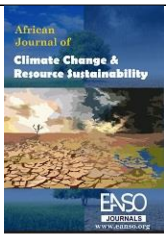

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Original Article

Evaluating Adaptive Capacity and Welfare of Farmers in Uganda's Climate-Vulnerable Regions Using an Index-Based Method

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ABSTRACT

The escalating impacts of climate change on agricultural regions in Africa underscore the urgent need for effective adaptation strategies. This study aims to quantify factors influencing the well-being and adaptation capacity of farmers in climate-vulnerable areas. Conducted from December 2023 to March 2024 in Kigezi and Acholi regions, the study sampled 320 farmers using random sampling. The Adaptive Capacity and Welfare Index (ACWI) was used to describe the well-being and adaptive capacity of farmers in climate-vulnerable areas. ACWI comprises five components (Access to Welfare Programs, Social Relationship Conditions, Family Welfare Conditions, Adaptation Capacity, Experience with Innovation/Technology, and Climate Change Extension). Linear regression results identify several significant factors influencing ACWI, such as village location, planting activities during the dry season, number of family dependents, cultivated land area, education level, income from rice farming, alternative employment, and fishing activities. Kigezi region showed a higher ACWI compared to Acholi, indicating better business diversification and climate change awareness. This study underscores the importance of considering local conditions and socio-economic factors in enhancing farmers' adaptive capacity and welfare. Policy recommendations should focus on improving access to resources, adaptation programs, training, and promoting farmer education and business diversification to ensure sustainability and productivity in agriculture amidst climate change challenges.

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INTRODUCTION

Climate change, characterized by floods and droughts which are potentially influenced by the El Niño phenomenon, has made several regions in Africa vulnerable, particularly areas that are food production centres. The impacts of climate change on agricultural areas in Africa include land and water resource degradation and infrastructure damage. Nearly all African regions, especially food-producing areas such as Sub-Saharan face significant climate vulnerability (Tchonkouang et al., 2024).

Existing research emphasizes the importance of farmers' capacity to adapt, relying on their perceptions and understanding of climate change. Traditional methods often fail to address climate change issues, highlighting the need to provide climate-related information to farmers. However, awareness alone does not drive action; factors such as education level, income, and farming experience influence adaptation decisions. Additionally, the involvement of local institutions and stakeholders is crucial for effective adaptation strategies, as they provide support, information, and resources needed by farmers (Abdulai et al., 2017; Alhassan et al., 2019; Kandel et al., 2023; Oo et al., 2017, 2018; Thi Hong Phuong, 2017; Thi Hong Phuong et al., 2017). Addressing climate change impacts in Africa requires comprehensive strategies at national, local, and individual levels (Kandel et al., 2023). Efforts should focus on enhancing farmers' adaptation capacities through improved access to information, financial support, and participatory approaches involving local communities and institutions. Additionally, innovative solutions such as microfinance and insurance schemes can help mitigate climate risks for smallholder farmers, but challenges in design, affordability, and sustainability must be addressed (Ahmed, 2016; Alhassan et al., 2019; Lebrini et al., 2021; Mishra & Pede, 2017; Musah-Surugu et al., 2018).

Collaborative efforts between stakeholders and the integration of climate change considerations into policymaking are essential for building resilience and ensuring sustainable agricultural development amidst changing climatic conditions. A comprehensive strategy is needed to enhance the capacity of communities, especially farmers, to adapt to climate change. The integrated programs to improve farmers' capacity emphasize not only physical support but also awareness, disaster resilience, and empowerment. Existing adaptation efforts mainly focus on providing technical skills and agricultural inputs, overlooking awareness-raising and disaster resilience initiatives (Aizaki et al., 2021; Ali et al., 2021; Mushtaq et al., 2020; Suji et al., 2020). The implementation of initiatives such as Science Field Shops, Climate Village Program, and Climate Field School has shown promising results in enhancing farmers' understanding and observation of climate changes, leading to the formation of rainfall observer clubs and empowering farmers to access resources independently.

However, the top-down approach predominates in these programs, with limited community involvement. The farmers' welfare remains threatened by climate-induced disasters, leading to increased poverty levels. Farmers' vulnerability to climate change is compounded by socioeconomic conditions, hindering their capacity to adapt effectively. Financial constraints and the dominance of informal lending exacerbate these challenges, hampering investment in resilient agricultural practices. Moreover, the majority of impoverished households rely on agriculture for sustenance, heightening the

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sector's vulnerability to climate-related risks (Ahmed, 2016; Alhassan et al., 2019; Mishra & Pede, 2017; Quandt & Kimathi, 2017). Ensuring farmers' welfare requires a holistic approach encompassing social, economic, and environmental dimensions. Access to extension services plays a pivotal role, yet its effectiveness is hindered by top-down approaches and limited community engagement. Enhancing farmers' livelihoods requires interventions addressing income diversification, market access, and social capital development (Aizaki et al., 2021; Ali et al., 2021; Ha et al., 2017; Mushtaq et al., 2020; Ngum et al., 2019; Suji et al., 2020; Thi Hong Phuong, 2017; Thi Hong Phuong et al., 2017).

Because agriculture, socioeconomic well-being, and climate change are intertwined, it is critical to implement multimodal solutions that are appropriate for local settings. Africa can effectively address the difficulties posed by climate change while preserving agricultural livelihoods and improving general welfare. This could potentially be achieved by empowering farmers, supporting sustainable practices, and creating community resilience. The purpose of this study is to quantify factors that characterize the well-being and ability for adaptation of farmers in climate-vulnerable areas.

THEORETICAL BACKGROUND

Vulnerability is defined as the propensity to be adversely affected, encompassing sensitivity to harm and a lack of coping capacity. Traditionally assessed through top-down, biophysical evaluations focusing on exposure to climate hazards, this approach has evolved to include bottom-up social, and contextual determinants. Vulnerability varies within communities and across societies, changing over time. It involves the presence of people, livelihoods, ecosystems, infrastructure, or cultural assets in areas that could be adversely affected. This concept bridges climate risk and disaster risk communities, enhancing disaster preparedness and sustainable development by integrating disaster risk management with climate change adaptation (IPCC, 2001, 2007). Vulnerability and resilience are very dynamic in both individual and community agricultural systems due to experiences coping with the effects of climate change. Individual farmers and their communities have tight relationships as part of agricultural life. Between vulnerability and resilience, adaptive capacity acts as a bridge and is influenced by both life experiences and outside interventions. The concepts of resilience, vulnerability, and adaptive capacity are presented as dynamic, interrelated states (Engle, 2011; Gallopín, 2006; Proag, 2014).

The impacts of climate change, such as disasters (floods, droughts, and pest outbreaks), on the agricultural sector at farming locations, create conditions of insecurity for communities reliant on farming for their livelihoods. The concept of insecurity refers to the state of being vulnerable to adverse effects and harm due to external factors. This insecurity results from resource scarcity, unpredictable environmental conditions, and inadequate coping mechanisms, leading to increased vulnerability and reduced resilience among affected populations (Chou et al., 2016; Fitzpatrick, 2005; Khairo et al., 2005; Martinez-Martinez et al., 2018; Piontak & Schulman, 2014)

The impacts experienced by farming households in areas affected by climate change can be viewed from multiple perspectives. Building on this premise, the primary focus of this research is to thoroughly examine and analyse the well-being of farmers within the context of climate change, including: (1) the conditions of the physical environment (Berkes & Folke, 2000; Endris & Nura, 2018; Haryono et al., 2011; Perdinan et al., 2018; Reardon & Vosti, 1995; Scherr, 2000), (2) the allocation of resources (Balaji et al., 2015; Berkes & Folke, 2000; Reardon & Vosti, 1995), (3) the sustainability of farming practices (Asnawi, 2015; Hossain et al., 2018; Jafry, 2012; Joshi et al., 2017; Nyanga et al., 2011; Pede et al., 2017; Vijayasarathy & Ashok, 2015; Yokoyama & Ali, 2009) (4) the economic factors (Adger, 2003; Chou et al., 2016; Darwis & Iqbal, 2007; Georgopoulou et al., 2017; Ilham, 2009; Ofoegbu et al., 2017; Ojekunle et al., 2013; Sadikin & Subagyono, 2009; Winarto et al., 2013), and (5) the fulfilment of nutritional and health needs

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(Adger, 2003; Bedran-Martins et al., 2018; Burgess & Shier, 2018; Hogan et al., 2011; Ofoegbu et al., 2017; Perdinan et al., 2018; Yokoyama & Ali, 2009).

The social system (Abdulai et al., 2017; Barua et al., 2017; Oloo & Omondi, 2017; Paul et al., 2016; Thi Hong Phuong, 2017; Thi Hong Phuong et al., 2017), the extension system (Banerjee, 2016; CDI-WUR, 2017; Gebrehiwot, 2015; Mariano et al., 2012; Takemura et al., 2014; Vanclay, 2004), and the innovation system (Bakhtina, 2011; Busse et al., 2014; Man, 2001; Mehta et al., 2014; Nieuwenhuis, 2002; Nzeadibe et al., 2012; Sandra Schillo & M. Robinson, 2017; Tambo & Wünscher, 2014) are three additional systems that are linked with the lives of communities involved in agriculture. These three systems are essential and have a significant impact on how agricultural households in their communities live socially and economically.

Adi (2013) and UN ESCAP (2017) indicate that there is considerable discussion on the relationship between community well-being and vulnerability to climate change. Social development programs aimed at enhancing well-being must account for the negative impacts of climate change, such as how environmental degradation leads to decreased or lost agricultural yields and other related issues. This position aligns with the people-centred development model of UN-ESCAP, emphasizing the significance of including environmental factors. Therefore, to effectively address the complexities of climate change vulnerability and to ensure long-term community well-being, holistic social development strategies as promoted by (Cox & Pawar, 2013; Midgley, 1995)—necessitate the incorporation of sustainability dimensions within a broader framework. According to Midgley (1995, 2012) and Cox and Pawar (2013), holistic social development strategies require the integration of sustainability dimensions into a more comprehensive framework to successfully address the complexities of climate change vulnerability and foster long-term community well-being. Midgley (1995, 2012) argues that social and economic growth are inseparable and that societal advancement requires a strong economic base. Additionally, an interdisciplinary strategy that incorporates knowledge from several social science disciplines is necessary to comprehensively understand and address societal issues. Cox and Pawar (2013) emphasize the need to address social development at various levels micro, meso, and macro to effectively promote community well-being. Cox and Pawar (2013); Midgley (1995, 2012) state an intervention approach to social development, highlighting the importance of focused and coordinated efforts to enhance socioeconomic conditions, including mitigating the effects of climate change.

Climate change is one of the most serious threats to sustainable development in Uganda, with adverse impacts on the environment, human health, food security, economic activities, natural resources, and physical infrastructure that require urgent interventions (Byamukama et al., 2018)

Research on farmers' well-being and ability to adapt in climate-vulnerable areas shows the application of thorough index-based techniques. Hong et al. (2023) used two index systems; one for measuring livelihood assets and another for analysing welfare changes to apply Amartya Sen's capabilities framework and the Sustainable Livelihood Framework (SLA). Farming families may be categorized into high, medium, and low welfare groups using these indicators. Using elements including exposure, sensitivity, and adaptation capability, Dwi et al. (2017) created the Livelihood Vulnerability Index (LVI) to assess how vulnerable agricultural families are to social and environmental changes. Similarly, Sahara et al. (2023) evaluated the well-being of farming families by utilizing metrics such as the Exchange Rate for Farmers' Household Income (ERFHI) and the income-to-expenditure ratio indicating that a substantial increase in crop production improves well-being and household income.

Furthermore, Liu et al. (2023) introduced a community resilience index encompassing environmental, economic, managerial, and social dimensions to evaluate the welfare of households

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relocated under poverty alleviation programs. They also developed the Agricultural Drought Resilience Index (ADRI) to measure community resilience against agricultural drought. Sun et al. (2023) applied resilience theory and the sustainable livelihood analysis framework to create an index of sustainable livelihood resilience for farmers, incorporating buffer capacity, self-organization, and learning capacity. These approaches provide in-depth insights into the factors influencing farmers' welfare and resilience, supporting the development of more effective policies aimed at enhancing the welfare of farmers in climate-vulnerable regions. The findings of these studies provide a justification to rely on for future references and clarification on the evaluations of adaptive capacity and welfare of farmers in the similar context of Uganda's climate-vulnerable regions using an index-based method.

METHODS

Sites of the Study

This study was conducted from December 2023 to March 2024 in Kigezi and Acholi regions. Climate change poses significant threats to agricultural systems, especially to smallholder farmers who rely heavily on rain-fed agriculture. Western and Northern Uganda are regions heavily dependent on agriculture where smallholder farmers face numerous challenges including increased temperatures, rampant pests and diseases, high environmental degradation, flooding and landslides, low agricultural production, erratic rainfall patterns, and extreme weather events.

Kigezi region

This region consists of 6 districts; Kabale, Rubanda, Rukiga, Kanungu, Kisoro, and Rukungiri. It is currently experiencing changes in precipitation and temperature which modify the evaporation and soil moisture storage leading to alterations in runoff and other components of hydrological systems. Extreme events, like floods and droughts, are more intense and frequent. The unpredictable rains and droughts are attributed to climate change and variability. Consequently, climate change and variability have caused a significant impact on soil nutrients which have affected the agricultural productivity in the area.

Acholi region

Acholi Subregion consists of 8 districts which are, Gulu, Omoro, Amuru, Nwoya, Agago, Pader, Kitgum, and Lamwo districts covering about 28,500 km2 near the Uganda -South Sudan border. The high population growth is impacting negatively the environment and natural resources, and this needs good food security to support the growing population. The region is well known for prolonged dry spells disrupting Agricultural productivity; and causing reduction and disappearance of water surface, bush fire that disrupt the natural ecosystem, therefore, the impact of climate change and its extremities cannot be resisted, with uncontrolled and high rate of environmental degradation.

Sampling and Data Collection at the Farm Level

Sampling locations were selected purposively based on information provided by the local government officials that are most vulnerable to floods and droughts. Consequently, two districts were chosen as sampling locations: Kabale and Gulu City, located in western and northern regions respectively where farmers have experienced the highest frequency of floods and crop failure in their farming areas and these two study areas are constituents of the selected regions for the study. Farmers, representing agricultural households, were assigned as the unit of analysis in this study. The sample size was determined using the sample size table (Krejcie & Morgan, 1970). A simple random sampling was applied to select respondents, resulting in a sample size of 320 respondents, with 191 farmers from Kabale district and 129 farmers from Gulu City.

Data Analysis

The data used to form the index scores consist of two types: (1) Complete data, where all variables are included, and (2) Selected data based on the

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CFA (Confirmatory Factor Analysis) method, where only variables (index sub-components) with a positive loading factor are chosen. The methods used for index scoring also consist of two types: (1) Percentage method and (2) CFA method. Both methods were used to obtain index scores of household conditions in climate-vulnerable locations from the available data, resulting in four index scores based on the data and methods used. The index scoring was also adjusted according to the respondents' areas of origin, resulting in two final index scores for respondents. This index aims to assess the adaptive capacity and welfare conditions of farmers in climate-vulnerable areas. The components and sub-components of the index were derived from preliminary research through Focus Group Discussions (FGDs) with farmers and agricultural extension officers in the study sites. Researchers formulated a series of open-ended questions based on welfare aspects and vulnerability indices from selected literature as references during the FGDs. The components and sub-components of the index measured in this study are presented in *Table 1* below.

Table 1: Components and number of sub-components of the index using complete data and CFA results

Component	Number of sub-components (Complete)	Number of sub-components (CFA)
Access to Welfare Programs	9	9
Social Relationship Conditions	17	5
Family Welfare Conditions	46	12
Adaptation Capacity	25	11
Experience with Innovation/Technology	8	4
Climate Change Extension	15	10

Index Scoring (Percentage Method)

The percentage method is an index scoring method based on comparing actual conditions in the field with ideal conditions. The steps are as follows:

- Calculate the total value of all variables within a specific dimension. For example, the total value of variables for the PIT dimension is calculated by summing the values of variables PIT01 through PIT08.
- Calculate the ideal maximum value of a dimension by multiplying the number 5 (maximum Likert score) by the number of variables in that dimension. For example, the PIT dimension has 8 variables, so the ideal maximum value is 8 x 5 = 40.
- Compare the TOTAL value with the IDEAL SCORE value to obtain the percentage of ideality for a particular respondent. For example, the first respondent in the table below has an IDEAL % value of 0.63. This indicates that the PIT condition for the first respondent meets 63% of the perfect ideal condition. The higher the IDEAL % value, the better the condition of the dimension for the respondent.
- Calculate the average of the IDEAL % values for a specific dimension. For example, the average IDEAL % value for the PIT dimension is 0.68 for respondents in Kabale District and 0.65 for respondents in Gulu City.

- Convert the average IDEAL % value into a Likert scale. The formula used for this conversion is as follows:

$$\text{Likert} = \left[\frac{(\text{IDEAL \% value}) - (\text{Lower limit IDEAL \%})}{(\text{Upper limit IDEAL\%}) - (\text{Lower limit IDEAL \%})} \times (\text{Upper limit Likert} - \text{Lower limit Likert})\right] + (\text{Lower limit Likert})$$

Description:

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IDEAL % value: Average IDEAL % value of the dimension

Upper limit IDEAL %: Upper threshold of the IDEAL % value range. In this case, the value is 1 (100%)

Lower limit IDEAL %: Lower threshold of the IDEAL % value range. In this case, the value is 0 (0%)

Upper limit Likert: Upper threshold of the Likert scale range. In this case, the value is 5 Lower limits

Likert: Lower threshold of the Likert scale range. In this case, the value is 1

Index Scoring (CFA Method)

The Confirmatory Factor Analysis (CFA) method is a method of index scoring using factor analysis to obtain weights or loading factors for each variable of a specific dimension. The index score is then obtained by summing all the results of multiplying variable values by their weights/loading factors. The entire calculation process using the CFA method is performed using SPSS software version 26. The steps are as follows:

- Calculate the weights (loading factors) for each variable. Below is an example of the calculation results of loading factors for variables from the PIT dimension.
- Multiply the weights (loading factors) by the standardized variable values (the standardized variables are variables whose values have been subtracted by the mean (average) value and then divided by the standard deviation.). This process is automatically done by the software. The result of this multiplication is called the factor score. Below is an example of factor score values for the PIT dimension.
- Calculate the average factor score value for a specific dimension based on the respondents' village of origin. For example, the average factor score value for the PIT dimension for respondents from Kabale District is 0.31, and for respondents from Gulu City is -0.21.

- Convert the average factor score value into a Likert scale. The formula used for this conversion is as follows:

$$\text{Likert} = \left[\frac{(\text{FS value}) - (\text{Lower limit FS})}{(\text{Upper limit FS}) - (\text{Lower limit FS})} \times (\text{Upper limit Likert} - \text{Lower limit Likert})\right] + (\text{Lower limit Likert})$$

Description:

FS value: Average factor score value of the dimension

Upper limit FS: Upper threshold of the factor score value range. In this case, the value is 3

Lower limit FS: Lower threshold of the factor score value range. In this case, the value is -3

Upper limit Likert: Upper threshold of the Likert scale range. In this case, the value is 5

Lower limit Likert: Lower threshold of the Likert scale range. In this case, the value is 1

Linear Regression

From the index measurement results, four groups of index values representing the same components/variables were obtained. A t-test analysis using STATA software version 17 was conducted to determine whether there are differences in the measurement results from these 2 methods. The subsequent test is a linear regression also using STATA software version 17, where the response variable is the average index value, and there are 16 determinant variables (factors), which consist of: the number of family non-farm labour (ratio), the number of family farm labour (ratio), the number of family dependents (ratio), duration as a farm member (ratio, years), farming experience (ratio, years), total rice field area, additional costs during dry planting season (ratio, IDR), farmer's education level (ordinal), fish farming (1=Yes, 2=No), household expenditure (ratio, IDR), income from

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non-rice (ratio, IDR), income from rice (ratio, IDR), age (ratio, years), alternative employment (1=Yes, 0=No), planting during dry season (1=Yes, 0=No), and farmer-fisherman (1=Yes, 0=No).

RESULTS AND DISCUSSION

Based on the data analysis, the Adaptive Capacity and Welfare Index (ACWI) is a combination of components from various literature sources such as (Engle, 2011; Gallopín, 2006; Proag, 2014) and the results of Focus Group Discussions (FGDs) to describe the adaptive capacity and welfare conditions. This index is considered more suitable for areas that have experienced vulnerability for a long time, while indices like LVI are more suitable for events that have recently occurred. In Africa, the largest tidal flood occurred in 2012, and both droughts and floods are increasingly occurring, albeit varying in scale (2020: The East Africa floods affected Rwanda, Kenya, Somalia, Burundi, Ethiopia, Uganda, the Democratic Republic of Congo, Djibouti, and Tanzania, with 700,000 people affected (HRČKOVÁ, n.d.).

This index connects the expanded concept of farmer welfare and their ability to adapt to climate change. Welfare is not only derived from income but also from social conditions and the sustainability of farming marked by adaptive capacity, which is measured in this index. The results of the index analysis also indicate that the welfare conditions and adaptive capacity in the two regions are still not ideal. The average for ACWI in Kabale is 3.01 and in Gulu City is 3.00.

Table 2: Adaptive Capacity and Welfare Index (ACWI)

Index components	Kabale District				Gulu City			
	ACWI -1	ACWI -2	ACWI -3	ACWI -4	ACWI -1	ACWI -2	ACWI -3	ACWI -4
Access to Welfare Programs (Awp)	3.36	2.94	3.36	2.94	3.44	3.04	3.44	3.04
Social Relationship Conditions (Src)	3.40	2.67	3.40	2.65	3.73	3.22	3.75	3.24
Family Welfare Conditions (Fwc)	3.85	2.67	3.80	2.71	3.93	3.22	4.02	3.20
Adaptation Capacity (Adc)	3.83	3.21	3.83	3.21	3.62	2.86	3.62	2.86
Experience with Innovation/Technology (EIT)	3.71	3.20	3.80	3.15	3.60	2.86	3.57	2.90
Climate Change Extension (Ccs)	3.95	3.40	3.95	3.40	3.52	2.73	3.52	2.73
Average	3.68	3.02	3.69	3.01	3.64	2.99	3.65	3.00

Description: ACWI 1 (complete data, percentage method); ACWI 2 (complete data, CFA method); ACWI 3 (CFA-selected data, percentage method); ACWI 4 (CFA-selected data, CFA method).

Source: field survey data analysis 2024

From these results, it can be concluded that the welfare improvement programs implemented have significant positive impacts on farmers and their families in various aspects, including access, implementation, evaluation, knowledge, and skill enhancement, as well as economic, health, and education conditions, as well as attitude and behaviour changes. All aspects of the Access to Welfare Program (Awp) received the same score, which is 3, indicating consistent improvement in various areas after participating in these programs.

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Overall, while aspects of Social Relationship Conditions (Src) still need improvement, the majority of aspects show support and positive conditions for the sustainability and progress of rice farming. The highest score in the KHS component is 4, indicating strong capabilities in overcoming obstacles, community support, attitudes, and behaviours, as well as cooperation and mutual assistance. Other scores, namely 3, indicate potential improvements in aspects such as communication, education, access and distribution of resources, mutual agreements, farming progress, and reducing group disparities.

Overall, the Family Welfare Conditions (Fwc) scores indicate good welfare in various aspects, but some areas can be improved to achieve optimal welfare. The highest score is 5 for the profitable selling price of unprocessed food, indicating strong economic aspects. Most other components received scores of 3 (income, investment, and farming capital) or 4 (farming knowledge and skills), indicating stable areas with some potential for improvement. High scores (5) include the profitable selling price of unprocessed food. Relatively high scores (4) cover many aspects such as knowledge and skills, access to capital, farming management, access to resources, family welfare and nutrition, health services, and education for children, indicating good welfare levels. Moderate scores (3) include the ability to meet family needs, independent farming capital, and family nutrition consumption, indicating stable areas but requiring improvement.

A study by Sisay (2024) finds that to address food/nutrition insecurity and poverty in agriculture, rural households are facing challenges like drought, floods, soil degradation, and limited access to capital for advanced technologies. The farmers are adopting livelihood diversification strategies to cope. Findings show that non-farm livelihood diversification alone improves smallholder farmers' welfare significantly but doesn't impact nutrition security. Joint participation in off-farm and non-farm diversification enhances nutrition security but not welfare. Solely engaging in off-farm diversification is most effective, benefiting both welfare and nutrition security. Policymakers should incentivize diversification, particularly in off-farm activities, to enhance adaptive capacity and welfare indices in vulnerable agricultural communities.

The Adaptation Capacity (Adc) aspect has indicator components with a score of 4 for farming knowledge, harvest yields, environmental threats, as well as pest and disease control programs. Some components with relatively high scores (3), especially related to knowledge and adaptation capacity to climate change for farming, indicate that although there is good awareness and understanding, there is still a need to improve the effectiveness of adaptation programs and extension services as well as access to resources. Meanwhile, some components have low scores (2), such as switching to non-rice farming, indicating that this alternative is less favoured or less relevant to farmers in this area. The results on the ACWI index for the KPA aspect indicate that overall, farmers in this area have adequate knowledge and skills for farming and facing environmental challenges. However, improvement is still needed in accessing resources, adaptation programs, and training to ensure the sustainability and productivity of farming.

The Experience with Innovation/Technology (Eit) aspect indicates that farmers have basic knowledge of existing technology, but there is still a need to improve access to information and introduce technologies that can specifically reduce crop losses due to floods and droughts. Efforts to improve technology and expand farmers' knowledge will greatly support enhancing their resilience to climate change. According to Shokati Amghani et al. (2023), effective programs should focus on practical, comprehensive training covering the entire crop supply chain, from growth to marketing, and include climate change adaptation strategies. Integrating fragmented farmlands can further enhance efficiency. Extension services agricultural productivity, with future research needed to refine these strategies across different climatic zones.

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In the Climate Change Extension (Cce) aspect, its constituent components obtained a score of 4 except for the component of using adequate equipment to support extension activities. From the survey results, it can be concluded that extension services in this regard are quite effective in providing clear, relevant, and easily understandable information related to climate change adaptation. However, there is a shortage in using adequate equipment to support extension activities. Nevertheless, these extensions have raised awareness and provided practical information that farmers can apply in facing climate change. There is room for improvement, especially in enhancing skills, abilities, and more specific guidance both individually and collectively in climate change adaptation actions.

Based on the findings discussed by Shokati Amghani *et al*. (2023) and Dzakaklo *et al*. (2024), welfare improvement programs have shown significant positive impacts on farmers and their families across various dimensions. These programs have enhanced access, implementation, evaluation, knowledge and skills, economic conditions, health, education, and attitudes and behaviours related to agriculture. The Access to Welfare Program (Awp) consistently improved across all aspects. Social relationship conditions (Src) require further enhancement, yet they generally support rice farming sustainability and progress.

The Knowledge, Skills, and Habits (KHS) component demonstrated capabilities in overcoming obstacles, community support, attitudes, behaviours, and cooperation. Areas such as communication, education, resource access, and reducing group disparities showed potential for improvement. Family Welfare Conditions (Fwc) indicated good welfare overall, focusing on economic aspects like profitable selling prices of unprocessed food. Adaptation Capacity (Adc) components related to farming knowledge, harvest yields, and pest/disease control showed good awareness. However, there is a need to improve adaptation to climate change and resource access. Effective climate change extension services (Cce) provide practical information, yet there's a need for better equipment support. These insights highlight the importance of comprehensive training, integrated farmland management, and targeted climate change adaptation strategies for sustainable agriculture. Institutional reforms and enhanced fund utilization, as recommended by Dzakaklo *et al*. (2024).

The t-test analysis results show that the index measurement methods yield different results. Therefore, in further analysis (regression), the 4th method (ACWI-4), which is more selective using data with the CFA method, is used. ACWI-4 has been selected to avoid duplication of indicators that are considered to measure the same condition.

Table 3: Results of unpaired t-test analysis with STATA

	ACWI-1	ACWI-2	ACWI-3	ACWI-4
FWAI-1		X	√	X
FWAI-2	X		√	√
FWAI-3	√	√		X
FWAI-4	X	√	X	

Description:
X = *There is a difference in variance between the two index measurement methods being compared.*
√ = *There is a similarity in variance between the two index measurement methods being compared.*

Source: field survey data analysis 2024

The results of the linear regression analysis indicate that the model has a Prob>F value of 0.000, which means it is acceptable, with an R-squared value of 0.2163 and Adj R-squared value of 0.1721, as well as Root MSE of 0.51841.

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Table 4: Results of linear regression analysis

Determinant Factors	Coefficient
Village (1= Kabale District; 2= Gulu City)	0.398*** (0.094)
The number of family non-farm labour (ratio)	-0.007 (0.060)
The number of family farm labour (ratio)	0.075 (0.057)
The number of family dependents (ratio)	-0.060** (0.025)
Experience as a farm member (ratio, years)	-0.006 (0.005)
Farming experience (ratio, years)	0.002 (0.004)
Total rice field area	0.075* (0.039)
Additional costs during dry planting season (ratio, IDR)	0.000 (0.000)
Farmer's education level (ordinal)	-0.062* (0.037)
Fish farming (1=Ya, 2=Tidak)	0.240* (0.125)
Household expenditure (ratio, IDR)	0.000 (0.000)
Income from non-rice (ratio, IDR)	0.000 (0.000)
Income from rice (ratio, IDR)	-0.000* (0.000)
Age (ratio, years)	-0.004 (0.004)
Alternative employment (1=Ya, 0=tidak)	-0.001* (0.037)
Planting during dry season (1=Ya, 0=tidak)	0.281*** (0.105)
Farmer-fisherman (1=Ya, 0=Tidak)	0.257*** (0.085)
Constanta	-0.609 (0.374)

*Note: *** p<0.01, ** p<0.05, * p<0.1 (Standard errors in parentheses)*

Source: field survey data analysis 2024

The results of the linear regression show that the following factors influence the Adaptive Capacity and Welfare Index (ACWI):

Village (study site), planting during the rainy season (yes/no), fisherman (significant at 99% level),

and the number of family dependents (significant at 95% level).

Total rice field area, farmer's education level, fish farming (yes/no), income from rice (IDR), and alternative employment (yes/no) (significant at 90% level).

The regression model has a negative constant, indicating that the conditions measured in the index will decrease without the measured factors.

Gulu City has a higher index compared to Kabale District. This may be due to higher vulnerability conditions, therefore farmers put more effort into improving their economy by diversifying their businesses, especially in fisheries (fishponds) and/or as fishermen. They are also more aware of signs of climate change. Anticipation measures include not planting during the rainy season, where the factors of planting during the dry season and farmer-fisherman are significant at 99%, and fish farming is significant at 90%.

Income from rice has a negative constant. Although significant, the coefficient is negative, meaning that the higher the income from rice farming, the lower the Adaptive Capacity and Welfare Index (ACWI). This is because income from rice is not considered the main support; farmers rely on various other businesses to increase their income. The alternative employment factor has a negative constant, meaning that farmers who allocate their time to other employment have a decreased index value. In the field, both from farming results and alternative employment in general (various types of employment), they have not yet driven an increase in the FWAI index value. Farmer education is significant but shows a negative value. This indicates that the welfare of farming and adaptation capacity is not supported by the level of education. Also, those with higher education levels are not focused on farming. Meanwhile, the higher the number of family dependents, the lower the index value, indicating that the ability of farmers (heads of households) is not sufficient solely from their farming results. The total rice field area shows that the index value

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increases as the rice cultivation area expands. This indicates that the total rice field area has an implicit influence on income and the willingness as well as ability of farmers to adapt.

Based on the findings from the linear regression analysis, several factors significantly influence the Adaptive Capacity and Welfare Index (ACWI) among farmers in different villages, aligning with findings by Baiyegunhi et al. (2022); Herianto et al. (2010); Sisay (2024) on agricultural resilience and adaptation strategies. The study identifies region location (Kigezi vs. Acholi), seasonal planting practices, and engagement in fish farming or fishing as pivotal determinants affecting ACWI. Gulu City exhibits a higher ACWI compared to Kabale District, likely attributed to increased vulnerability prompting farmers to diversify income through fish farming and fishing, as noted by Herianto et al. (2010). Furthermore, the study underscores the negative impact of income from rice cultivation on ACWI, supporting Baiyegunhi et al. (2022); Herianto et al. (2010); Sisay (2024) insights into the limitations of single-crop reliance for enhancing adaptive capacities and welfare indices. The positive influence of total rice field area on ACWI also aligns with Herianto et al. (2010) emphasis on farm size in bolstering economic resilience and adaptive strategies. Additionally, the study's observation of the detrimental effect of having more family dependents on ACWI resonates with discussions on household dynamics and economic challenges in agricultural contexts. Moreover, the indication that alternative employment may not consistently improve welfare indices reflects from (Herianto et al., 2010; Sisay, 2024) findings on the complexities of income diversification in rural settings. These findings collectively underscore the need for policies promoting diversified farming practices and supporting non-agricultural income sources to strengthen resilience and adaptive capacities in vulnerable agricultural communities. The implications of these findings provide a strong foundation for the development of policies and programs aimed at improving the welfare and adaptation capacity of farmers in climate-vulnerable areas.

CONCLUSION

This study confirms the importance of considering local conditions and socio-economic factors in measuring and enhancing the Adaptive Capacity and Welfare Index (ACWI) in two districts in the study regions. ACWI can be used to describe the well-being and adaptive capacity of farmers in climate-vulnerable areas. The analysis conducted indicates that although welfare improvement programs have had positive impacts, there are still areas that need improvement, particularly in social relationships and family welfare aspects.

Linear regression results identify several significant factors influencing ACWI, such as location, planting activities during the dry season, number of family dependents, cultivated land area, education level, income from rice farming, alternative employment, and fishing activities. Gulu City shows a higher index value compared to Kabale District, indicating that business diversification and awareness of climate change are better in Gulu City. To improve ACWI, greater efforts are needed to improve access to resources, adaptation programs, and more effective training. Farmer education and business diversification should also be considered to ensure the sustainability and productivity of farming activities.

Implications of measuring ACWI also suggest that efforts to diversify livelihoods, expand the food cultivation areas, and manage family dependents wisely can play a key role in improving the welfare and adaptation to climate change for farmers. Thus, policy recommendations can focus on strengthening socio-economic and education infrastructures, as well as increasing access to relevant resources and technology.

COMPETING INTERESTS DISCLAIMER

The authors have stated that none of the work disclosed in this paper may have been influenced by any known conflicting financial interests, non-financial interests, or personal ties.

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