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RESEARCH ARTICLES

Adaptations to Climate Variability in Northern Uganda: Implications for Food Security

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Abstract

This study examined the relationship between climate variability adaptation strategies and household food security. Specifically, it investigated the adaptation practices employed by farmers and assessed their impact on food availability by comparing food security outcomes between adapting and non-adapting households. Data were collected from 375 randomly selected households in Agoro and Madi Opei sub-counties, known for their transitional climatic conditions. Employing questionnaires, field observations, and key informant interviews, the study found early planting (38.2%), new crop varieties (25.4%), drought-resistant crops (21.6%), and small-scale irrigation (7.8%) to be the primary on-farm adaptations, while motorcycling (50%), retail (25%), and construction-related activities (10%) dominated off-farm strategies. In the surveyed households, 1.2% experienced inadequate food availability, 95.7% exhibited moderate food security, and 3.1% demonstrated adequate food security. The study revealed a positive correlation between adaptation practices and food security, suggesting that various adaptation strategies can enhance household resilience to climate variability.

Keywords: adaptations, climate variability, food security, household

Introduction

Climate variability represents a significant global challenge, impacting individuals in developed and developing countries. The effects of climate variability are most acutely felt by the most impoverished and water-scarce countries, which cannot adapt (Boko et al., 2007). The term “climate variability or change” is defined by the Intergovernmental Panel on Climate Change (IPCC) as “a change or variation in the average weather conditions over time” (IPCC, 2007). Evidence of climate variability and change includes a reduction in ice extent at the poles and high peaks, an increase in temperature, a change in precipitation patterns, an elevation in sea level, and a rise in ocean temperatures and acidification (EPA, 2014). Projections indicate that the sea level may rise further, precipitation patterns may change, ocean acidification may increase, and global temperatures may rise by 4.5°C by 2080 (IPCC, 2014; IPCC, 2022).

The impact on agriculture is likely to be detrimental, with fluctuations in output resulting from climate variability. This will also hurt food security and stability (Richard et al., 1998). In Africa, the rise in temperatures and alteration in precipitation patterns have rendered the region vulnerable to the consequences of climate variability (Kansiime, 2012; Filho et al., 2022). It was thus projected that Africa would experience a decline in rain-fed agriculture of up to 50% by 2020 and beyond. This was likely to exacerbate the food security threat in the region, which depends on local technology and methods for food production (Boko et al., 2007; Hlophe-Ginindza, and Mpandeli, 2021). The effects of climate variability have been observed across all components of food security, with a range of impacts. These include instances of crop failure, which have contributed to rising food prices and reduced access to food. Reducing incentives to invest in agricultural production will reduce food stability. Furthermore, a reduction in crop yields impacts food availability and utilization, influencing consumption patterns and prompting changes in the nutrient content of food

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and compromising food safety (Bloem et al., 2010; Devereux et al., 2020).

In East and Central Africa, the erratic weather patterns have resulted in various consequences, including insufficient pasture and a decline in crop yields, contributing to increased food insecurity (Palmer et al., 2023). The future climatic variability projections indicate that there will be changes in rainfall patterns, distribution, duration, and increased temperatures. These changes will further harm agriculture, the region's primary export earner and employment sector (Christensen et al., 2007). This will, in turn, exacerbate the region's food security problem. The effects of climate change have been observed in the agricultural sector, which is the primary source of food for a rapidly growing population (Deschenes and Greenstone, 2012; Pearce, 1996). In Uganda, climate variability and change have resulted in a reduction in crop yields, loss of livestock, loss of farm inputs such as seeds and fertilizers, flooding of gardens, price fluctuations, loss of soil nutrients, and a reduction in soil moisture, ultimately leading to crop failure. These factors have collectively contributed to declining food security among numerous households (Onyutha et al., 2021; CARE, 2011).

In response to the effects of climate variability, humans have developed the capacity to adapt. The specific adaptation practices employed vary from one location to another and are also contingent upon the socio-economic circumstances of the individual farmers. The objective is to minimize crop failure, enhance crop yield, reduce livestock loss, and increase water availability and agricultural productivity (IPCC, 2015; Osaliya et al., 2022). Farmers have recognized that adaptation represents the sole viable method of managing the impacts of climate variability and change (IPCC, 2022; CARE, 2011). Farmers in developing countries have adopted reactive and anticipatory adaptation strategies to mitigate the adverse effects of climate variability and change (Mavhura et al., 2022). Reactive adaptations include measures such as erosion control, irrigation, migration, using and applying fertilizers, alterations to planting and harvesting times, soil fertility maintenance, introducing new crops, and rainwater harvesting, among others. In contrast, anticipatory adaptations encompass the development of drought-resistant crops, diversified and intensified soil water management, and enhanced food production (UNFCC, 2007; Sperling and Szekely, 2005).

Previous research has covered several aspects of climate change and variability, with many studies focusing on the determinants of adaptation strategies (Asfaw et al., 2015; Kabubo- Mariara and Mulwa., 2019; Burke and Lobell., 2009; Atube et al., 2021; Marie et al., 2020; Ojo et al., 2021). In Uganda, Patterson et al. (2016) studied the impact of climate change on the diminishing population of the Batwa tribe; Wichern et al. (2019, 2023) used a crop suitability analysis to assess food security in Uganda. A common feature of these studies is that they have paid less or no attention to an in-depth analysis of adaptation practices at the household level. To better understand adaptation levels, it is crucial to understand the practices given that government efforts might not be effective in this given geographic context. A detailed analysis of the effectiveness of these practices is key to guiding targeted government interventions.

Despite the global adoption of adaptation practices, food insecurity remains a significant challenge, particularly in developing countries (FAO, 2016; Mukute et al., 2017). It has been observed that the Ugandan nation is experiencing a decline in food security. Northern Uganda, particularly the Acholi region, has been designated a borderline food-insecure area (IPC, 2021), despite implementing diverse climate variability adaptation practices. The study was guided by the following objectives:(1). Identify the adaptation practices adopted by smallholder farmers and (2) Assess the extent to which these practices influence food availability and security.

Materials and Methods

Study Area

The study area is situated within the tropical zone of northern Uganda, as illustrated in Figure 1. It is located at the latitude of 3032 47' 48" and longitude of 32048 6". The area is bordered to the north by South Sudan, to the east and southeast by Kitgum District, to the south by Pader District, to the southwest by Gulu District, and to the west by Amuru District. Neo-Archean gneissose magmatic rocks predominantly characterize the geology of northern Uganda. These include granite, diorite, anthosites, and monazites. Additionally, some areas are characterized by intrusive, felsic igneous rocks comprising feldspar and quartz. These constitute parts of the basement complex rocks, formed during the Precambrian era, and are of considerable age. The crystalline Precambrian basement is situated beneath the sedimentary formations. Most of the stones in the study area are metamorphic and have been altered from their original igneous state due to changes in mineral content resulting from temperature and pressure (Ocitti, 1996). The area's altitude ranges

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from 975 to 1524 meters above sea level (Mubiru, 2009). It is situated in the northern interior plateau, which is sometimes referred to as a peneplain. The area is characterized by many hills (Ocitti, 1996).

The region encompasses several seasonal wetlands, including Yiklar and Akeno, as well as streams such as Lagura and Larubi. Several permanent rivers, including Ateppi, Nyimur, Aringa and Pager traverse the region. These rivers flow in a northerly direction, ultimately converging with the Achwa River. Others flow directly into South Sudan (Ocitti, 1996). The region receives an average annual rainfall of 800 mm, although precipitation patterns have become increasingly erratic due to climate variability (USAID, 2013; Mubiru, 2009). The mean temperature is 26°C, although there has been an increase in recent decades (USAID, 2013; Mukute et al., 2017).

The area is characterized by the presence of two distinct soil types. These include latosols, which are shallow soils that develop on hard rocks, and plinthosols, with a high content of iron or aluminum (Bakama and Bakama, 2010). The soil in this area is of low productivity and unsuitable for crop cultivation. However, they support large-scale animal rearing and tree growth (Bakama and Bakama, 2010). However, the soil exhibits high productivity in certain locations, particularly in areas where clay loam and sandy loam are present. The predominant vegetation type in this area is savannah vegetation. The savannah grassland is characterized by scattered trees with small leaves and highly deciduous trees that are drought-resistant, collectively dominating the area. In general, grass constitutes the dominant form of plant life, with an average height of approximately one meter. The dominant grass species in the area are elephant grass (*Pennisetum purpureum*) and spear grass (*Heteropogon contortus*). During the dry season, the grass dries up, causing the brown cover to be visible and a high level of nutrient recycling, thereby rendering the soil fertile and conducive to agricultural activities.

Methods of Data Collection

The study employed a cross-sectional research design, whereby data was collected at a single time and reflected the prevailing conditions at the time of the study. The study area, Lamwo district, is comprised of nine sub-counties. Two sub-counties were randomly selected, and fifteen villages were considered. A sample of 375 household respondents was randomly selected from a total population of 5,997 households, drawn from twenty-five (25) households in each village. This sample size was chosen to ensure good coverage and the desired precision and confidence level (White, 2022). The data was collected using various methods, including questionnaires, interviews, observation, and focus group discussions with farmers. Information on the adaptation practices employed by farmers was obtained through direct observation, the administration of questionnaires, interviews with key informants (such as agricultural officers), and focus group discussions with farmers.

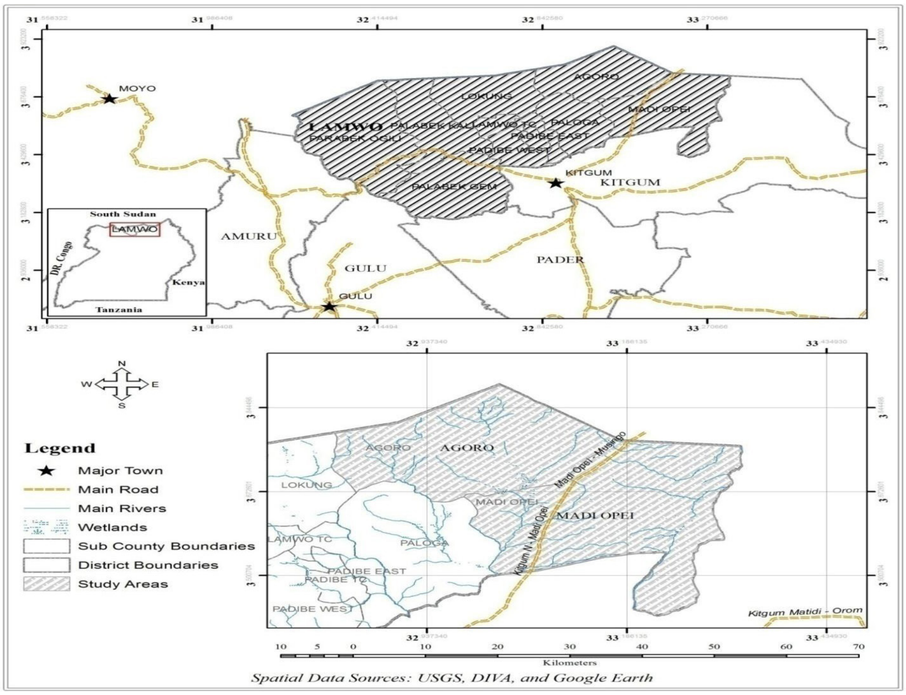

Figure 1. Map of the study area in Uganda

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To ascertain the relationship between climate change adaptation practices and food availability, farmers must indicate the months in which their households had sufficient food to meet their nutritional needs. The concept of "Months of Adequate Household Food Provision" was adopted by Coates et al. (2007). This was employed to evaluate the status of food availability for the households in question. The Months Adequate Household Food Provision (MAHFP) calculates food availability based on the number of months a given household has access to sufficient food. The total score is 12, with each month being assigned a score of one (1) MAHFP = 12. A score of approximately 12 indicates a state of food security, whereas a score below 12 suggests a lack of food availability, indicating a state of food insecurity at the household level. To ensure data accuracy and consistency, the researchers compared the field responses with statistics provided by the UBOS annual agricultural survey report (2019). Notable bias in the answers related to food availability was noted among those adopting off-farm activities, with many stating notably low figures for fear that authorities would use this to levy taxes on them.

The score is classified into three categories of food availability. The first category comprises scores between 10 and 12, indicating that a household has adequate food availability throughout the year. The second category encompasses scores between 4 and 9, denoting that a household has moderate food availability. A score of less than 3 indicates that a household has inadequate food availability (Coates et al., 2007). A chi-square analysis was employed to ascertain any statistically significant differences between the adapter and non-adapter groups regarding their food security status at the household level. To consider the ethical issues of the results from the study, personal consent was considered. All participants were contacted, and their consent was sought to participate in the study.

Results and Discussion

Climate Variability and Change Adaptations in The Study Area

It was established that out of 375 farmers sampled for the study, 323 farmers (86.1%) were practicing adaptations to climate variability, while 52 farmers (13.9%) were not practicing any adaptations to climate variability. The details can be seen in Table 1.

The study demonstrates a notable prevalence of climate change adaptation practices. Most sampled farmers have indicated that they are engaged in adaptation strategies to address climate change and variability impacts. This was attributed to the effective role played by the community development offices, which provided extension services, and to the operation of wealth creation implemented by retired army officers, which replaced the National Agricultural Advisory Services (NAADS). The dissemination of accurate meteorological information and guidance on appropriate responses to mitigate food insecurity in the region has been facilitated. They have provided drought-resistant seedlings and other agricultural inputs. As observed by Atube et al. (2021) and Jha and Gupta (2021), the role of extension services in climate change adaptation is paramount. Studies by Asare-Nuamah and Bochway (2019) and Gebre et al. (2023) also indicated that extension services are of great importance in providing technology and information management, capacity development through education, and policy implementation for climate change adaptation. The farmers in this area have adopted both on-farm and off-farm adaptation strategies. This is meant to ensure economic diversification so that an off-farm activity can offer subsistence to the household in cases of crop failure.

Reasons for Adaptation or Non-adaptation of Farmers in the Area

During the focus group discussion with farmers in the study area, it was observed that most farmers implementing adaptations indicated that they were doing so in response to encouragement from extension workers and the recognition that the rainfall seasons had become shorter and, at times, erratic and destructive. Furthermore, most farmers were observed to be employing early planting as an adaptation strategy. The farmers responded to the availability of precipitation by planting at the appropriate time. The traditional farmer's calendar had been abandoned. Furthermore, it was determined that some were cultivating new crop varieties that exhibited accelerated maturation. Crop and enterprise diversification were observed to be occurring. This

Table 1. Level of farmers' adaptation to climate change in the study area

Farmer groups	Number of farmers	%
Adapters	323	86.1%
Non-adapters	52	13.9%
Total	375	100%

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was implemented to mitigate the impact of crop failure and climate variability. In contrast, farmers who did not adopt these adaptations stated they were not responsible for these occurrences despite experiencing the short rains and unanticipated onset and cessation. These individuals believe that such occurrences are natural and have always been the case and will continue to do so. Furthermore, they stated that there had been a reduction in crop yield. However, this was attributed to the overuse of the land due to increased population and the impact of a decade-long civil war. These findings align with the review done by Buhaug and Uexkull (2021), who asserted that conflict had hampered climate change adaptation in Afghanistan. Agricultural insurance would be a good remedy to create confidence among farmers and financial institutions about the creditworthiness of the farmers. Madaki et al., (2023), elaborated that agricultural insurance was key to ensuring effective adaptation to climate change in Nigeria.

On-farm and Off-farm Adaptation Practices in the Study

Adaptations may be implemented on-farm or off-farm. On-farm adaptation encompasses incorporating climate change adaptation measures within the existing agricultural operations without necessitating a complete departure from farming activities. Conversely, off-farm adaptations entail farmers relinquishing agricultural pursuits and pursuing alternative endeavors. This study revealed that among the 323 farmers implementing climate change adaptations, 283 (88%) adopted on-farm adaptations, while 40 (12%) engaged in off-farm adaptations. Table 2 and Figure 2 present the on-farm and off-farm adaptations employed by the farmers in the study area.

The dominant on-farm adaptation practices observed in the study area were the early planting of crops at the onset of the rainy season, the cultivation of

Table 2. On-farm and off-farm adaptation practices in the study area

Adaptations	Practices	Number of farmers implementing climate adaptation
On-farm	Early cropping	108
	Early maturing crop varieties	72
	Application of fertilizers	2
	Drought resistant crops	61
	Irrigation	22
	Diversification of crops	18
	Rainwater harvesting	2
Off-farm	Motorcycle transportation	45
	Brick making	25
	Vending at local markets	26

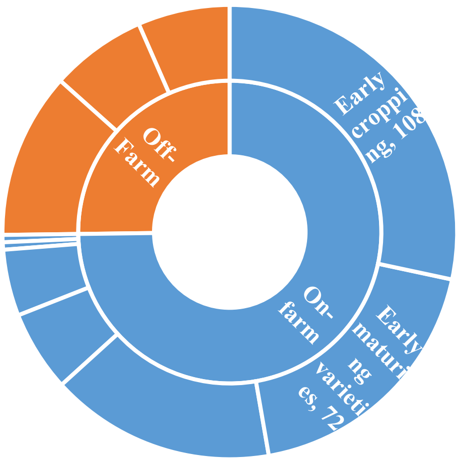

Figure 2. A sunburst chart showing the off-farm and on-farm strategies and the number of adopters per strategy.

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early maturing varieties, and the growing of drought-resistant varieties. Other techniques employed included the irrigation of crops during periods of rainfall failure, the application of fertilizers, and the implementation of water harvesting practices. Furthermore, the study identified off-farm practices that farmers have undertaken to adapt to the effects of climate change. This entailed transitioning from the cultivation of crops and the rearing of livestock on the farms themselves to the pursuit of alternative activities outside the farms. This included the purchase of motorcycles and the provision of rural transport (by motorcycle) as a means of generating income to purchase food and other essentials, the production of bricks, the operation of small shops, and the sale of goods at weekly markets, as well as working in roadside markets. Many farmers opted to sell their land and livestock to fund the initiation of off-farm activities, generate income, and procure food.

In the focus group discussion, the farmers indicated that the availability of information from various sources, including extension workers, community leaders, and other sources, had motivated them to continue farming. This finding is also supported by the research of Ayanwuyi (2013), which revealed that information infrastructure, including extension services, newspapers, radio, meetings and training, and other forms of communication, guides farmers in their adaptation strategies. Additionally, it was ascertained that early planting had been a customary practice in the region. The adoption of early planting, the use of early maturing varieties, the diversification of crops, and the planting of drought-resistant varieties resulted in increased yields. This finding is corroborated by research by Tao and Zhang (2010). Furthermore, other factors were identified as influencing the selection of an adaptation strategy, including farm size, household size, education, age, membership of a farm-based organization, and socio-economic and institutional factors. The following studies support these findings: Uddin et al. (2014), Yong et al. (2014), Esfandiari et al. (2020), Destaw and Fenta (2021), Adeagbo et al. (2021), Kabir et al. (2021), Kumar et al. (2021), Mwinkom et al. (2021) and Gebre et al. (2023). It is also noticeable that a limited number of households have adopted irrigation and using fertilizers. This is attributed to the lack of capital since the area has no public irrigation systems, necessitating farmers to acquire such equipment at personal costs. The price of fertilizers is also high and not affordable for many farmers. This calls for a concerted effort by the government to subsidize the costs of irrigation equipment and fertilizers and establish public irrigation systems to serve farmers. This would also help to build confidence among farmers and agricultural creditors since crop failure due to drought would be dealt with.

Adopting off-farm activities is limited by the availability of money-lending institutions and the risk associated with rain-fed agriculture. Yet small farmers desire to play safe in the face of uncertainties of rain-fed agricultural enterprises. The financial lending institutions cannot risk lending money to agriculture because of the uncertainties associated with farming. This was also the case with Yiridomoh et al., 2022, who established that women smallholder farmers do not have the security to secure loans. Rasquez and Lambin (2006) noted that smallholder farmers should focus on agriculture and expand to other off-farm ventures like trade to diversify opportunities. Off-farm as a strategy of adaptation can be seen as a way to reduce climate change risk (Adger et al., 2004; Mertz et al., 2011). Other studies that have identified off-farm activities as a way of increasing wealth and reducing vulnerability to climate change include (Motsholapheko et al., 2011; Badjeck et al., 2010; Uddin et al., 2014; Chah et al., 2013).

Climate Variability Adaptation Strategies and Food Security

The objective of climate variability adaptation is to reduce the impact of climate variability on households, with the primary goal of ensuring food security at the household level. It was necessary to ascertain the efficacy of the adaptation practices concerning food security. Table 3 illustrates the correlation between the implementation of specific adaptation practices and the resulting impact on the food security status of the households engaged in these practices.

As evidenced in Table 3, the most effective adaptation strategies for mitigating the impact of climate variability on food security at the household level included early planting of crops to capitalize on the early rains, planting early maturing crop varieties, planting drought-resistant crop varieties, and the utilization of irrigation and water harvesting techniques. Although a minority of farmers could not achieve adequate food availability, the majority could maintain a moderately secure food situation (with food available for four to nine months). Furthermore, no households were found to be experiencing severe food insecurity (with food available for one to three months per year). However, most farmers who used fertilizers were classified as having a moderate food security situation at the household level. Concerning non-farm adaptation strategies, farmers engaged in vending and brickmaking were predominantly classified as experiencing a moderate food security situation. It was found that no farmers were experiencing either an adequate or a severe food insecurity situation.

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Conversely, farmers who employed motorbike transportation as a strategy were classified as experiencing severe food insecurity. Despite its popularity, this strategy is among the least effective in addressing food insecurity at the household level. This is because most of the motorcycles used are acquired on loan/credit and daily remittances, which makes it hard for the riders to make any savings required to ensure food availability (Rahman and Mishra, 2019). As Connolly-Boutin et al. (2016) suggested, a more holistic approach involving livelihood diversification would better ensure food security in sub-Saharan Africa.

Establishing the Relationship between Adaptation and Non-adaptation to Food Security

The food availability between those practicing adaptations and those not practicing adaptations is described in Table 4. Most farmers implementing adaptations (323) were in the category of moderate food availability (95.7%, 309). The remaining 3.1% (10) were in the food security status category, indicating adequate food availability. Conversely, 1.2% (4) of farmers were in the category of severe food insecurity, indicating inadequate food availability. Conversely, among the 52 households that were not implementing adaptations, 28.8% were classified as facing an inadequate food situation. This figure is significantly higher than that of 1.2% of those practicing adaptations to climate variability who were in the same problem. Most farmers implementing adaptations (95.7%) are in the category of moderate food availability. Similarly, 71.2% of those not practicing adaptations are in the same category. No household that did not implement adaptations was found to have adequate food availability within the study area. In contrast, 2.7% of households that did adopt climate change adaptations fell into this category. This finding reveals the adverse effects of climate change in the area, and adaptation strategies are no longer an option but a necessity. This calls for a concerted effort by government and local communities to ensure people embrace climate change resilient practices. Alternatively, there may be a need for a mindset change among the non-adopting farmers to realize that food availability does not only mean having food stocks in the house, but even the ability to buy food equates to food availability.

Comparative Analysis of Adopters and Non-adopters Concerning Food Availability at the Household

There are significant differences in food availability status between farmers who practice climate change and variability adaptation and those who do not. Farmers practicing climate change and variability adaptation are more likely to attain food security than those not practicing. However, even among the adopters, most households (95.7%) were classified as having moderate adequate food availability, while 3.1% were identified as having sufficient food availability. This significant percentage of households associated with food insecurity highlights a larger issue affecting the region beyond climate change adaptation. This finding is analogous to the results of a study conducted by Al Dirani et al. (2021) in Lebanon, which demonstrated that 7.5% of individuals who adopted climate change adaptation strategies fell within the category of food security, while 89% were classified as being in a moderate food-secure category. Nonetheless, given that adopters had a better chance

Table 3. Climate change adaptation practice/strategies and food security

	Number of farmers and percentage of total farmers surveyed			
	Food security at the household level			
Adaptations	1-3 months	4-9 months	10-12 months	Total
Planting during early rains	-	105 (97.2%)	3 (2.8%)	108 (100%)
Planting early maturing crops	-	70 (97.2%)	-	70 (100%)
Use fertilizers	1 (1.4%)	70 (97.2%)	1 (1.4%)	72 (100%)
Plant drought resistant	-	59 (96.7%)	2 (3.3%)	61 (100%)
Practice irrigation	-	18 (81.8%)	4 (18.2%)	22 (100%)
Water harvesting	-	2 (100%)	-	2 (100%)
Vending	-	10 (100%)	-	10 (100%)
Motors cycling	3	17 (85%)	-	20 (100%)
Brick making	-	4 (100%)	-	4 (100%)
Total	4 (1.2%)	309 (95.7%)	10 (3.1%)	322 (100%)

Notes: The number of months under the column “food provision” indicates when the households are secure in terms of food provision, i.e.,3, 9, and 12 months.

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Table 4. The food availability of farmers according to their adaptation status

	Number of farmers and percentage of total farmers surveyed			
	Food security at the household level			
	Inadequate	Moderate	Adequate	Total
Practicing adaptations	4 (1.2%)	309 (95.7%)	10 (3.1%)	323 (100%)
Not-practicing adaptations	15 (2.8%)	37 (71.2%)	-	52 (100%)
Total	19 (5.1%)	346 (92.2%)	10 (2.7%)	375 (100%)

Table 5. Chi-square results of differences in food availability status among climate change adapters and non-adapters

	Value	df	Asym. Sig (2-sides)
Pearson Chi-square	90.34	2	0.000
Likelihood ratio	58.6472	2	0.000
Linear by linear	63.458	1	0.000
No. of valid cases	375		

of being food secure, as evidenced by the chi-square analysis (Table 5), adaptation strategies must be encouraged among many more farmers. The majority of adaptation practices result in increased yields. This finding was also corroborated by the studies conducted by Gebre et al. (2023), Amare and Simane (2018), Tsegaye (2015), and Zakari et al. (2022). The researchers concluded that any level of adaptation is preferable to no adaptation at all. Furthermore, Gabre et al. (2023) observed that an increased likelihood of food security was associated with the adoption of a greater number of adaptation strategies by farmers in Northern Kenya.

Conclusions

The study revealed that many households in the area had already implemented adaptation strategies, while only a minority had not yet adopted such measures. The primary factor responsible for the high adoption of these strategies was strong extension services that provide an adequate infrastructure for disseminating information on climate variability, change, and potential adaptation strategies. The most common on-farm adaptation strategies included early planting of crops, cultivation of early-maturing varieties, and introduction of drought-, pest-, and disease-resistant varieties. Most farmers utilized these strategies. These on-farm adaptation approaches will likely support households in achieving food security. Irrigation and fertilizers are the least common on-farm strategies, despite their potential to enhance food security at the household level. The government needs to intervene to reduce the costs of irrigation equipment and fertilizers, provide public irrigation infrastructure, and offer guarantees for agricultural credit. Additionally, it should encourage the diversification of both on-farm and off-farm activities. Such interventions will ensure sustainable food security in the region. Implementing any adaptation strategy provides greater food security than without such measures. Adopting multiple adaptation strategies has been shown to improve food security status. Future research should examine the long-term impacts of adaptation strategies and evaluate the effectiveness of various combinations. Such an examination would enable policymakers to devise targeted interventions tailored to specific regions.

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