East African Journal of Social and Applied Sciences (EAJ-SAS)
Vol.6, No.1 Publication Date: June 30, 2024
ISSN: (Online) 2714-2051, (Print) 0856-9681
Full articles of this journal are available at: https://journals.mocu.ac.tz/index.php/eaj-sas

Cite this article as: Joseph, L. (2024). Community-based adaptation strategies for enhancing ecological resilience to climate change among agro-pastoral communities in the Lake Victoria Basin, Tanzania. *East African Journal of Social and Applied Sciences,* 6(1), 1-14.

COMMUNITY-BASED ADAPTATION STRATEGIES FOR ENHANCING ECOLOGICAL RESILIENCE TO CLIMATE CHANGE AMONG AGRO-PASTORAL COMMUNITIES IN THE LAKE VICTORIA BASIN, TANZANIA

Laurent Joseph
Department of Management Science
Institute of Finance Management
ORCID ID: https://orcid.org/0000-0002-9750-6803
Email: laurentjoseph1977@gmail.com

ABSTRACT
Climate change presents extraordinary challenges, significantly impacting both human and ecological systems in Tanzania's Lake Victoria Basin (LVB). This study investigates how Community-Based Adaptation Strategies (CBASs) enhance ecosystem resilience in the face of changing climate patterns. The research employs a mixed-methods approach, integrating quantitative analysis of CBASs with Participatory Rural Appraisal (PRA). Additionally, focus groups, questionnaires, and interviews were used to broaden the data set, involving 708 participants. The study also included the testing of soil properties, such as pH, organic content, nutrient levels, and fodder quality. Random sampling was utilized to select respondents for questionnaires, while interviewees were purposively chosen. The sample size for this study was 708 participants. Qualitative data were analysed through thematic analysis, and quantitative data were processed using SPSS. The study found that CBASs such as reforestation, agroforestry, beekeeping, alternative cooking fuels, climate-smart livestock production, crop diversification, soil conservation, sustainable land management, water use technology, and soil management strategy have significantly improved agro-pastoralist adaptability and bolstered ecological resilience in the study area. The findings indicate that CBASs have the potential to transform and modify local ecology, leading to ecosystem restoration, reforestation, and the preservation of biodiversity hotspots. Collectively, these efforts have enhanced both community and ecosystem adaptation. The study's results contribute to a deeper understanding of practical strategies for increasing climate resilience in agricultural and pastoral contexts and offer valuable insights for local communities, policymakers, development experts, and other stakeholders. It is recommended that expanding effective adaptation techniques in the LVB requires empowering diverse groups and fostering increased synergy among all stakeholders.

Keywords: Agricultural-pastoralist, Agro-pastoral communities, Climate change impacts, Community-based adaptation strategies, Ecosystem resilience.
Paper type: Research paper
Type of Review: Peer Review

1. Introduction

Climate change poses a significant threat to human communities and ecosystems worldwide, particularly impacting vulnerable populations (Ogega et al., 2023). Its consequences include the disruption of ecosystem interdependence and a threat to human survival, affecting food security, natural resources, health, the economy, and infrastructure across various scales (Kijazi et al., 2019; Kapitza et al., 2021). In Sub-Saharan Africa, climate change is causing severe damage, including the loss of indigenous fauna and flora, crop failures, livestock losses, arable land desiccation, increased temperatures, and heightened pest

and insect populations, as well as a rise in disease prevalence (Urama & Ozor, 2010). Similarly, East Africa faces significant risks from climate change, including health complications, stunted economic growth, drought, reduced food production, loss of native habitats, and damage to human and infrastructural facilities (Joseph, 2022).

In East Africa, Tanzania is experiencing a range of adverse effects due to climate change. These include alterations in rainfall patterns, outbreaks of plant diseases, food shortages impacting consumer preferences, water scarcity, and fluctuating lake water levels that accelerate environmental and ecosystem degradation (Joseph, 2022). The Lake Victoria Basin (LVB), which spans a large region in East Africa—including parts of Tanzania, Uganda, and Kenya—is crucial for both ecological and socio-economic reasons, particularly in agro-pastoral activities. This region is characterized by seasonal variations marked by irregular rainfall and elevated temperatures (Urama & Ozor, 2010). In response to these challenging climatic conditions, LVB communities have adopted community-based adaptation strategies (CBASs) aimed at environmental protection and strengthening ecosystem resilience. These strategies are developed through participatory processes that involve local communities, development actors, and disaster risk reduction experts.

The findings of the study highlight the importance of CBASs in supporting the sustainability of social and natural ecosystems and their interactions (Ogega et al., 2023). CBASs offer a range of benefits, including income stability, preservation of traditional societal values, reinforcement of community identity, and increased participation of women and vulnerable groups in enhancing ecological resilience. Among these strategies, reforestation plays a critical role in mitigating the effects of climate change, improving the community's adaptability to changing conditions, and reducing overall vulnerability. However, there remains a significant knowledge gap regarding the specific CBASs employed, their integration with modern technologies to bolster community resilience, and their adaptability within the LVB. This gap hinders informed decision-making and effective implementation of measures to enhance ecological resilience in the face of ongoing climate challenges. Therefore, this study aims to investigate the specific community-based adaptation strategies used to improve ecological resilience amid climate change in the LVB.

2. Theoretical Framework

This study is grounded in theories of ecological resilience that enable both ecosystems and communities to adapt to environmental changes. Ecological resilience is defined as the capacity of an ecosystem to absorb disturbances and reorganise in response to changes, while maintaining its essential functions, structure, and feedback mechanisms (Holling, 1973). This concept is based on the understanding that ecosystems are dynamic and adaptive systems capable of transitioning through various states of equilibrium. In this framework, community vulnerability to climate change and community dependence on natural resources are central to developing effective adaptation strategies. The study focuses on Community-Based Adaptation Strategies (CBASs), which emphasise local knowledge and community-led initiatives. These strategies reflect the importance of local participation in the planning and implementation processes essential for sustainable adaptation.

The study explores the role of CBASs in enhancing local capacity to promote community resilience and adaptation within the Lake Victoria Basin (LVB). It finds that these strategies significantly contribute to improving community recovery and coping mechanisms in response to climate change. Key elements of the theoretical framework include adaptability, the ability to respond to damage and capitalize on opportunities based on social and economic factors as well as access to resources and local institutions. By integrating ecological resilience theories with CBASs, this framework offers a comprehensive approach to mitigating the impacts of climate change.

Adaptive governance is a crucial aspect of this framework, encompassing flexible and inclusive decision-making processes that align with the dynamic nature of both ecological and social systems. According to Folke (2006), adaptive governance is vital for building resilience at various scales, from local communities

to broader ecological regions. From this perspective, enhancing adaptive capacity through CBASs can lead to greater ecological resilience. The study also highlights the limitations of CBASs in the absence of robust institutional support and effective political integration. Supportive institutions are essential for providing resources and knowledge, facilitating the linkage of adaptation strategies to broader development goals. Therefore, this study emphasises the interdependence between CBASs, adaptive capacity, and ecological resilience, underscoring their collective role in improving community sustainability in the face of climate change.

3. Research Methods

This study was conducted in the Lake Victoria Basin (LVB), specifically covering the districts of Bunda, Geita, Sengerema, and Bukoba (see Figure 1). The LVB spans approximately 251,000 km² and is shared by five riparian states: Tanzania, Kenya, Uganda, Rwanda, and Burundi, with Tanzania encompassing about 44% of the basin (URT, 2021). The region experiences bimodal precipitation patterns: the long rains occur from March to May, while the short rains fall from October to December (Mariki, 2015). Annual rainfall varies across the basin, ranging from 1,350 mm in the Kenyan part to 2,400 mm in the Ugandan part. The area was chosen for study due to its high vulnerability to climate change, combined with significant agricultural, pastoral, and mining activities (Urama & Ozor, 2010).

Figure 1: A Map Showing Studied Districts in LVB.

The research utilized a comprehensive mixed methods approach (MMA), integrating both qualitative and quantitative methods to provide a thorough understanding of social experiences, as endorsed by Cresswell (2012) and Uddin and Anjuman (2014). Participants for questionnaires, focus group discussions, and interviews were selected using both random and purposive sampling techniques to ensure a diverse and representative sample. The study included 708 respondents, which met the recommended sample size for each significant subgroup within the population (Alawi & Naho, 2022). The MMA approach was crucial for gaining in-depth insights into social intricacies and contexts. Qualitative data were collected using the Participatory Rural Appraisal (PRA) method, which is a community-centred approach that empowers communities to research, analyse, and take ownership of their findings. PRA enhances the reliability and validity of results through methodological triangulation (Narayanasamy, 2012; Alam & Ishan, 2012). This approach facilitates peer learning and encourages self-driven initiatives, making it particularly suitable for assessing the conditions within rural communities (Alawi & Naho, 2022). Data collection involved questionnaires, focus group discussions, and interviews.

Random sampling was employed to select 564 respondents from the four districts who completed the questionnaires. Households with assigned unique identifiers were identified using local government records. A random number generator ensured unbiased selection, giving all households an equal chance of inclusion in the study (Mills, 2011; Creswell, 2012b). The household questionnaires were directed at heads of selected households or their representatives knowledgeable about local environmental practices. This focus ensured the relevance of the data to the study objectives, particularly regarding CBASs aimed

at improving ecological resilience, observed changes following CBAS implementation, and challenges faced by agro-pastoral communities. Structured and semi-structured interviews provided detailed opinions and experiences from 16 respondents across the four districts, including environmental experts, government officials, NGO experts, and community leaders. These interviews enriched the research findings on ecological resilience (Mills, 2011; Creswell, 2012). Focus group discussions were held with 128 participants across the four districts to explore the impact of CBASs on ecological resilience. Participants were divided into 16 groups based on age and gender. The focus groups were organised according to the guideline that suggests 6 to 8 participants per group (Leitao & Vergueiro, 2000). Each group discussion lasted between one to two hours, gathering qualitative data through open expression and interactions among respondents (Charmaz, 2006). In total, the study sample comprised 708 individuals from the districts of Bunda, Geita, Sengerema, and Bukoba, as detailed in Table 1 below.

Table 1:The total sample size per data collection method

S/N	Type of Data Collection Method	Sample size per method
1	Questionnaire	564
2	Interview	16
3	Focus Group Discussion (FGD)	128
	Total sample	708

Source: Field Data, 2022

Quantitative data were also collected through experiments measuring nutrient levels in forage and soil properties. Near-infrared spectroscopy (NIRS) and High-Performance Liquid Chromatography (HPLC) were used to analyse nutrients in fodder, while soil test kits, pH meters, and environmental sensors assessed soil properties. Closed questionnaires provided additional quantitative data.

The study employed two distinct methods of data analysis. Qualitative data were analysed using thematic analysis, while quantitative data were analysed through statistical methods. For quantitative data, the analysis process included editing, coding, and summarizing data before inputting it into the Statistical Package for Social Sciences (SPSS) version 26. Experimental results related to soil properties such as pH, organic matter, nutrient concentrations, and forage nutrients were analysed descriptively. Qualitative and quantitative data were analysed separately to complement and enhance the overall findings, as guided by Raj (2017).

4. Findings and Discussions

This section presents the research findings on Community-Based Adaptation Strategies (CBASs) that enhance ecosystem resilience in the face of climate change. It also explores the ecological transformations resulting from the implementation of CBASs in the study areas.

4.1 Community-based adaptation strategies in enhancing ecological resilience

The study's findings indicate that agro-pastoral communities employ a range of Community-Based Adaptation Strategies (CBASs) to improve ecosystem resilience. These strategies include reforestation and tree planting, the use of alternative fuels for cooking (AFC), climate-smart livestock production, agroforestry technology, beekeeping, soil conservation, livestock destocking, supplementary feeds for livestock (SFL), rainwater harvesting and storage (RWHS), livelihood diversification, and weather forecasting strategies (LMWFT), as detailed in the following sections.

4.1.1 Tree planting and reforestation strategy

Figure 2 illustrates the participation of 564 individuals from the four districts in the Lake Victoria Basin. The findings reveal that a majority of participants support tree planting as a means to enhance ecosystem resilience in the region, with 59.2% favouring this strategy. Support for tree planting was notably high in Bukoba, Bunda, and Geita, with rates of 66.67%, 64.76%, and 56.19%, respectively. In Sengerema, nearly half of the respondents expressed interest in this initiative and identified various tree species suitable for

planting. These species include Moringa oleifera, Grevillea robusta, Eucalyptus spp., Jacaranda mimosifolia, Mangifera indica, Azadirachta indica, and Khaya anthotheca. These species are recognized for their ecological benefits, including carbon fixation, soil improvement, erosion prevention, and provision of various ecosystem services. For example, pine and eucalyptus trees are notable for their rapid growth and effective carbon sequestration, demonstrating high potential for reforestation projects.

These findings align with previous research by Rizvi et al. (2015), which emphasises that tree planting is crucial for climate stabilization, ecosystem regulation, biodiversity enhancement, and carbon cycling. Additionally, they support the conclusions of Bengtsson et al. (2003), who found that tree planting significantly improves water infiltration, storage, and nutrient cycling, thereby reducing soil loss and environmental degradation. Overall, the results of this study affirm that tree planting is a vital strategy for promoting ecological resilience and enhancing the sustainability of local communities.

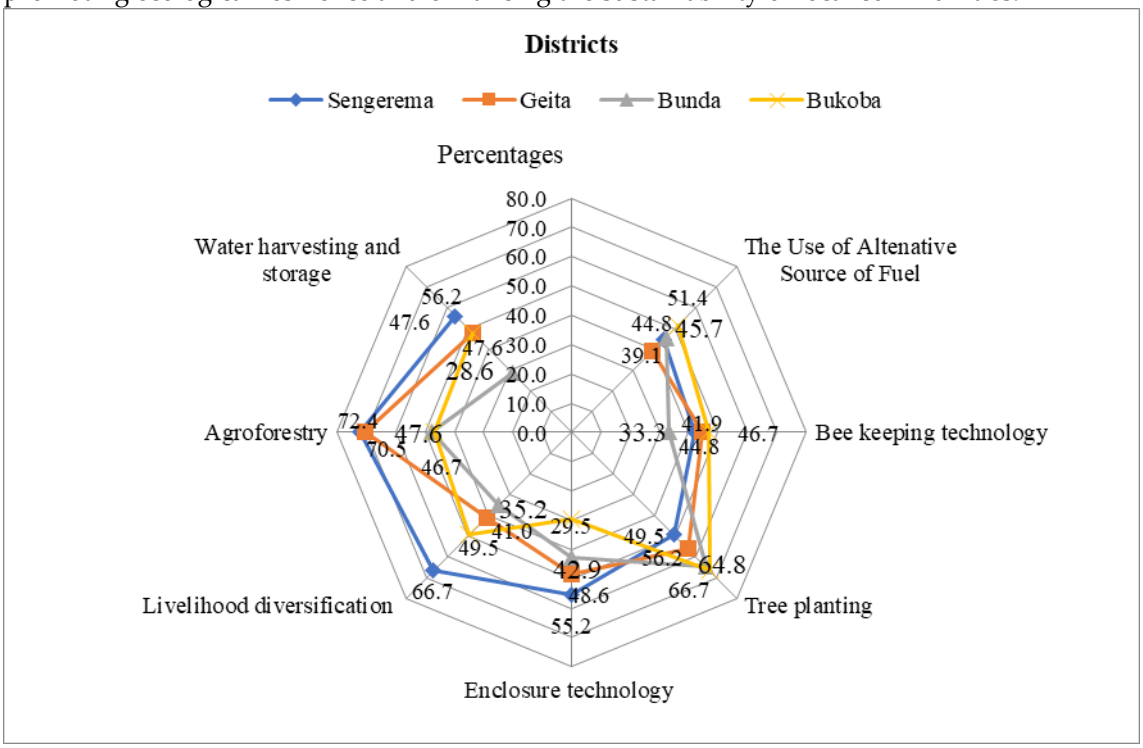

Figure 2: Agro-pastoralist Strategies in enhancing Ecosystem Resilience
Source: Field Data, 2023

4.1.2 Use of alternative fuel for cooking

The study found that introducing alternative fuel sources in Lake Victoria Basin (LVB) communities is a key Community-Based Adaptation Strategy (CBAS) aimed at enhancing ecological resilience to climate change. Analysis of data from 564 participants revealed a 45.23% success rate for this strategy, with the highest adoption rates observed in Bukoba (51%), Bunda (45.71%), and Sengerema (44.76%). In contrast, Geita had the lowest success rate at 39.05%. Participants identified several alternative fuels, including sawdust, biogas, solar cookers, fuel-efficient stoves, and paper briquettes. These alternative fuels address environmental issues associated with the traditional use of firewood and charcoal, such as deforestation and soil erosion.

Biogas not only serves as a renewable energy source but also produces nutrient-rich fertilizer, which enhances soil fertility. Similarly, both biogas and solar energy contribute to reduced greenhouse gas emissions and improved food security. Among the paper briquettes, those made from torrefied residues were preferred over sun-dried ones due to their lower smoke emissions. The density of torrefied briquettes ranged from 0.72 g/cm^3 to 0.98 g/cm^3, and their structure was more defined. Furthermore, the use of a paper binder made the briquetting process more complex; for example, carrot leaf briquettes

required five days of fermentation to achieve better compactness compared to sun-dried cabbage briquettes. Additional details on briquette compaction can be found in Figure 3.

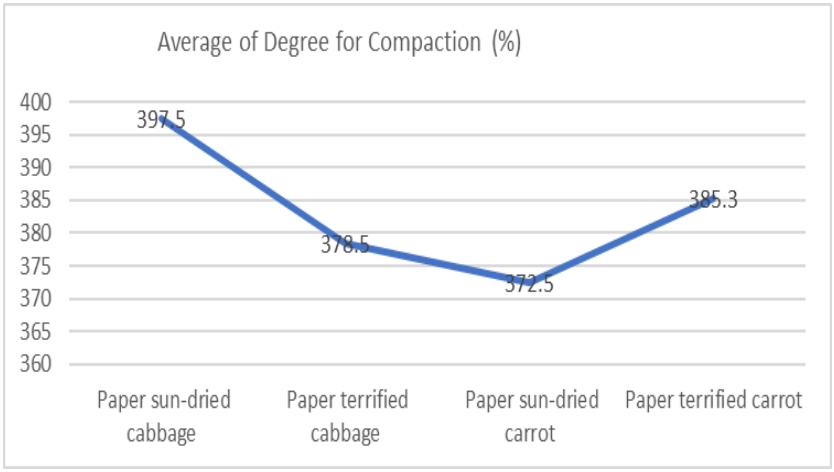

Figure 3: Degree for Compaction for Each Type of Briquettes
Source: Field Data, 2023

The study observed a shift away from firewood and charcoal among agro-pastoral communities due to associated health risks. Consequently, village leaders from Nyamuswa, Kishinda, and Nyantorotoro, located in districts such as Bunda, Sengerema, and Geita, have been encouraged to seek renewable energy sources. This transition aims to mitigate health risks, support environmental sustainability, and enhance local ecosystem resilience.

4.1.3 Application of climate-smart livestock production strategies

Key informants across all four studied districts reported the use of technology to bolster ecosystem resilience. At the farm level, climate-smart agriculture, combining various livestock systems, offers a means to reduce greenhouse gas emissions from manure and enteric sources. This approach also enhances carbon sequestration, contributing to a balanced carbon footprint.

4.1.4 Agroforestry technology

The study revealed that 59.28% of participants employ agroforestry technology to bolster ecosystem resilience against climate change, with adoption rates varying by district. The highest adoption rate was in Sengerema (72%), while Bukoba had the lowest (46.67%). Participants noted that agroforestry fosters interaction among ecological, economic, and socio-ecological systems, thereby enhancing climate change management. Interviews from Sengerema highlighted benefits such as improved nutrient cycling and integrated pest management, which bolster tree resilience and support beneficial organisms like native pollinators. Supporting literature, including Van Noordwijk (2019), underscores that agroforestry strengthens agricultural system resilience to climate change. In the Lake Victoria Basin, two primary agroforestry systems were identified: agroforestry (integration of crops and trees) and silvopastoral (combination of forestry and livestock). These methods aid climate adaptation and ecosystem resilience by mitigating tree cover loss, optimizing resource use, influencing rainfall patterns, and applying adaptive management strategies based on climate projections.

The study emphasises the multifaceted benefits of agroforestry, including reduced dependence on vulnerable crops and diversified income sources. It enhances biodiversity, supports landscape restoration, improves soil and water management, and promotes alternative livelihoods, thereby strengthening societal and ecosystem resilience. These findings align with previous research by Ulsrud et al. (2008) and Ajayi et al. (2011), which recognize agroforestry as a crucial socio-ecological system that improves ecosystem resilience and carbon sequestration. FAO (2010) assessments further validate these benefits, showing that integrating trees and shrubs into agriculture enhances food security, mitigates climate change effects, and reduces vulnerability. Smith (2010) also highlighted agroforestry's high resilience and

low risk, optimizing natural resource use. Overall, the results suggest that agroforestry is a sustainable CBAS with significant environmental and economic benefits.

4.1.5 Beekeeping (apiculture) technology

Beekeeping is another climate-friendly livelihood option adopted by the agro-pastoral communities across the four districts studied in the Lake Victoria Basin to enhance resilience against climate change effects. The study found that communities are transitioning from traditional to modern beekeeping systems (apiculture) due to their increased production of bee-related products such as honey and wax. As shown in Table 2, by the year 2022, Sengerema district had 587 beekeepers, Bukoba district had 147, and Bunda district had 89.

Table 2: Number of Bee Keepers Since 2010 up to 2022

	Number of Bee keepers			
Years	**Bunda**	**Sengerema**	**Geita**	**Bukoba**
2010	3	14	2	6
2015	10	30	6	17
2022	89	587	56	147
Mean	34	210.3	21.3	56.7
SDV	38.2	274.6	23.8	62.9

Source: Field Data, 2022

The results indicate that from 2010 to 2022, there was a significant variation in the number of beekeepers per district, with standard deviations as follows: Sengerema, 274.6; Bukoba, 62.9; Bunda, 38.2; and Geita, 23.0. This variation reflects a rapid increase in the number of beekeepers across these districts. Factors contributing to this increase include beekeeping education provided by village, district, and county officials, the economic benefits of beekeeping, climate variability, and support from non-governmental organisations (NGOs). The study found that beekeeping methods in the region enhance ecosystem resilience in several ways, such as through pollination, prevention of forest invasion, and fostering economic relationships. These impacts are detailed below:

> Pollination is a critical ecosystem service provided by bees, essential for the survival and genetic diversity of numerous plant species. Bees play a vital role in cross-pollination, which is crucial for crops such as cotton, sunflowers, potatoes, onions, and cabbage in districts like Bunda, Sengerema, Bukoba, and Geita. The study corroborates the Food and Agriculture Organisation's 2007 assertion that many plant species depend on bees for effective pollination.

Furthermore, the research highlights a complex interdependence between bees and trees in forest ecosystems. Bees are central to plant reproduction and the maintenance of forest biodiversity. They also contribute to the natural expansion of forests and help prevent illegal overexploitation of forest resources. This study underscores the significant role of beekeeping in maintaining the biological balance, diversity, and health of forest ecosystems, as well as the economic benefits it provides to local communities bordering these forests. In this context, both traditional and modern beekeeping practices are observed to coexist. Figure 4: Panel A shows modern beekeeping technology used in Bukoba, while Panel B illustrates the inclusive participation of both men and women in beekeeping activities.

Figure 4: Modern Technology of Beekeeping in Bukoba District
Source: Field Data, 2022

From an economic perspective, beekeeping is a lucrative venture for small-scale farmers, as it aligns with natural agroecological patterns and offers a sustainable source of income. It generates employment opportunities and income through the sale of bee-related products. For instance, in 2022, Sengerema district earned 317,400,000 Tanzanian shillings from honey sales, while Bunda district generated 81,090,000 Tanzanian shillings. These figures suggest that beekeeping not only provides financial benefits but also helps reduce the pressure to clear vegetation for agricultural purposes.

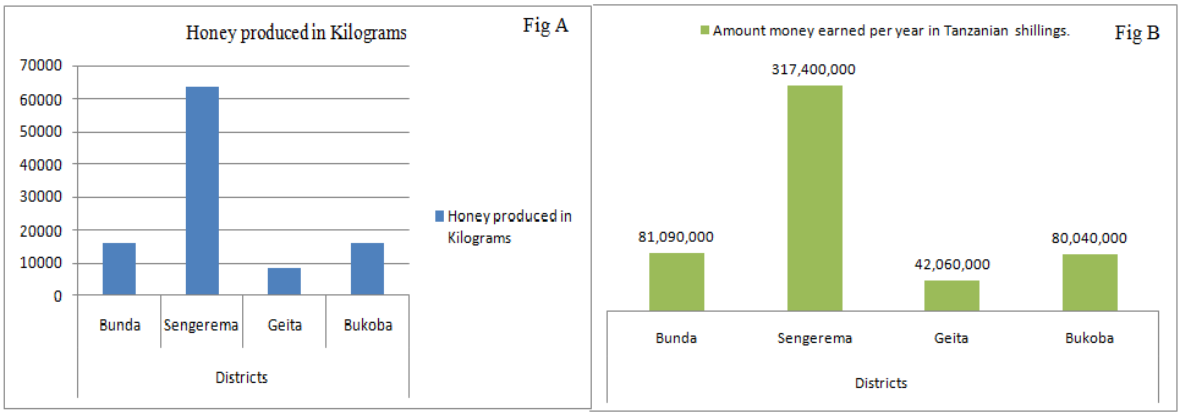

Figure 5: The Amount of Honey produced in each District in Figure "A" and the income gained in Figure "B" in year 2022.
Source: Feld Data, 2022

4.1.6 Soil conservation strategy

Another Community-Based Adaptation Strategy (CBAS) reported by study participants is soil conservation. This strategy, revealed through discussions and responses from participants in the studied districts, includes cover cropping, terracing, and contour farming. These practices are crucial for ecosystem adaptability and soil health. Contour farming effectively reduces soil erosion, while diverse planting systems enhance soil stability and increase organic matter. Intercropping cereals with legumes not only promote agroecosystem diversity but also improves resilience to environmental challenges and enhances soil health through better nutrient cycling. The results indicate that these strategies significantly bolster ecological resilience, consistent with previous research, including Lema and Majule (2009) on Tanzanian farmers' soil management techniques. Similarly, Mendelsohn et al. (2000) and Nyong et al. (2007) emphasise the effectiveness of practices such as zero tillage, mulching, and contour farming in conserving soil carbon and promoting agricultural sustainability.

4.1.7 Destocking of large livestock and adoption of small ruminants

The study found that livestock destocking is a key CBAS used to enhance ecosystem resilience in response to climate change. This strategy reduces grazing pressure and improves vegetation and soil health. In Bunda district, many cattle and donkeys were sold, leading to more sustainable herd sizes, with households averaging nine cattle, down from over 100 in some cases. In contrast, Bukoba district averaged six cattle per household, while Sengerema averaged twelve. This data underscores a shift toward sustainable livestock management in response to environmental issues. The study highlights the environmental benefits of raising smaller livestock, such as goats, sheep, pigs, and chickens, over larger animals like cows and donkeys. This transition helps reduce greenhouse gas emissions, protect ecological systems, enhance farming diversity, and promote various agricultural practices. Key benefits include improved nutrient recycling, pest control, and soil quality, supporting the sustainability of the pastoral industry and encouraging ecologically responsible agriculture. Overall, the findings suggest that transitioning to smaller livestock can significantly contribute to a more sustainable agricultural landscape.

4.1.8 The use of supplementary feeds for livestock

The study revealed that a variety of livestock feed supplements (see Table 3) are used to enhance ecosystem resilience as part of the CBAS. These include energy-rich concentrates such as corn bran, wheat bran, and cottonseed cake, which are commonly used for cattle, sheep, goats, and donkeys, along with feeds like elephant grass, Napier grass, and sweet potato vines. These supplements improve ecosystem resilience and livestock health by boosting the immune system and reducing disease susceptibility. The analysis shows that hay from natural pastures has the highest metabolizable energy (ME) at 11.02 MJ/kg, followed by molasses-treated Napier grass silage at 10.3 MJ/kg. Despite its high crude protein content of 21.5%, star grass has the lowest ME at 8.34 MJ/kg, while corn has the lowest crude protein content at 9.24%. Natural mixed pastures have the highest digestibility at 65.01%, with molasses-treated Napier grass silage slightly better at 66.01%. Star grass hay has the lowest digestibility at 53.1%.

These findings highlight the critical role of supplementary feed in strengthening the resilience of pastoral communities, as supported by Joseph (2016). Various feed types, including maize bran, hay, sunflower seed cake, and cottonseed cake, are discussed with a focus on regional production in Tanzania and seasonal price fluctuations. The results corroborate previous studies, such as DelCurto (2000), which found that alfalfa hay significantly increased weight gain in cattle. Wambugu et al. (2011) identified Calliandra calothyrsus as a cost-effective protein source for livestock, and Maleko et al. (2018) demonstrated that dairy feed improves livestock health and reduces dependence on natural resources. Overall, livestock supplementary nutrition enhances health, reduces overgrazing, and promotes ecological balance, underscoring its vital role in alleviating pressure on natural resources and supporting sustainability.

Table 3: Nutrients of Forages Consumed by Livestock in the Study Area

Nutrient	Preserved pasture species (silage and hay)						
	Silage					Hay	
	Maize + BSG	Maize + molasses	Maize alone	Napier alone	Napier + molasses	Star grass alone	Mixed natural pastures
Protein %	16.1	10.3	9.24	13.8	15.1	21.5	15.9
Sugar %	0.6	<0.60	<0.51	1.92	3.7	3.34	1.1
Starch %	<0.11	<0.11	16.1	<0.11	<0.11	<0.11	5.39
Fiber %	23.5	27.9	20.1	27.9	23.1	20.9	21.1
Oil %	4.33	3.3	3.3	6.1	5.28	3.29	5.5
Ash %	6.11	6.12	6.01	11.91	11.01	9.1	6.92
Energy (MJ/kg)	10.01	8.6	9.6	9.7	10.3	8.34	11.02
NDF in %	55.9	64.01	49.1	56.5	46.9	49.6	51.5
ADF %	27.8	34	25.7	39.92	34.3	33.2	27.1
Digestibility%	60.8	55.8	62.1	57.98	63.01	53.1	65.1
Dry Matter	23.01	19.3	31.8	14.01	26.01	13.8	27.4

Source: Field Data, 2022

4.1.9 Rainwater harvesting and storage

The study conducted in Bunda, Geita, Sengerema, and Bukoba examined how agropastoral communities enhance ecosystem resilience through rainwater harvesting (RWH) and water storage (WSS) strategies. Notably, 45% of participants considered these strategies essential, with the highest adoption in Sengerema (56.19%), followed by Geita and Bukoba (47.62%), and the lowest in Bunda (28%). Three primary methods of water harvesting were identified: rainwater harvesting using systems such as gutters and tanks; surface water retention through small dams; and groundwater recharge via recharge wells. Focus Group Discussions (FGDs) revealed that these practices reduce soil erosion, maintain soil quality, promote irrigation during droughts, enhance vegetation, control flooding, and provide water for livestock. In Bunda District, various water management structures, such as charcoal dams and immersion wells, were noted for their role in improving soil quality.

The study highlights the benefits of RWHS for irrigation, agricultural productivity, food security, and livestock production. Soil conservation measures improve ecosystem resilience by preventing erosion and soil fertility loss. This supports Zhu et al. (2004), who advocate for integrating RWH into water management systems in both rural and urban areas. RWH alleviates water shortages, reduces pressure on traditional sources, mitigates non-point source pollution, controls waterlogging, and prevents flooding. Additionally, it addresses climate change impacts and enhances stormwater management, underscoring its multiple benefits for sustainable water resource management. Overall, implementing water management strategies is crucial for promoting sustainability in agropastoral communities.

4.1.10 Promoting diversified livelihoods among agropastoral communities

The promotion of diversified livelihoods among agropastoral communities in the Lake Victoria Basin has increased resilience by reducing overdependence on natural resources. Sustainable land-use practices are essential for maintaining ecosystem health and supporting local biodiversity. Examples of this shift include the involvement of youth in motorcycle taxi services, known locally as boda-boda, and the engagement of the elderly in beekeeping. A discussant in Geita remarked, "These processes diversify income and enhance vital ecosystem functions like carbon sequestration, water filtration, and pollination" (Anonymous, Geita District, 11th June 2022). Additionally, diversifying income sources helps mitigate the impact of weather extremes and supports environmental sustainability and ecological resilience. Overall, these initiatives contribute to enhancing the region's economic benefits through improved environmental stewardship.

4.1.11 Utilization of local and modern weather forecasting strategies

The study explored various traditional weather prediction methods used by agropastoral communities in the Lake Victoria Basin (LVB). These methods, rooted in Indigenous Knowledge Systems (IKS), involve observing natural indicators such as animal behaviour, cloud formations, and plant responses to provide valuable insights for local agriculture. For instance, the fruit yield of the mvule tree signals favourable rainfall, while the wild olive tree indicates the start of the rainy season. Stunted growth in aloe vera suggests drought conditions, and Indigenous grasses are monitored for growth and pigmentation. The study also highlights community-based rainfall monitoring (CbRM), where residents record and share rainfall data to enhance local weather forecasting. The use of technology, including mobile apps and SMS services, further improves the dissemination of weather information, providing timely updates and alerts based on nearby weather station data. A key informant in Nyamuswa Village noted, "Short Message Service (SMS) services provide weather updates and alerts to their subscribers" (Anonymous, Bunda District, 16th May 2022).

4.3 Impacts of community-based adaptation strategies on ecological adjustments

Assessing ecological changes in the LVB reveals significant impacts from the community-based agricultural strategies adopted by agropastoral communities. The study identifies several ecological improvements resulting from these strategies, particularly in soil health and fertility. The findings indicate that adopting sustainable agricultural practices, such as compost application and crop rotation, has markedly improved soil quality. This has not only enhanced agricultural productivity but also reduced

land degradation in the studied districts: Bunda, Sengerema, Geita, and Bukoba. Table 4 presents data on soil health and fertility trends before and after the implementation of these community-led strategies. Overall, the results support the effectiveness of CBAS in promoting sustainable agriculture while improving soil quality in the region.

Table 4: State of soil health and fertility before and after application of CBS

Soil Properties	Bunda District		Sengerema District		Geita District		Bukoba District	
	Before CBASs	After CBASs	Before CBASs	After CBASs	Before CBASs	After CBASs	Before CBASs	After CBASs
Soil pH	5.7	6.0	6.0	6.2	5.5	5.8	6.2	6.3
Organic Matter (%)	2.8	4.0	3.5	4.5	2.3	3.0	3.8	4.2
Nitrogen (N, ppm)	15	22	18	20	12	14	20	23
Phosphorus (P, ppm)	8	12	10	11	7	9	11	13
Potassium (K, ppm)	70	75	80	85	60	70	90	95
Cation Exchange Capacity (CEC)	12	14	14	15	10	12	16	17

Source: Field Data: 2022

The introduction of Community-Based Adaptation Strategies (CBAS) in four districts has significantly enhanced soil health and fertility. Results indicate notable improvements, including increased soil stability, compactness, and pH levels; higher organic matter content, which boosts soil fertility and microbial activity; and improved levels of essential nutrients such as nitrogen, phosphorus, and potassium. Additionally, there has been an increase in cation exchange capacity, which enhances nutrient retention. These changes highlight the positive impact of CBAS on soil quality, which likely translates into enhanced agricultural productivity and ecosystem protection.

The study also underscores the environmental benefits of CBAS, particularly in terms of reforestation and biodiversity conservation. The initiatives have facilitated forest restoration and the protection of critical ecosystems. Increased forest cover contributes to carbon sequestration and supports biodiversity, including endangered species. A notable example of successful collaboration is the partnership between the Tanzania Forest Services Agency and local communities. This partnership has led to the planting of 5,100,000 seedlings across 4,591 hectares in the Geita region, thereby increasing tree biodiversity and improving ecosystem resilience (see Figure 6).

Figure 6: Reforestation in Geita Region which has Changed the Landscape
Source: Field Data, 2022

In this context, Community-Based Adaptation Strategies (CBAS) within the Lake Victoria Basin have led to positive ecological changes, including improved soil health, reforestation, enhanced water management, and wetland conservation. These advancements highlight the potential of CBAS to enhance ecological flexibility in the face of climate change. However, it is crucial to continue monitoring these changes and address any unintended ecological impacts to ensure the long-term sustainability of these practices.

5. Implications of this Study's Findings

The findings of this study are highly significant for both policy development and implementation, as they illuminate the roles played by various stakeholders, including government agencies, academic institutions, scientists, rural and agricultural communities, non-governmental organisations (NGOs), and community-based agencies (CBAs). This study's primary contribution lies in its ability to inform the creation of tailored policies that integrate community-driven adaptation strategies within broader national and local climate action plans. A key component for the success of any policy intervention is the empowerment of local communities. The findings communicate the urgent need to strengthening institutional support for the purpose of enhancing the resilience of agro-pastoral communities against the imminent threats posed by climate change. Strengthening local governance frameworks, encouraging NGO involvement, and improving extension services are crucial for effective capacity-building. These community-focused adaptation strategies may serve as models for other regions facing similar climate-related challenges, potentially fostering ecological resilience on a larger scale and guiding efforts towards a sustainable future. The study exemplifies how integrating traditional knowledge with modern scientific technology can stimulate adaptive livelihoods and reduce vulnerability to climate change.

Moreover, the study highlights the necessity of strategic resource allocation towards community-based adaptation initiatives. Such initiatives should include essential components like early warning systems, sustainable agricultural practices, and infrastructure development. By advancing ecological resilience through these community-driven approaches, the study illustrates the complex relationships between climate resilience, sustainable livelihoods, and the Sustainable Development Goals (SDGs) such as Climate Action (SDG 13), Life on Land (SDG 15), and Zero Hunger (SDG 2). The interconnected nature of these elements implies that progress in one area can positively impact others, thereby paving the way for a more resilient and synergistic future.

6. Conclusion and Recommendations

The research underscores the importance of community-driven adaptation strategies in increasing ecosystem resilience to climate change within the Lake Victoria Basin of Tanzania. Through participatory approaches, these communities have demonstrated their ability to innovate and adapt using traditional methodologies and local resources, achieving beneficial outcomes for both ecosystem health and community well-being. Key findings reveal that CBAS encompass a range of sustainable practices, including tree planting, reforestation, alternative cooking fuels, agroforestry, beekeeping, soil conservation, livestock management, rainwater harvesting, and drip irrigation. These strategies contribute to water security, sustainable agriculture, and biodiversity conservation. The research highlights the need to harness and support such local initiatives, emphasising the importance of an integrative approach that considers both environmental and socio-economic dimensions. Community-based adaptation strategies are therefore crucial for fostering collaboration among stakeholders and empowering vulnerable populations to build resilience in the face of ongoing climate challenges. The findings in this study offer valuable insights for enhancing community-based adaptation in the Lake Victoria Basin, Tanzania. They emphasise the necessity of significant investments in capacity building and knowledge sharing with local communities to enable the effective implementation of appropriate adaptation measures. Therefore, it is recommended that:

(i) The stated strategies in this study should be integrated into national and regional policies-making processes to ensure alignment with recommendations and to secure access to necessary resources.

(ii) Strengthening local governance is also vital to fostering collaborative partnerships between government agencies, NGOs, and grassroots organisations, and to leveraging successful subnational initiatives to develop broader regional models.

(iii) An inclusive approach that incorporates indigenous knowledge and promotes gender equality is essential for strengthening climate resilience. Furthermore, a diverse set of strategies should be considered for agro-pastoral communities to enhance ecosystem resilience, including reforestation, alternative energy sources, climate-friendly livestock farming, agroforestry, beekeeping, soil protection, and rainwater harvesting.

(iv) Finally, establishing a comprehensive climate adaptation policy framework is crucial for integrating these measures effectively and improving both environmental resilience and community sustainability.

References

Ajayi, C. O. Place, F.; Akinnifesi, F. K. & Sileshi, G. W. (2011). Agricultural success from Africa: the case of fertilizer tree systems in southern Africa Malawi, Tanzania, Mozambique, Zambia and Zimbabwe. *International Journal of Agricultural Sustainability,* 9(1), 126-136.

Alam, A. & Ishan, S. (2012). Role of participatory rural appraisal in community development: a case study of Barani area development project in agriculture, livestock and forestry development in Kohat *International Journal of Academic Research in Business and Social Sciences*. 2 (8), 25-38.

Alawi, S. M. & Naho, N. A. (2022). Perceptions of educational stakeholders on the introduction of entrepreneurship subjects at secondary schools in Zanzibar. https://doi.org/10.56556/jssms.v1i3.107

Bengtsson, J., Angelstam, P. & Elmqvist, T. (2003). Reserves, resilience and dynamic landscapes. *Ambio*, 32, 389-396

Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative analysis*. Sage Publications Inc.

Creswell, J. (2012). *Educational research*. Pearson Education Inc

DelCurto, T., Hess, B. W., Huston, J. E. & Olson, K. C. (2000). Optimum supplementation strategies for beef cattle consuming low-quality roughages. *Journal of Animal Science,* 77, 1–16.

Food and Agriculture Organization of the United Nations. (2010). *Climate-smart agriculture policies: Practices and financing for food security, adaptation, and mitigation*. The Hague Conference on Agriculture, Food Security, and Climate Change.

Folke, C. (2006). Resilience: the emergence of a perspective for social-ecological systems analyses. *Global Environmental Change*, 16, 253-267. http://dx.doi.org/10.1016/j.gloenvcha.2006.04.002

Holling, C. S. (1973) Resilience and stability in ecological systems. *Annual Review of Ecology and Systematics,* 4, 1-23. http://dx.doi.org/10.1146/annurev.es.04.110173.000245

Joseph, L. (2016). Pastoralists' resilience and adaptation to the impact of climate change in Semi-Arid Rangelands: A case of Longido District, Tanzania. Unpublished doctoral thesis, University of Dodoma

Joseph, L. (2022). The liability of climate change on constraining women's rights in the Southern Highlands, Tanzania: A case of Kilolo District. *East African Journal of Environment and Natural Resources*, 5(1), 58-74. https://doi.org/10.37284/eajenr.5.1.577

Kapitza, S., Van Ha, P., & Kompas, T. (2021). Assessing biophysical and socio-economic impacts of climate change on regional avian biodiversity. *Scientific Reports, 11*(1), 3304. https://doi.org/10.1038/s41598-021-82474-z

Kijazi, A., Chang'a, L., Luhunga, P., Ng'ongolo, H., Merchades, M. & Levira, P. (2019). The contribution of the global framework for climate services adaptation programme in Africa (GFCS APA) in National Adaptation Plan (NAP) Process for Tanzania. *Atmospheric Climate Science*, 9, 650–661. doi: 10.4236/acs.2019.94040

Leitao, B. J. & Vergueiro, W. (2000). 'Using the focus group approach for evaluating customers' opinions: the experience of a Brazilian academic library. *New Library World*, 101 (2), 60-65.

Lema, M. A. & Majule, A. E. (2009). Impacts of climate change, variability and adaptation strategies on agriculture in semi-arid areas of Tanzania: The case of Manyoni District in Singida Region, Tanzania. *African Journal of Environmental Science and Technology*. 3 (8), 206-218

Maleko, D., Msalya, G., Mwilawa, A., Pasape, L. & Mtei, K. (2018). Smallholder dairy cattle feeding Strategies and practices in Tanzania: failures, successes, challenges and prospects for sustainability. *International Journal of Agricultural Sustainability,* 16(2), 201-213.

Mariki, S. (2015). Conservation with a human face? Comparing local participation and benefit sharing from a national park and a state forest plantation in Tanzania. https://doi.org/10.1177/2158244013512665

Mendelsohn, R., Dinar, A. & Dalfelt. A. (2000). *Climate change impacts on African agriculture: Preliminary analysis prepared for the World Bank*. District of Columbia.

Mills, G. (2011). *Action research: a guide for teachers' researcher* (4th edition). Pearson Inc.

Narayanasamy, N. (2012). Participatory rural appraisal: principles, methods and application; SAGE Publications; DOI: https://doi.org/10.4135/9788132108382

Nyong, A., Adesina, F. & Elasha, O. (2007). The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel. *Mitigation and Adaptation Strategies for Global Change*, 12, 787-797.

Ogega, O. M., Scoccimarro, E., & Misiani, H. (2023). Extreme climatic events to intensify over the Lake Victoria Basin under global warming. *Scientific Reports, 13*, 9729. https://doi.org/10.1038/s41598-023-36756-3

Raj, B. (2017). An investigation into the barriers associated with the use of smart classroom technology in middle schools. Unpublished. doctoral thesis, Tamil University.

Rizvi, A. R., Baig, S., Barrow, E. & Kumar, C. (2015). Synergies between climate mitigation and adaptation in forest landscape restoration. IUCN.

Smith, J. (2010). Agroforestry: reconciling production with protection of the environment. a synopsis of research literature. *Organic Research Centre*, 1- 24.

Uddin, M. & Anjuman, N. (2014). Participatory rural appraisal approaches: An overview and an exemplary application of focus group discussion in climate change adaptation and mitigation strategies. https://doi.org/10.3329/ijarit.v3i2.17848

Ulsrud, K., Sygna, L. & O`Brien, K. (2008). *More than rain: identifying sustainable pathways for climate adaptation and poverty reduction*. Development Fund.

United Republic of Tanzania (2021). *National Climate Change Response Strategy (2021-2026).* Vice President's Office, Division of Environment.

Urama, K. C., & Ozor, N. (2010). Impacts of climate change on water resources in Africa: the role of adaptation. *Climate Adaptation*, 1,1-29. https://pdfs.semanticscholar.org/2eac/cdb9c3b59556f2b39bd549482a773010fc8f.pdf.

van Noordwijk, M, Coe, R., Sinclair F. L., Luedeling, E., Bayala J., Muthuri, C. W., Cooper, P., Kindt, R., Duguma, L. A., Lamanna, C. & Minang, P. A. (2021). Climate change adaptation in and through agroforestry: Four decades of research initiated by Peter Huxley. *Mitigation and Adaptation Strategies for Global Change*, 26, 1-18. https://doi.org/10.1007/s11027-021-09954-5

Wambugu, C., Place, F. & Franzel, S. (2011). Research, development and scaling-up the adoption of fodder shrub innovations in East Africa. *International Journal of Agricultural Sustainability*, 9(1), 100-109.

Zhu, K., Zhang L., Hart W., Liu M. & Chen, H. (2004). Quality issues in harvested rainwater in arid and semi-arid Loess Plateau of northern China *Journal of Arid Environments*, 57(4), 487–505.