual rainfall of 1330 mm which falls mainly from April to November peaking in April and August. The dry season is from December to March and the average monthly minimum and maximum temperatures are 17°C and 29°C, respectively (Oriangi, 2013). Amuru district lies between longitudes 30° E and 32° E and 2° N and 4° N. The district is endowed with vast fertile soils that support farming (UBOS, 2016). Amuru experiences dry and wet periods throughout the year and receives a mean annual rainfall of 1434 mm (Nimusiima et al., 2013). The wettest period extends from April to October, with its peaks in May, August and October while the dry season is from the end of November to the end of March. Average maximum and minimum temperatures in Amuru are 30.5°C and 16.8°C, respectively (NEMA, 2012).

### Sampling design and sample size

The target population of smallholder farmers was selected using a multistage sampling technique. First, the two districts were purposively selected based on the limited researched information regarding the adaptation of smallholder farmers to the effects of climatic change, and the highly agrarian nature of their population and location in the cattle corridor. From each district, two sub-counties; Paboo and Lamogi (in Amuru), and Akokoro and Chegere (in Apac district) were randomly selected. In each of the selected Sub-counties, two parishes were randomly selected giving a total of eight parishes. From each of the parishes, one village was randomly selected making a total of eight villages for the entire study. Finally, 395 households (Krejcie & Morgan, 1970) were randomly and proportionally selected from the eight villages, 260 for Apac and 135 for Amuru districts. A cross-sectional survey (conducted from December 2018 to May 2019) was employed to collect primary data from farming household heads. The survey was piloted at Paicho Sub County in Gulu district with 20 farmers (13 males and 7 females). The surveys were carried out by trained data enumerators. The primary data acquired included data on the socio-economic characteristics of the farmers, e.g. gender, age, marital status, land owned, land cultivated, education level, farming experience, annual farm income, distance to the nearest market, time taken to the nearest market, access to extension services, access to credit facilities

and farmer group membership. During the interview, individual farmers/household heads were asked to estimate the quantity (kilograms) of maize, beans and groundnuts harvested per unit area (acres) of land cultivated for the last three seasons from the period of data collection. The household heads were also asked what climate change adaptation strategies they implement to counter the impacts of climate change on their farming activities.

### Statistical analysis

Independent sample t-test was used to evaluate differences in mean crop yields for adapters and non-adapters of the different climate change adaptation strategies. Econometric analyses were used to examine the impacts of adaptation intensity on crop yield. According to a previous study by Onzima et al. (2019), the yield outcome variable as a result of adopting climate change adaptation strategies is conceptualized in two sequential steps. Firstly, farmers have to decide on the number of climate change adaptation strategies to use for crop production. Secondly, the use of the adopted climate change adaptation strategies would then impact on the yield of the crop in question. Consequently, the impact of using a given number of climate change adaptation strategies (adaptation intensity) would be observed in the yield. The general equation for estimating the effect of adaptation intensity of crop yield is thus specified as:

$$Y_{ik} = \alpha_{ik} + X'_{ik}\beta_k + \gamma_k A_{ik} + \varepsilon_{ik} \quad (1)$$

where  $Y_{ik}$  is the yield of the  $k$ th crops (beans or maize or groundnuts) for the  $i$ th household,  $\alpha$  is the regression constant,  $X_{ik}$  is a vector of explanatory variables that can have potential influence on crop yield for the  $k$ th crops for the  $i$ th household. Table 1 presents a description of the variables and their *a priori* expectation on yield.  $\beta$ , is a vector of coefficients associated with explanatory variables.  $A_{ik}$  is the adaptation intensity which is the number of climate change adaptation strategies being used by the  $i$ th farmer for the  $k$ th crop, while,  $\gamma_k$ , is the expected effect of adaptation intensity on the yield of the  $k$ th crop.  $\varepsilon$ , is the normal stochastic error term associated with the yield. In this study, a separate model was estimated for each of the three most common crops (maize, beans and groundnuts) that were being produced by the farmers in the study area.

Whereas Equation (1) could easily be estimated using the Ordinary Least Squares (OLS) approach, the study adopted the two-stage least squares (2-SLS) approach. This was because OLS approach would introduce bias since the adaptation decision variable (adaptation intensity) is endogenous, and thus violates the exogeneity assumption that is required for the OLS model (Di Falco et al., 2011; Huang et al., 2015; Khanal et al., 2018; Onzima et al., 2019). In controlling for the potential endogeneity of the adaptation intensity variable, the study adapted a control function approach (CFA) using instrumental variables. The CFA assumes that adaptation intensity is a function of all the exogenous variables,  $X'$  in the yield equation, in addition to at least one instrumental variable. Consequently, in the first stage, the adaptation intensity variable is regressed against all the exogenous variables hypothesized for the yield equation in addition to at least one independent variable (IV) as specified in Equation (2).

$$A_{ik} = \sigma_{ik} + X'_{ik}\beta_k + \rho_k z_{ik} + e_{ik} \quad (2)$$

where  $z$  is the instrumental variable and  $\rho$  is the coefficient associated with the instrumental variable and is expected to be insignificant. In the second stage, the yield variable is regressed against all the exogenous

variables and the first stage residuals as specified in Equation (3).

$$Y_{ik} = \alpha_{ik} + X'_{ik}\beta_k + \gamma_k A_{ik} + \varphi \bar{w} + \varepsilon_{ik} \quad (3)$$

where  $\bar{w}$  is the residuals generated from the first stage regression. In estimating the instrumental variable 2-SLS, the challenge is usually in selecting the appropriate instrument to use. According to Onzima et al. (2019), the choice of a valid instrument depends on intuition, economic reasoning and statistical properties. A valid independent (IV) should have a significant influence on the first stage dependent variable (adaptation intensity), without being confounding for the second stage dependent variable (yield). In this study, after several attempts, the variable farm income (in natural logarithms), was the best fit to be used as an IV for the beans and groundnut models, while, the variable access to extension services was the best for use as an IV for the maize model. Household income may have no direct effect on yield but can only influence yield indirectly. The effect depends on how the availability (or non-availability) of farm income influences household production decisions including access to inputs. Similarly, access to extension also has no direct effect on the yield but is expected to have an indirect effect. This is so

**Table 1.** Description of variables used in the study and their apriori expectations.

| Variable           | Description/measurement                                                                                                                             | Apriori expectation |
|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|
| Yield              | Yield of maize, beans and groundnuts (in natural logarithms). Three different models were estimated for beans, maize, and groundnuts, respectively. | NA                  |
| Adapt_int          | Number of climate change adaptation strategies being used by a farmer for the production of specific crop                                           | +                   |
| Credit             | Access to credit (1 = yes, 0 = no)                                                                                                                  | +                   |
| Married            | Marital status (1 = married, 0 = otherwise)                                                                                                         | +/-                 |
| no_educ            | Dummy for farmer who has no formal education (1 = yes, no = 0)                                                                                      | -                   |
| Primary            | Dummy for farmer who has primary level education (1 = yes, no = 0)                                                                                  | -                   |
| Secondary          | Dummy for farmer who has secondary level education (1 = yes, no = 0)                                                                                | +                   |
| Tertiary           | Dummy for farmer who has tertiary level education (1 = yes, no = 0)                                                                                 | +                   |
| HHsize             | Household size (number of members in the household)                                                                                                 | +                   |
| log_dist           | Distance to the market (in natural logarithm)                                                                                                       | -                   |
| Timetaken          | Time taken to the market in minutes                                                                                                                 | -                   |
| Land_cultivated    | Size of land cultivated (acres)                                                                                                                     | +                   |
| Land_owned         | Size of land owned (acres)                                                                                                                          | +                   |
| Farming_exp        | Farming experience (years)                                                                                                                          | +                   |
| Group <sup>a</sup> | Group membership (1 = yes, 0 = no)                                                                                                                  | +/-                 |
| Male               | Gender indicator (1 = male, 0 = female)                                                                                                             | +/-                 |
| log_farmY          | Farm income (in natural logarithm)                                                                                                                  | +                   |
| Climate_info       | Farmer has ever received climate change information (1 = yes, 0 = no)                                                                               | +                   |
| log_crop_ent       | Number of crop enterprise cultivated by a farmer (in natural logarithm)                                                                             | +                   |
| District           | District dummy (1 = Amuru, 0 = Apac)                                                                                                                | +/-                 |

<sup>a</sup>In this study we look at groups loosely as a group formed by farmers within the same locality who are either engaged in farming activities such rotational cultivation or are engaged in some financial activities such as rotational savings and savings and loans, or both. In most cases these groups were involved in both farming and financial activities.

because the household has a choice of putting into practice or not the knowledge of information obtained from the extension. During analysis, the chosen IV was insignificant in the first stage regression, supporting its exogeneity.

## Results and discussions

### *Adaptation strategies and crop production*

In this study, 13 climate change adaptation strategies used by farmers in Apac and Amuru districts were identified. Table 2 shows the proportion of farmers using the different strategies in their farming. The results are disaggregated for beans, groundnuts and maize that were the most common among the study group. It shows that the most common climate change adaptation strategies used by small-holder farmers in the study area were related to varietal adjustments including using planting different crop varieties each time, planting drought-resistant varieties, and early maturing varieties, and use of improved seeds. Changing the time of planting was also being practiced by over 90% of the farmers for the different crops. The least common strategy was irrigation. Strategies related to improving soil nutrients including the use of chemical fertilizers and compost were also practiced by relatively few farmers.

The climate change adaptation strategies reported in this study were also reported in others previous (Amare et al., 2018; Amare & Simane, 2017; Atube

et al., 2021; Eshetu et al., 2021; Fadina & Barjolle, 2018; Liu & Basso, 2020; Marie et al., 2020; Vo et al., 2021; Zizinga et al., 2017). However, it was surprising that in this study that climate change adaptation strategies that are geared towards climate smart agriculture (CSA) such as mulching, conservation agriculture, intercropping, crop rotation, integrated crop-livestock management as defined by the World Bank (2013) and recommended by the African Union agenda 2063 (Tumwesigye et al., 2019) were insignificant and therefore not reported. This could be because developing nations' agricultural extension messages to farmers focus mainly on technology based strategies (Norton & Alwang, 2020) such as improved crop varieties, drought resistant varieties, early maturing crop varieties but less so on the traditional climate smart agricultural practices. However, the proportion of farmers that use the different strategies usually varies from location to location depending on so many factors. According to Vo et al. (2021), farmers' decision to adapt any climate change adaptation strategy is influenced by the level of farmers' income, the severity of the climate change impact and efficacy of the adaptation strategy. There are also several other socio-economic and institutional factors that can influence a farmer's decision to adapt to different climate change adaptation strategies (Amare & Simane, 2018; Atube et al., 2021; Eshetu et al., 2021; Zizinga et al., 2017). Therefore, it is expected that once these factors are at play, farmers would choose to practice only those strategies that would give the satisfaction they need. Farmers usually adapt a combination of climate change adaptation strategies to attain maximum benefits from using the strategies.

**Table 2.** Proportion of farmers using the different climate adaptation strategies while producing beans, maize and groundnuts in Apac and Amuru districts in 2018.

| Adaptation strategy                  | Proportion of farmers using the practice (%) |       |            |
|--------------------------------------|----------------------------------------------|-------|------------|
|                                      | Beans                                        | Maize | Groundnuts |
| Change planting time                 | 90.32                                        | 89.57 | 90.98      |
| Use of improved seeds                | 54.84                                        | 60.19 | 49.62      |
| Practicing soil conservation         | 31.05                                        | 38.39 | 30.83      |
| Practicing Irrigation                | 11.69                                        | 13.27 | 11.28      |
| Use of chemical fertilizers          | 22.18                                        | 26.07 | 23.31      |
| Use of Compost                       | 17.74                                        | 22.75 | 17.29      |
| Intensive use of pesticides          | 61.29                                        | 64.45 | 65.41      |
| Practicing Crop rotation             | 94.35                                        | 92.89 | 93.98      |
| Fallowing the garden                 | 68.15                                        | 66.82 | 62.41      |
| Use of different crop varieties      | 97.18                                        | 94.79 | 96.24      |
| Practicing tree planting             | 39.52                                        | 38.39 | 36.09      |
| Planting early-maturing varieties    | 88.71                                        | 89.57 | 90.23      |
| Planting drought-resistant varieties | 80.24                                        | 81.52 | 74.44      |

Note: Percentages need not add up to 100% since adaptation strategy is multi-response and farmers can use more than one strategy.

### *Comparing adaptation strategies and yield of major crops*

A comparison of yield of the three major crops in the study area between adapters and non-adapters generally show that adapters realized significantly higher yield of all the three crops than non-adapters of at least eight of the climate change adaptation strategies (Tables 3–5). However, this was not the case for bean farmers who practiced soil conservation and for groundnut farmers who used compost. The findings suggest that the mean bean yield for those who fallowed their garden ( $p = 0.037$ ), practiced tree planting ( $p = 0.010$ ), practiced irrigation ( $p = 0.039$ ) and used chemical fertilizers ( $p = 0.073$ ) were

significantly higher than the mean bean yield for those who did not use these practices (Table 3).

For maize yield (Table 4), findings show that those who used chemical fertilizers ( $p = 0.079$ ), intensively used pesticides ( $p = 0.001$ ), practiced tree planting ( $p = 0.017$ ) and practiced irrigation ( $p = 0.006$ ) had significantly higher mean maize yield than the mean yield for those who did not use those agronomic practices.

In the case of groundnuts (Table 5), study findings suggest that the mean groundnut yield for those who used chemical fertilizers ( $p = 0.014$ ), intensively used pesticides ( $p = 0.001$ ) and fallowed their gardens ( $p = 0.010$ ) had significantly higher mean groundnut yield than for those who did not use those practices.

The increased mean yields observed in beans, maize and groundnuts in this study could be attributed to reduced soil erosion as a result of roots holding tightly together soil particles to resist water runoffs

from rain. Furthermore, the increased mean yield of the crops considered in this study could be due to enhanced nutrients in the soil as a result of farmers using fertilizers and fallowing of their gardens. Irrigation as a practice in beans and maize farming could have increased moisture in the soil which led to increased mean yield in beans and maize but not groundnuts. The lack of increase in yield of groundnuts could be attributed to the type of irrigation used, where water from sprinkler irrigation does not penetrate deeply in the soil as much as drip irrigation yet the groundnut pods need more water to develop. This finding is consistent with that of Gireshsingh and Mahindra (2016) who reported that under sprinkler irrigation, the yield of groundnuts was much lower than in the drip irrigation probably due to an increase in evaporation from the wet leaves and soil surface resulting in less water penetrating the ground, consequently affecting the development of the

**Table 3.** Bean yield of adapters and non-adapters of climate change adaptation strategies in Apac and Amuru districts in 2018.

| Adaptation strategies                | Mean     |              |            | t-stat  | P value |
|--------------------------------------|----------|--------------|------------|---------|---------|
|                                      | Adapters | Non-adapters | Difference |         |         |
| Planting drought-resistant varieties | 125.58   | 85.83        | 39.75      | 0.939   | 0.174   |
| Use of improved seeds                | 116.29   | 115.24       | 1.05       | 0.030   | 0.488   |
| Use of chemical fertilizers          | 164.30   | 103.49       | 60.81      | 1.462*  | 0.073   |
| Intensive use of pesticides          | 134.15   | 89.64        | 44.51      | 1.248   | 0.107   |
| Fallowing the garden                 | 139.141  | 73.20        | 65.94      | 1.801** | 0.037   |
| Use of different crop varieties      | 117.21   | 152.50       | -35.29     | 0.268   | 0.395   |
| Practicing tree planting             | 168.10   | 85.25        | 82.85      | 2.344** | 0.010   |
| Changing time of planting            | 122.77   | 68.41        | 54.36      | 0.929   | 0.177   |
| Practicing soil conservation         | 79.31    | 131.41       | -52.10     | 1.408*  | 0.080   |
| Practicing Irrigation                | 195.17   | 103.93       | 91.24      | 1.773** | 0.039   |
| Use of Compost                       | 81.33    | 125.43       | -44.1      | 0.968   | 0.167   |
| Practicing Crop rotation             | 119.33   | 77.08        | 42.25      | 0.547   | 0.293   |
| Planting Early-maturing varieties    | 123.56   | 71.61        | 51.95      | 0.989   | 0.162   |

\*, \*\*&\*\*\* implies statistically significant at  $p < 0.1$ ,  $p < 0.05$  and  $p < 0.01$ , respectively.

**Table 4.** Maize yield of adapters and non-adapters of climate change adaptation strategies in Apac and Amuru district in 2018.

| Adaptation strategies                | Mean     |              |            | t-stat   | P value |
|--------------------------------------|----------|--------------|------------|----------|---------|
|                                      | Adapters | Non-adapters | Difference |          |         |
| Planting drought-resistant varieties | 302.73   | 229.73       | 73         | 0.895    | 0.186   |
| Use of improved seeds                | 311.61   | 248.26       | 63.35      | 0.942    | 0.174   |
| Use of chemical fertilizers          | 363.33   | 260.45       | 102.88     | 1.415*   | 0.079   |
| Intensive use of pesticides          | 362.56   | 144.59       | 217.97     | 3.269*** | 0.001   |
| Fallowing the garden                 | 302.07   | 263.03       | 39.04      | 0.574    | 0.283   |
| Use of different crop varieties      | 295.46   | 157.50       | 137.96     | 0.854    | 0.197   |
| Practicing tree planting             | 372.73   | 232.36       | 140.37     | 2.141**  | 0.017   |
| Changing time of planting            | 293.51   | 249.55       | 43.96      | 0.435    | 0.332   |
| Practicing soil conservation         | 250.64   | 314.08       | -63.44     | 0.956    | 0.170   |
| Practicing Irrigation                | 488.81   | 254.75       | 234.06     | 2.571*** | 0.006   |
| Use of Compost                       | 253.19   | 300.09       | -46.9      | 0.623    | 0.267   |
| Practicing Crop rotation             | 299.78   | 165.63       | 134.15     | 1.156    | 0.125   |
| Planting Early-maturing varieties    | 295.36   | 222.22       | 73.14      | 0.663    | 0.254   |

\*, \*\*&\*\*\* implies statistically significant at  $p < 0.1$ ,  $p < 0.05$  and  $p < 0.01$ , respectively.

**Table 5.** Groundnut yield of adapters and non-adapters of climate change adaptation strategies in Apac and Amuru districts in 2018.

| Adaptation strategies                | Mean (SE) |              |            | t-stat   | P value |
|--------------------------------------|-----------|--------------|------------|----------|---------|
|                                      | Adapters  | Non-adapters | Difference |          |         |
| Planting drought-resistant varieties | 493.01    | 422.85       | 70.16      | 0.685    | 0.247   |
| Use of improved seeds                | 494.11    | 451.24       | 42.87      | 0.463    | 0.322   |
| Use of chemical fertilizers          | 661.06    | 415.50       | 245.56     | 2.225**  | 0.014   |
| Intensive use of pesticides          | 565.34    | 267.96       | 297.38     | 3.094*** | 0.001   |
| Fallowing the garden                 | 560.77    | 344.27       | 216.5      | 2.351**  | 0.010   |
| Use of different crop varieties      | 474.00    | 396.67       | 77.33      | 0.264    | 0.396   |
| Practicing tree planting             | 561.40    | 424.75       | 136.65     | 1.424*   | 0.079   |
| Changing time of planting            | 491.43    | 311.36       | 180.07     | 1.141    | 0.128   |
| Practicing soil conservation         | 482.84    | 468.46       | 14.38      | 0.145    | 0.443   |
| Practicing Irrigation                | 317.54    | 492.675      | -175.13    | 1.201    | 0.116   |
| Use of Compost                       | 247.69    | 509.11       | -261.42    | 1.981**  | 0.025   |
| Practicing Crop rotation             | 485.22    | 308.75       | 176.47     | 0.970    | 0.167   |
| Planting early-maturing varieties    | 448.97    | 702.91       | -253.94    | 1.626    | 0.053   |

\*, \*\*&\*\*\* implies statistically significant at  $p < 0.1$ ,  $p < 0.05$  and  $p < 0.01$ , respectively.

underground groundnut pods. According to Magombeyi et al. (2018), there are usually significant variations in yields from different agricultural water management technologies. The application of pesticides to maize and groundnuts crops could have led to a reduced infestation of these crops by pests and diseases increasing their mean yields.

This study, however, established that farmers who practiced soil conservation ( $p = 0.080$ ) in bean gardens and those who used compost ( $p = 0.025$ ) in groundnut gardens had significantly lower mean bean and groundnut yields, respectively, than their counterparts who did not. This could be attributed to the quality of the mulch material with intent to conserve soil and the compost used which if not properly dried and spread to the right thickness could either harbour pests or promote the growth of weeds which in the end negatively affect the crops'

performance in terms of growth and yield. This finding corroborates with earlier studies (e.g. Edralin et al., 2017; Nankya et al., 2017; Ramaekers et al., 2013) which revealed positive effect of proper application of mulch and compost as a means of soil conservation on crop yield. The finding by Ikeh et al. (2019) also found that semi-dried mulch materials may increase weed growth which could lead to competition for soil nutrients with the crop.

The application of fertilizer in all the crops observed in this study which led to significantly higher mean yield could be attributed to increased intake of soil nutrients which is enhanced by inorganic components such as nitrogen, phosphorus and potassium in fertilizers which are greatly needed for the growth of the crops (Itelima et al., 2018). Through irrigation as depicted in beans and maize, there could be increased soil infiltration by water leading to

**Table 6.** Effect of adaptation intensity on maize yield.

| maize_log                  | Pooled |           |       | Amuru  |           |       | Apac   |           |       |
|----------------------------|--------|-----------|-------|--------|-----------|-------|--------|-----------|-------|
|                            | Coef.  | Std. Err. | P > z | Coef.  | Std. Err. | P > z | Coef.  | Std. Err. | P > z |
| Adapt_int                  | 0.211  | 0.477     | 0.658 | -0.156 | 2.305     | 0.946 | 0.040  | 0.449     | 0.928 |
| credit                     | 0.598  | 0.483     | 0.215 | 1.124  | 1.298     | 0.387 | 0.343  | 0.523     | 0.512 |
| HHsize                     | 0.034  | 0.059     | 0.568 | -0.169 | 0.177     | 0.341 | 0.030  | 0.076     | 0.697 |
| Land_cultivated            | 0.279  | 0.257     | 0.277 | -0.570 | 0.593     | 0.337 | 0.367  | 0.255     | 0.150 |
| Farming_exp                | -0.011 | 0.014     | 0.444 | 0.063  | 0.111     | 0.571 | -0.017 | 0.016     | 0.288 |
| group                      | -0.287 | 0.328     | 0.381 | 0.075  | 2.329     | 0.974 | -0.165 | 0.353     | 0.641 |
| logland                    | -0.258 | 0.289     | 0.373 | -0.195 | 0.435     | 0.654 | -0.298 | 0.505     | 0.555 |
| Male                       | 0.251  | 0.304     | 0.409 | 1.321  | 0.762     | 0.083 | 0.121  | 0.320     | 0.705 |
| log_crop_ent               | -0.233 | 0.646     | 0.718 | -3.720 | 1.865     | 0.046 | 0.154  | 0.693     | 0.824 |
| log_farmY                  | 0.299  | 0.165     | 0.070 | 1.170  | 1.934     | 0.545 | 0.314  | 0.139     | 0.024 |
| Climate_info               | 0.405  | 0.426     | 0.342 | -4.573 | 2.540     | 0.072 | 0.461  | 0.448     | 0.304 |
| district                   | 0.499  | 0.714     | 0.484 |        |           |       |        |           |       |
| _cons                      | -2.271 | 2.343     | 0.332 | 6.018  | 9.278     | 0.517 | -1.596 | 2.564     | 0.534 |
| N                          | 181    |           |       | 23     |           |       | 158    |           |       |
| Wald chi <sup>2</sup> (16) | 59.25  |           |       | 83.35  |           |       | 51.68  |           |       |
| Prob > chi <sup>2</sup>    | 0.000  |           |       | 0.000  |           |       | 0.000  |           |       |

increased water uptake by the beans and maize plants resulting in increased yield. In the case of tree planting, it could result to reduced soil erosion since tree roots hold together soil particles leading to reduced soil erosion and retained water and soil nutrients that are highly needed for the healthy growth of maize.

Whereas for all the crops, most of adaptation strategies (except use of compost, different crop varieties and soil conservation in the case of beans) were associated with higher yield, not all of them were associated with significant crop yield differences between adapters and non-adapters. For example, in the case of beans, only five out of the 13 practices were associated with significant yield differences between adapters and non-adapters, while, for maize, only four were associated with significant yield differences between adapters and non-adapters, and in the case of groundnuts, only five practices were associated with significantly higher yields. Whereas, it is anticipated that each of the climate change adaptation strategy is meant to cushion the crops from weather shocks, and thereby yielding higher than situations where there were no such practices, these findings presents a dilemma on the effectiveness of some of the practices. This dilemma can be explained by two main scenarios. First, where farmers have adapted the practices poorly, the impact will be minimal. Addressing this challenge requires farmers to be made aware of the best practices especially through climate smart agricultural extension (Manalo IV et al., 2020; Nord et al., 2021). Secondly, with increasing intensity and unpredictability of climate change effects including changes in rainfall patterns, there could have been a mismatch between the climate change risk and the associated adaptation strategy. This second challenge may require a multi-throng approach including adoption of transformational climate change adaptation strategies as opposed to the incremental climate change adaptation. Fedele et al. (2019) observed that use of transformative climate change adaptation has the potential of increasing sustainability of effort and efficiency of intervention with respect to climate change adaptation. According to Rickards and Howden (2012), transformational adaption involves significant changes in land use coupled with introduction of new products including ecosystems services. The successful implementation and adoption of transformational adaptation requires that the limits of the current climate change adaptation strategies are

treated as the starting point for any transformational adaption (Panda, 2018). Adoption of transformational adaptation have been shown to be associated with significant education and engagement, innovation, and institutional development (Ajulo et al., 2020) which are all relevant in the context of smallholder farming.

## *Adaptation intensity and effects on crop yield*

### *Effect of adaptation intensity on maize yield*

The study results on the yield of maize are presented in Table 6. The coefficient of residuals included testing for endogeneity of adaptation in the yield of maize function was not significant, suggesting that the adaptation decisions made by these farmers towards the strategies used to reduce the effects of climate change on the yield of maize could be exogenous in the yield function. We however maintained them in the equation to show the results of this test. The Wald test confirms the importance of variation included in explaining variations in the maize yield (Wald  $\chi^2(16) = 59.25$ ,  $p$ -value = 0.000). Results show that adaptation intensity had no significant influence on maize yield across the two districts and for the pooled model. Maize yield was instead significantly influenced by other factors including the numbers of crop species farmers engage in and farm income.

The results indicate that the number of crop species farmers plant in one season and household farm income had a strong and significant effect on maize yield (Table 6). Farmers in Amuru district who planted few crop species but majorly maize realized significantly ( $p = 0.046$ ) better maize yield than those households that planted maize together with many other crops species in the same season (Table 6). Farmer households in Apac district that had higher revenues from farm income had significantly ( $p = 0.024$ ) higher yield in maize compared to their counterparts that depended majorly on non-farm income in their households. This finding provides evidence that moving towards specialization of crop species and increased dependence on farm household income by household is associated with improved maize yield. Our finding corroborates with a study by Takim (2012) which showed that intercropping maize with legumes such as beans and cowpeas reduces grain yield due to competition between the two crops compared to sole maize cropping. Furthermore, the findings of Thornton and Herrero (2015)

**Table 7.** Effect of adaptation intensity on bean yield.

| bean log                   | Pooled |           |                     | Amuru  |           |                     | Apac   |           |                     |
|----------------------------|--------|-----------|---------------------|--------|-----------|---------------------|--------|-----------|---------------------|
|                            | Coef.  | Std. Err. | <i>P</i> > <i>z</i> | Coef.  | Std. Err. | <i>P</i> > <i>z</i> | Coef.  | Std. Err. | <i>P</i> > <i>z</i> |
| Adapt_int                  | 0.582  | 0.214     | 0.006               | 0.450  | 0.250     | 0.072               | 0.529  | 0.408     | 0.195               |
| credit                     | 0.334  | 0.306     | 0.275               | 0.352  | 0.504     | 0.485               | 0.464  | 0.435     | 0.286               |
| married                    | 0.222  | 0.397     | 0.577               | −0.027 | 0.625     | 0.966               | 0.188  | 0.586     | 0.748               |
| no_educ                    | −0.276 | 0.729     | 0.705               | −0.781 | 1.044     | 0.454               | 0.073  | 0.904     | 0.936               |
| primary                    | 0.806  | 0.501     | 0.108               | 0.863  | 0.705     | 0.221               | 0.918  | 0.620     | 0.138               |
| secondary                  | 0.987  | 0.464     | 0.033               | 1.106  | 0.623     | 0.076               | 1.116  | 0.625     | 0.074               |
| HHsize                     | 0.033  | 0.041     | 0.420               | 0.051  | 0.049     | 0.295               | −0.027 | 0.104     | 0.796               |
| log_dist                   | −0.243 | 0.219     | 0.268               | −0.238 | 0.234     | 0.309               | −0.162 | 0.285     | 0.570               |
| Time taken                 | 0.405  | 0.267     | 0.130               | 0.259  | 0.228     | 0.256               | 0.384  | 0.362     | 0.289               |
| Land_owned                 | 0.000  | 0.002     | 0.872               | 0.002  | 0.002     | 0.365               | −0.051 | 0.242     | 0.833               |
| Farming_exp                | −0.022 | 0.012     | 0.069               | −0.011 | 0.017     | 0.525               | −0.029 | 0.016     | 0.062               |
| group                      | −0.705 | 0.325     | 0.030               | −0.724 | 0.359     | 0.043               | −0.699 | 0.534     | 0.190               |
| logland                    | −0.109 | 0.289     | 0.708               | −0.108 | 0.294     | 0.712               | 0.377  | 1.186     | 0.750               |
| Male                       | 0.347  | 0.343     | 0.312               | −0.197 | 0.469     | 0.674               | 0.762  | 0.515     | 0.138               |
| log_crop_ent               | −1.588 | 0.544     | 0.004               | −0.963 | 0.662     | 0.146               | −2.354 | 0.949     | 0.013               |
| district                   | 2.347  | 0.443     | 0.000               |        |           |                     |        |           |                     |
| _cons                      | −0.228 | 1.663     | 0.891               | 2.457  | 2.010     | 0.222               | 0.751  | 2.671     | 0.779               |
| N                          | 199    |           |                     | 81     |           |                     | 118    |           |                     |
| Wald chi <sup>2</sup> (16) | 152.34 |           |                     | 61.96  |           |                     | 50.43  |           |                     |
| Prob > chi <sup>2</sup>    | 0.000  |           |                     | 0.000  |           |                     | 0.000  |           |                     |

revealed that farmers who specialize on a particular crop species per season and mainly depend on farm income realize better crop yield than their counterparts who plant many crop species and also depend less on-farm income.

#### *Adaptation intensity and effects on bean yield*

The findings as presented in Table 7 show that adaptation intensity had a significant influence on bean yield for the pooled model. This specifically implies that farmers who adopted an additional climate change adaptation strategy realized significantly ( $p = 0.006$ ) higher yields than those farmers who adopted fewer adaptation strategy as a means to reduce the effects of climate change on bean yield. This means that the more adaptation strategies to the effects of climate change farmers used, the better the yield of beans. This finding is in agreement with earlier studies that found that farmers who adopt more adaptation strategies experience increased food productivity (Onzima et al., 2019).

The study findings further show that level of education of the household head positively influenced bean yield in the pooled model. This suggests that households that had their heads who attained up to the secondary level of education realized significantly ( $p = 0.033$ ) higher bean yield than households whose heads attained only primary or no education at all (Table 7). This means that household heads that attained secondary education were 0.987 times more likely to have a better yield of beans than

their counterparts that attained below secondary education.

Table 7 also shows that household heads who belonged to farmer group(s) had a significantly negative influence on bean yield in the pooled model ( $p = 0.030$ ) and in Amuru district ( $p = 0.043$ ). This finding means that farmers who belonged to farmer group (s) were 0.705 and 0.724 times less likely to have a better yield of beans in the pooled model and in the Amuru district than those farmers who did not belong to any farmer group. This is partly in agreement with the findings of Mwaura (2014) which revealed that membership to farmer groups does not necessarily lead to the adoption of high yielding technologies and increased productivity. This could be associated with the shifting of resources including capital, management and labour to other crop species that are of higher values as indicated in the MAAIF's report of, 2010. Nevertheless, that same study (Mwaura, 2014) found that membership to farmer groups was observed to lead to the achievement of higher yields in banana and cassava. This could be because farmers who belong to farmer groups have better opportunities to access more extension services and therefore have better yields than those who do not belong to any farmer groups (Iyabano et al., 2021; Nyberg et al., 2021). This particular finding could probably be due to the reluctance of members of a group with the view that group benefits are never owned individually which makes individuals put more effort in personal than group initiatives.

This study also revealed that the number of crop species grown by a farmer in a season had a significant influence on bean yield both at the pooled ( $p = 0.004$ ) level and in Apac district ( $p = 0.013$ ). This specifically means that the number of crop species a farmer engaged in significantly influenced the yield of beans both in the pooled level and in Apac district. From the pooled model and Apac district model, farmers who grew more than one crop species were 1.588 and 2.354 times, respectively less likely to have better yield of beans than those who grew only one crop species. This could be because those who grew only one crop species are able to direct all production resources to bean production resulting in better yield than those who grew many crop species and use the little available resources in the family to cater for all the different crop species they are growing. This finding corroborates with the findings of earlier studies (Bottrell & Schoenly, 2018) that confirm that the direction of resources by farmers on one crop species grown produces better yield than when resources are directed to many crop species grown in the same cropping season.

### Adaptation intensity and effects on groundnut's yield

Results in Table 8 shows that adaptation intensity had no significant influence on groundnut's yield across the two districts and for the pooled model. Groundnuts' yield was instead significantly influenced by other factors including level of education, distance

to market, time taken to market, size of land owned, farming experience and districts both at the pooled model and at district levels. The findings in this study showed that household heads in Apac that did not attain any formal education ( $p = 0.004$ ) were 3.809 times less likely to have higher groundnut yields than their counter parts who attained formal education. This could be because better-educated farmers may have higher incomes and are more aware of pests and disease management systems which make them have better crop yields than those not formally educated.

Household heads that had to move long distances to market by road in the pooled model ( $p = 0.001$ ) and in Apac district ( $p = 0.003$ ), respectively were 0.771 and 0.850 times less likely to have high groundnuts yield than their counterparts who were nearer the markets. This is in line with the findings of Amare and Simane (2017) in which he contends that more farmers in rural areas tend to adopt innovations when there is improved infrastructure such as better roads and markets. This could be because easier access to agricultural inputs, agricultural extension services and the market creates more demand for the farmers to produce more groundnuts for the readily available market. Another probable reason for this could be that a short distance to the market increases the incentive of farmers to produce surplus foods that can easily be taken to the market. An additional explanation could also be that farmers who are far from the market could be having

**Table 8.** Effect of adaptation intensity on groundnut yield.

| gnut_log                   | Pooled |                  |         | Amuru  |                  |         | Apac   |           |         |
|----------------------------|--------|------------------|---------|--------|------------------|---------|--------|-----------|---------|
|                            | Coef.  | Robust Std. Err. | $P > z$ | Coef.  | Robust Std. Err. | $P > z$ | Coef.  | Std. Err. | $P > z$ |
| Adapt_int                  | 0.453  | 0.510            | 0.374   | 1.040  | 0.603            | 0.085   | -0.674 | 0.410     | 0.100   |
| credit                     | -0.147 | 0.544            | 0.788   | -0.527 | 0.947            | 0.578   | -1.099 | 0.715     | 0.124   |
| married                    | 0.427  | 0.619            | 0.490   | 1.170  | 1.347            | 0.385   | 1.241  | 0.932     | 0.183   |
| no_educ                    | -0.692 | 1.301            | 0.595   | 1.482  | 1.897            | 0.435   | -3.809 | 1.309     | 0.004   |
| primary                    | 0.251  | 0.982            | 0.799   | 1.542  | 1.499            | 0.304   | -1.823 | 1.179     | 0.122   |
| secondary                  | 0.057  | 0.969            | 0.954   | 1.801  | 1.565            | 0.250   | -1.727 | 1.281     | 0.177   |
| HHsize                     | 0.007  | 0.113            | 0.950   | 0.112  | 0.166            | 0.502   | 0.066  | 0.122     | 0.590   |
| log_dist                   | -0.771 | 0.228            | 0.001   | 0.479  | 0.547            | 0.381   | -0.850 | 0.290     | 0.003   |
| Timetaken                  | 1.007  | 0.279            | 0.000   | -0.735 | 0.993            | 0.459   | 0.673  | 0.251     | 0.007   |
| Land_owned                 | 0.070  | 0.060            | 0.245   | 0.242  | 0.112            | 0.031   | 0.330  | 0.202     | 0.103   |
| Farming_exp                | -0.056 | 0.022            | 0.012   | -0.055 | 0.026            | 0.035   | -0.015 | 0.032     | 0.636   |
| group                      | -0.519 | 0.426            | 0.223   | -0.154 | 0.562            | 0.784   | 0.221  | 0.875     | 0.800   |
| logland                    | -0.349 | 0.927            | 0.707   | -3.227 | 1.749            | 0.065   | -0.083 | 1.046     | 0.937   |
| Male                       | 0.120  | 0.547            | 0.826   | -0.455 | 0.960            | 0.635   | 0.313  | 0.591     | 0.596   |
| log_crop_ent               | -0.448 | 1.090            | 0.681   | -3.247 | 1.389            | 0.019   | 2.041  | 1.650     | 0.216   |
| district                   | 1.645  | 0.569            | 0.004   |        |                  |         |        |           |         |
| _cons                      | 2.924  | 3.190            | 0.359   | 5.592  | 4.039            | 0.166   | 7.561  | 2.548     | 0.003   |
| N                          | 100    |                  |         | 46     |                  |         | 54     |           |         |
| Wald chi <sup>2</sup> (16) | 45.02  |                  |         | 69.43  |                  |         | 324.65 |           |         |
| Prob > chi <sup>2</sup>    | 0.000  |                  |         | 0.000  |                  |         | 0.000  |           |         |

difficulty in accessing agricultural extension services that should prompt them to utilize irrigation as a method of improving yield amidst change.

Households that had to take a longer time walking to the market by road in the pooled model ( $p=0.000$ ) and in Apac district ( $p=0.007$ ) were 1.007 and 0.673 times, respectively more likely to have better groundnut yields than their counterparts that took shorter time. In this study, time taken to the market is a proxy of the road distance, the means of transport used and the cost of transportation to the market. This particular finding contrast with other previous studies which show a decrease in the tendency of farmers to adopt climate change strategies as the market gets further away from their farms (Uddin et al., 2014). A study by Amare and Simane (2017) in the upper Blue Nile basin of Ethiopia also revealed that there is more adoption of modern farming technologies in areas with good roads which eases farmers' access to the market. According to Abid et al. (2015), farmers nearer to markets have a better avenue to share and exchange information among themselves and other service providers making such farmers more likely to adopt innovations that promote crop yield. Easy access to the market by farmers according to Sinyolo et al. (2017) increases their incentive to produce in surplus. However, in this particular study, this interesting finding could be because farmers living far from urban areas could be having bigger pieces of land that they cultivate and even allow other portions to fallow to enhance soil fertility and therefore increased crop yields. Additionally, the difficulty in the transportation of farm produce to distant markets through poor roads by individual farmers could have probably been eased by increased access to the far-away farmers by middlemen who travel long distances to buy from the farm gate hence providing a ready market for the far-away farmers.

Households that owned bigger pieces of land in Amuru district had significant ( $p=0.031$ ) influence and were 0.242 times more likely to have better groundnuts yields than those owning smaller pieces of land. Households that had long experience in farming in the pooled model ( $p=0.012$ ) and in Amuru districts ( $p=0.035$ ) were 0.056 and 0.055 times, respectively less likely to have better groundnuts yields than their counterparts who had shorter experience in farming. This is an interesting finding which is contrary to other studies such as the one by Amare et al. (2018) which was conducted in

Dejen District, the Nile Basin of Ethiopia which established that as one becomes more experienced in farming, the probability of adopting improved farming methods increases resulting to better crop yields. However, in this particular study, the less experienced farmers could be better placed to access better extension services and market information using modern communication techniques such as mobile phones, radios and televisions which enable them to have higher groundnut yields than the more experienced farmers who may not be exposed to the same communication platforms.

Households that had many crop species grown in Amuru district ( $p=0.019$ ) were 3.247 times less likely to have better groundnut yields than those that specialized in growing only groundnuts. This probably means that the more crop species a farmer grows in a season, the less the yield of groundnuts by that same farmer. This situation could be because those who grew only one crop species directed all their production resources to groundnut production hence had better groundnut yield than those who grew many different crop species besides growing groundnuts. After all they had to sparingly distribute the little available resources in the family to cater for all the crop species the households grew in that season. This finding corroborates with the findings of Bottrell and Schoenly (2018) that confirm that the direction of resources by farmers on one crop species grown produces better yield than when the limited resources are directed to many crop species grown in the same cropping season.

Households that grew groundnuts in the two districts of Amuru and Apac when pooled together were found to have significant ( $p=0.004$ ) influence on groundnut yield and were 1.645 times more likely to have better groundnut yield than when analysed at the individual district level.

## Conclusions

This study assessed the effect of adaptation intensity of smallholder farmers to climate change on crop yield with a particular focus on maize, groundnuts and beans in Apac and Amuru districts. Using 395 smallholder farmer household heads across two districts in northern Uganda as the study sample size, we found that the most common climate change adaptation strategies used by smallholder farmers in the study area were related to varietal adjustments including using different crop varieties each time,

planting drought-resistant varieties, and early maturing varieties, and use of improved seeds. Changing the time of planting was also being practiced by over 90% of the farmers for the different crops. The least common strategy was irrigation. Strategies related to improving soil nutrients including the use of chemical fertilizers and compost were also practiced by relatively few farmers. A comparison of the yield of the three major crops in the study area between adapters and non-adapters generally show that adapters realized significantly higher yield of all the three crops than non-adapters of most of the climate change adaptation strategies. This is interesting because if access to agricultural extension services and weather information could be improved, a significant number of farmers could be protected against the adverse effects of climate change such as droughts and floods. However, this was not the case for bean farmers who practiced soil conservation and for groundnut farmers who used compost probably due to the quality of the mulch material which if not properly dried and evenly spread to the right thickness could either harbour pests or promote the growth of weeds which at the end negatively affect the crops' performance in terms of growth and yield. Such lack of significant effects of adaptation practices, that should have led to yield increments points to the need to shift from incremental adaptation to transformational adaption which is usually recommended where incremental adaptations fails. Drawing from the above findings, the study recommends that government and development partners should focus on strengthening appropriate agricultural practices that have shown positive impact on crop yield. In addition, the government needs to strengthen agricultural extension services to farmers on the use of improved seeds, traditional climate smart agricultural practices such as mulching, conservation agriculture, intercropping, crop rotation, integrated crop-livestock management to enhance smallholder farmers' awareness of these practices leading to improved crop yield. Government should create access to credit schemes through soft loans with government financial institutions, Savings and Credit Cooperatives Societies (SACCOS) and Village Savings and Loan Associations (VSLA) to increase the adaptation intensity of smallholder farmers in northern Uganda. Lastly, there is need to understand smallholder farmers perception on why farmers choose to adopt certain climate change adaptation practices instead of adapting to the whole package.

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## Data availability statement

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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