ADAPTATION FINANCE MECHANISMS AND CLIMATE RESILIENCE: A CASE OF TOCHI IRRIGATION COOPERATIVE SOCIETY IN OYAM DISTRICT

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DECLARATION

I Ojok Michael hereby do declare that this dissertation titled "Adaptation Finance Mechanisms and Climate Resilience: A Case of Tochi Irrigation Cooperative Society In Oyam District," is my original work and has never been presented for any academic award in any university or institution.

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APPROVAL

We hereby approve that this dissertation entitled "Adaptation finance mechanisms and climate resilience: A case of Tochi irrigation cooperative society in Oyam district, has been written under our guidance and supervision.

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DEDICATION

This dissertation is dedicated to my beloved mother (Anna Ajwang) and my aunt (Joyce Freda Apio). Your unconditional love, patience, and support have been the foundation of my academic journey. I share this achievement with you both. Thank you.

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LIST OF ABBREVIATION AND ACRONYMS

AC	Adaptation Committee
AF	Adaptation Fund
AFMs	Adaptation Finance Mechanisms
CERs	certified emission reductions
CG	Cooperative governance
GEF	Global Environment Facility
NAP	National Adaptation Plan
PPCR	Pilot Project for Climate Resilience
PPP	Public-Private Partnership
R & D	Research and Development
TICS	Tochi Irrigation Cooperative Society
UNFCCC	United Nations Framework Convention on Climate Change

ABSTRACT

This study examined the influence of adaptation finance mechanisms on climate resilience at Tochi Irrigation Cooperative Society in Oyam District, Uganda. Specifically, it identified adaptation finance mechanisms accessible to cooperative members, assessed climate-related risks, established the relationship between adaptation finance mechanisms and climate-related risks, and determined the moderating influence of cooperative governance on these relationships. The study was guided by Resilience Theory and adopted a mixed-methods approach incorporating a correlational research design. Quantitative data were collected using questionnaires, while qualitative data were obtained through key informant interviews. The dissertation reports 92 respondents in the abstract, and quantitative data were analysed using the Statistical Package for the Social Sciences (SPSS).

The findings indicated that infrastructure development and public–private partnerships (PPPs) were the principal adaptation finance mechanisms examined. Skilled extension services (68.4%), water reservoirs (67.1%) and access roads (64.6%) were among the most frequently reported infrastructure components. Within PPP arrangements, shared proceeds (62.0%), collaborative policy formulation (59.5%) and resource sharing (58.2%) were prominent, while technology transfer and joint investment-related arrangements remained areas requiring improvement. Regarding climate-related risks, respondents reported substantial concerns about increased agricultural input costs (mean = 4.22), inadequate access to machinery (mean = 4.20) and delayed planting (mean = 4.10). Correlation findings demonstrated significant negative associations between adaptation finance indicators and climate-related risks. Road infrastructure, for example, recorded a correlation of (r=-0.70) with production risks, while shared proceeds under PPP arrangements recorded a correlation of (r=-0.66) with the relevant climate-risk indicator. The moderation analysis further established statistically significant interaction effects between adaptation finance mechanisms and cooperative governance for production risks ((B=-0.22, p=0.018)), flood risks ((B=-0.18, p=0.027)) and livelihood risks ((B=-0.19, p=0.021)). These results indicate that cooperative governance significantly moderates the relationships between adaptation finance mechanisms and the three climate-risk outcomes. The study concludes that infrastructure investments and PPP arrangements are important correlates of climate resilience at Tochi Irrigation Cooperative Society, while cooperative governance plays a significant moderating role. It recommends strengthening climate-resilient infrastructure, improving transparency and accountability within the cooperative, expanding inclusive PPP arrangements, increasing access to appropriate agricultural technologies and promoting gender-responsive adaptation finance. Further research should examine the longer-term effects of adaptation finance mechanisms and compare outcomes across irrigation schemes.

CHAPTER ONE

INTRODUCTION AND BACKGROUND

1.0 Introduction

The researcher explored the influence of adaptation finance mechanisms on climate resilience at Tochi Irrigation Cooperative Society in Oyam District. This chapter is presented under the following sections: introduction, background to the study, problem statement, objectives of the study, general objective, specific objectives, research questions, significance of the study, conceptual framework.

1.1 Background to the Study

To begin with climate change refers to shifts in the mean state of the climate or in its variability, persisting for an extended period (decades or longer). Climate change may be due to natural changes or to persistent anthropogenic changes in the composition of the atmosphere or in land use (USAID 2007). The world is already experiencing changes in average temperature, shifts in the seasons, an increasing frequency of extreme weather events, and slow onset events. The faster the climate changes and the longer adaptation efforts are put off, the more difficult and expensive responding to climate change will be to actual or expected climatic stimuli and their effects. Climate change adaptation refers to changes in processes, practices and structures to moderate potential damages or to benefit from opportunities associated with climate change. In simple terms, countries and communities need to develop adaptation solutions and implement actions to respond to current and future climate change impacts.

The United Nations Framework Convention on Climate Change (UNFCCC) defined climate finance as local, national or transnational support from public, private and alternative sources of financing to support mitigation and adaptation actions (Hyman 2022). Developed-country Parties to the United Nations Framework Convention on Climate Change (UNFCCC) have committed to mobilizing US$100 billion annually by 2020 to support climate action in developing countries (UN 2009). Some estimates of finance with climate objectives committed to developing countries globally suggest it increased from US$58.6 billion in 2016 to reach US$71.2 billion in 2017, but that this growth slowed to total US$78.9 billion in 2018 (OECD, 2020). These funding flows, especially as they relate to adaptation, are recognized as a key dimension of climate justice (Khan et al., 2020). This is because many

developing countries, including African countries, have contributed among the least to historical greenhouse gas emissions responsible for anthropogenic climate change yet face many of the most severe risks (International Monetary Fund 2020)

African nations 33 of which are classified as Least Developed Countries (LDCs)(UNCTAD, n.d.) have been recognized as 'particularly vulnerable to the adverse effects of climate change' in the UNFCCC context since 2007 (UNFCCC, 2007). Globally, many African countries are among the most sensitive to the impacts of climate change on food security, health, economies and ecosystems Without inclusive development and targeted adaptation measures, climate change is projected to push tens of millions more Africans into extreme poverty by 2030 (Hallegatte et al., 2016). Compounding this vulnerability is that many African countries have limited financial capacity to instigate adaptation (United Nations, 1992). While African countries (including farmers, businesses and households) are already investing in adaptation, the magnitude of the projected climate impacts far outweighs existing capacity to adapt (Schaeffer et al., 2015). Failure to adapt will, in turn, propel a negative feedback cycle that undermines development and magnifies climate risks (Niang et al., 2014). The World Bank estimates that, globally, sub-Saharan Africa will bear the highest adaptation costs per unit of gross domestic product (0.6-0.7% of GDP), owing to lower GDPs but also to higher costs of adaptation for water resources, due to changes in precipitation patterns (World Bank, 2010). This inequity in the vulnerability of African countries to climate impacts, despite their relatively low contribution to the root causes of climate change, highlights a systemic injustice that finance for climate change adaptation aims to address (Savvidou et al. 2021).

Climate change presents a significant challenge to agricultural production, food security and rural livelihoods, particularly among communities whose economic activities depend heavily on rainfall, water availability and natural resources. Changes in rainfall patterns, rising temperatures and the occurrence of extreme weather events can disrupt agricultural production, damage infrastructure and undermine household income. The Intergovernmental Panel on Climate Change (IPCC, 2022) emphasises that climate risks arise from the interaction of climatic hazards with exposure and vulnerability, while adaptive capacity influences the ability of communities to manage adverse impacts.

Climate change adaptation therefore requires investments and institutional arrangements that enable communities to anticipate, manage and recover from climate-related shocks and

stresses. Adaptation finance is important in this process because it supports the mobilisation and allocation of resources for interventions that reduce vulnerability and strengthen resilience. The United Nations Framework Convention on Climate Change (UNFCCC, 2019) identifies adaptation finance as an important area for mobilising public, private and other sources of funding to support climate action. However, the availability of finance alone does not guarantee resilience; resources must be accessible, appropriately allocated and effectively used to address the specific risks faced by vulnerable communities.

Infrastructure constitutes one of the principal mechanisms through which adaptation finance can support agricultural resilience. Irrigation canals, reservoirs, dams, drainage systems, access roads, storage facilities and agricultural equipment can help farmers manage water availability, reduce production disruptions and maintain access to markets during periods of climatic stress. Agricultural extension services and information systems also support adaptation by providing farmers with technical knowledge and information needed to respond to changing climatic conditions. The effectiveness of these investments depends on their suitability, accessibility, maintenance and integration into local agricultural systems.

Public–private partnerships (PPPs) provide another potential mechanism for mobilising resources and supporting climate adaptation. Through collaboration among government institutions, private-sector actors, cooperatives and other stakeholders, PPP arrangements can facilitate the sharing of financial resources, labour, technology, expertise and risks. Such arrangements can help address resource constraints that individual farmers or public institutions may be unable to overcome independently. Nevertheless, partnerships may deliver limited benefits where financing arrangements are inadequate, responsibilities are unclear, technology transfer is weak or farmers have limited influence over decisions affecting their livelihoods.

Climate resilience in agricultural communities extends beyond the availability of infrastructure and financial resources. It also concerns farmers' capacity to maintain agricultural production, manage flood-related disruptions and sustain their livelihoods when exposed to climatic shocks. Production risks may include increased input costs, delayed planting, reduced yields, limited access to machinery and crop failure. Flood risks may involve waterlogging, damage to agricultural infrastructure, disruption of transport and displacement of farming activities. Livelihood risks may arise through declining household income, financial distress, food insecurity and reduced employment opportunities. These

interconnected risks demonstrate the importance of examining climate resilience across agricultural production, flood management and household livelihoods.

Cooperative governance may influence the extent to which adaptation finance mechanisms contribute to resilience. Norris et al. (2008) identify economic resources, social capital, information and communication, and community competence as important resources associated with community resilience. Similarly, Ostrom (1990) demonstrates the importance of collective organisation and self-governance in managing shared resources. Within an irrigation cooperative, participation in decision-making, accountability, transparent reporting, effective communication and information sharing can support the coordination and use of adaptation resources. Conversely, weak governance may limit members' access to resources, undermine collective decisions and reduce the effectiveness of infrastructure investments and partnerships.

In Uganda, irrigation development provides an important opportunity to strengthen agricultural production and reduce dependence on rainfall. However, the benefits of irrigation infrastructure and associated adaptation initiatives depend on the availability of complementary resources, effective management and the capacity of farmers to respond to climate-related risks. Irrigation schemes must therefore be examined not only in terms of the infrastructure and financial arrangements available to farmers but also in terms of how these resources interact with cooperative institutions and local vulnerability.

Tochi Irrigation Cooperative Society in Oyam District provides a relevant setting for examining these relationships. The study identifies infrastructure development and PPP arrangements as the principal adaptation finance mechanisms under investigation. Its findings indicate that skilled extension services, water reservoirs and access roads were among the most frequently reported infrastructure components, while shared proceeds and collaborative policy formulation were prominent PPP arrangements. At the same time, the findings identify continuing concerns relating to agricultural input costs, access to machinery, delayed planting and other climate-related risks. These results suggest the need to examine not only which adaptation finance mechanisms are accessible to cooperative members but also how they relate to production, flood and livelihood risks.

In Uganda, climate change adaptation has been scaled down or decentralized to the community level in which a number of climate change adaptation projects are being implemented. Notable climate change adaptation measure has been the establishment of

irrigation schemes across the country to facilitate the adaptation of farmers to the impact of climate change. Through the "Farm Income Enhancement and Forest Conservation Programme: Project -2 (FIEFOC – 2)," funded through loan from the African Development Bank five irrigation schemes have been established in the districts of Oyam, Nebbi, Butaleja, Kween, and Kasese (AfDB 2015). The project seeks to contribute to improvement of farm incomes, rural livelihoods, food security and climate resilience, sustainable natural resources management and agricultural enterprise development. However, in this proposed study, the researcher intends to consider Tochi Irrigation Cooperative Society in Oyam District, with the study population being rice farmers in the Tochi Irrigation Cooperative Society. It should be noted that Tochi Irrigation Cooperative Society is a component of Tochi Irrigation project. The researcher believes the objectives of Tochi irrigation Scheme perfectly align with the proposed study, thus the researcher will examine the influence of adaptation finance mechanisms on climate resilience at the Tochi Irrigation Cooperative Society in Oyam District.

1.2 Problem Statement

Handmer et al. (1999) posited that poorer regions and countries will have difficulty in adapting to climate change, since they lack the wherewithal, that is technical and financial. It has long been recognised that assistance will be provided to the most vulnerable countries to help meet the costs of adaptation. Climate finance is predominantly provided by five donors: Germany, Denmark, EU institutions (excluding the European Investment Bank), the United Kingdom (UK) and the African Development Bank (AfDB), providing around 15%, 11% (Denmark, EU institutions and the UK) and 10% of all climate-related finance flows over the period, respectively (Partners for Resilience 2020). The 2022 report of the UNFCCC Standing Committee on Finance recognizes that climate finance flows will be insufficient to address the climate crisis(Murphy 2023). It calls for consideration of climate finance including adaptation finance within the context of broader finance flows for development objectives and alignment with national development plans (UNFCCC Standing Committee on Finance, 2022).

Funding worth shillings 42 billion from the African Development Bank (AfDB) was used to construct Tochi Irrigation Scheme in Oyam District. The irrigation scheme is intended to enhance the climate adaptive capacity of rice growers, improve their incomes and promote environmental conservation in the area. However, beneficiary farmers of the project are still

grappling with adaptation to climatic changes. For instance in 2021 farmers in the Tochi Irrigation Scheme suffered a setback after floods submerged some of their rice fields in the irrigation scheme following heavy rains in the River Tochi catchment areas (AfDB 2021). Additionally, they also raised technical glitches related absence of access road between farm fields, silting up of main drainage canal, water not reaching fields due to lack of land leveling, among others (AfDB 2021). The Ministry of Water and Environment handed over the project that started in 2016 Tochi Irrigation scheme in Acaba Sub-county in Oyam to the farmers under Tochi Irrigation Cooperative Society to enhance rice production. It is up on the above highlighted challenges of climate change adaptation that the researcher intends examine the role of adaptation finance mechanisms in enhancing climate resilience at Tochi Irrigation Cooperative Society.

1.3.1 Purpose of the Study

To examine the role of adaptation finance mechanisms in enhancing climate resilience at Tochi Irrigation Cooperative Society.

1.3.2 Specific objectives

i. To identify the adaptation finance mechanisms accessible to members of Tochi Irrigation Cooperative Society.
ii. To assess the level climate-related risks at the Tochi Irrigation Scheme.
iii. To establish the linkages between finance mechanisms and climate-related risks at Tochi Irrigation Scheme.
iv. To determine the influence of cooperative governance on the relationship between adaptation finance mechanisms and climate-related risks resilience.

1.4 Research Questions

i. What are the adaptation finance mechanisms accessible to members of Tochi Irrigation Cooperative Society?
ii. What is the level of climate-related risks at Tochi Irrigation Scheme?
iii. What are the linkages between finance mechanisms and climate-related risks at Tochi Irrigation Scheme?
iv. What is the influence of cooperative governance on the relationship between adaptation finance mechanisms and climate-related risks?

1.5 Significance of the study

The study intends to examine the influence of climate finance mechanisms on climate resilience at Tochi Irrigation Scheme in Oyam District. When completed, the study findings may be used by decision makers in relevant ministries like Ministry of Environment and Ministry of Disaster Preparedness to formulate a sustainable policy aimed at mitigating the scourge of climate change in relation to promotion of sustainable livelihood.

The research findings could be used to guide the government in tailoring climate change adaptation and mitigation measures to the local context of Oyam District. Lastly, the researcher will undertake the study as a precondition for his attainment of Master of Development Studies of Gulu University which the researcher is pursuing.

1.6 Conceptual framework

The conceptual framework for this study is informed primarily by the Community Resilience Framework proposed by Norris et al. (2008), with complementary insights from the Sustainable Livelihoods Framework developed by the Department for International Development (DFID, 1999) and Ostrom's (1990) work on collective action and self-governance. These frameworks provide a theoretical basis for examining how adaptation finance mechanisms influence climate resilience and how cooperative governance conditions this relationship.

The independent variable is adaptation finance mechanisms, operationalised through infrastructure development and public–private partnerships. Infrastructure includes irrigation facilities, reservoirs, canals, roads, storage facilities and agricultural equipment that support farmers' capacity to respond to climate-related challenges. Public–private partnerships encompass collaborative arrangements through which public institutions, private-sector actors and other stakeholders mobilise financial, technical and material resources for climate adaptation.

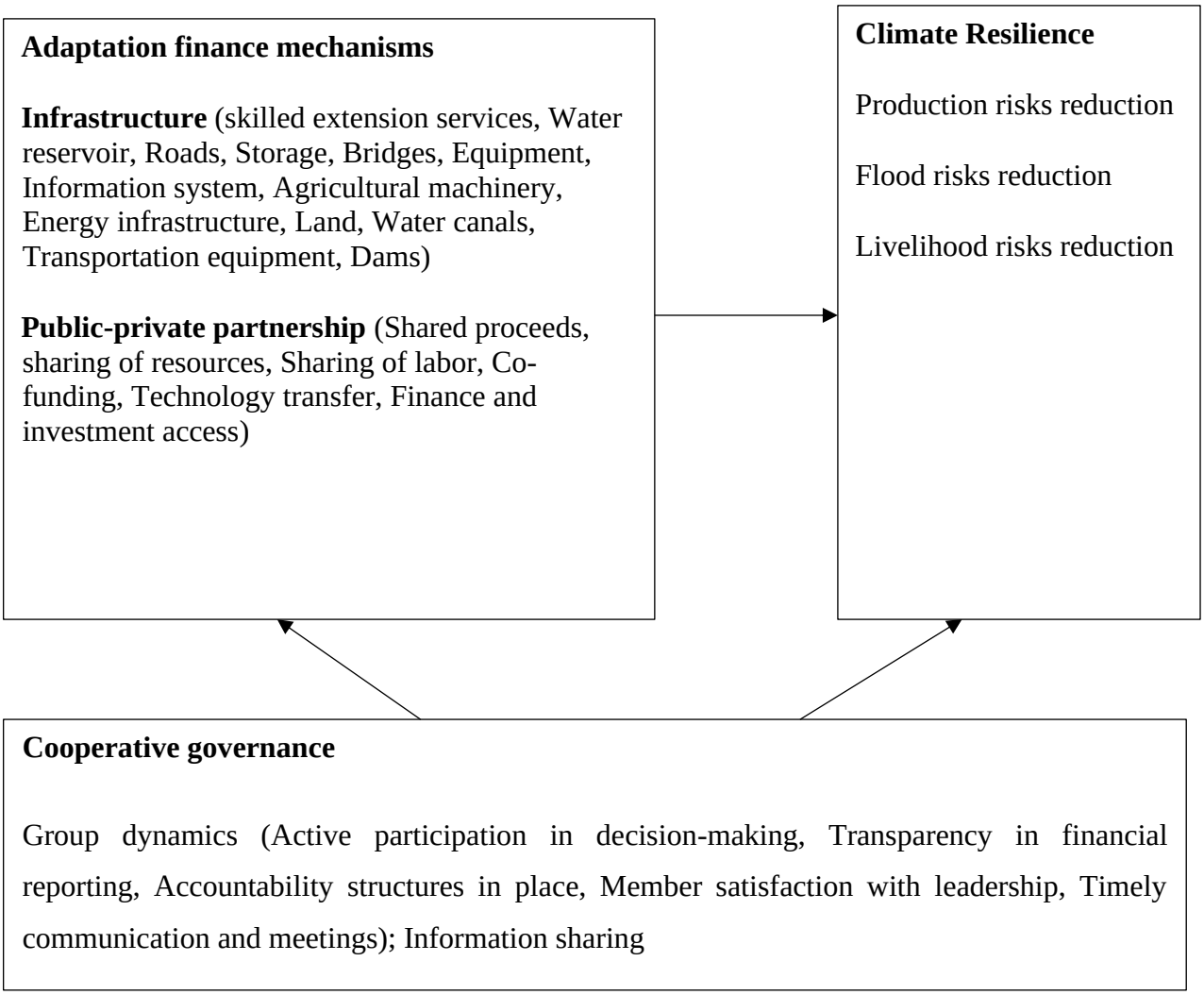
The dependent variable is climate resilience, measured in terms of resilience to production risks, flood risks and livelihood risks. These dimensions reflect the capacity of farmers to maintain or recover agricultural production, manage flood-related disruptions and sustain their livelihoods in the face of climate variability and related shocks.

Cooperative governance is conceptualised as a moderating variable and is operationalised through group dynamics and information sharing. Effective group interaction and the timely exchange of information may strengthen collective decision-making, improve the utilisation of adaptation resources and enhance the effectiveness of infrastructure investments and public–private partnerships. Conversely, weaknesses in cooperative coordination and information sharing may limit the benefits derived from adaptation finance mechanisms.

The framework therefore proposes that adaptation finance mechanisms influence climate resilience and that the strength or direction of this relationship may vary according to the effectiveness of cooperative governance. This proposition is consistent with the community resilience perspective, which emphasises economic resources, social capital, information and communication, and collective competence as important dimensions of resilience (Norris et al., 2008). The Sustainable Livelihoods Framework further explains how access to financial and physical assets and the institutional context shape people's capacity to cope with vulnerability and sustain livelihood outcomes (DFID, 1999). Ostrom's (1990) work provides additional insight into how collective organisation and self-governance influence the management of shared resources.

The framework guides the investigation of the relationship between adaptation finance mechanisms and climate resilience among members of Tochi Irrigation Cooperative Society in Oyam District, Uganda.

Figure 1: Conceptual framework



Source: Adapted from Community Resilience Framework (Norris et al. 2008)

Adaptation finance mechanisms refer to the financial arrangements, instruments and collaborative approaches through which public, private and alternative sources of finance are mobilised and channeled towards interventions that help communities adjust to actual or anticipated climate change impacts, reduce vulnerability and strengthen climate resilience (United Nations Framework Convention on Climate Change [UNFCCC], 2019; Intergovernmental Panel on Climate Change [IPCC], 2022).

In the context of this study, adaptation finance mechanisms are operationally defined as the infrastructure investments and public–private partnership arrangements through which financial, physical and technical resources are mobilised and utilised to strengthen farmers' capacity to withstand and recover from climate-related production risks, flood risks and livelihood risks at Tochi Irrigation Scheme in Oyam District, Uganda. Infrastructure

investments encompass irrigation canals, reservoirs, dams, roads, storage facilities and agricultural equipment that support climate-resilient agricultural production. Public–private partnerships involve collaborative arrangements among government institutions, private-sector actors and other stakeholders to mobilise funding, share resources and risks, and facilitate technology transfer for climate adaptation (UNFCCC, 2019).

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

In this chapter the researcher shall review literatures that are related to the variables, concepts and theories under the proposed study. The literature review is organized under the following sections: resilience theory; adaptation finance mechanisms; climate resilience; cooperative society; and summary.

2.1 Resilience Theory

Resilience theory was first described in 1973 by C.S. Holling, who studied how populations function within ecological systems, particularly after some sort of ecological stress(Chillrud 2017).

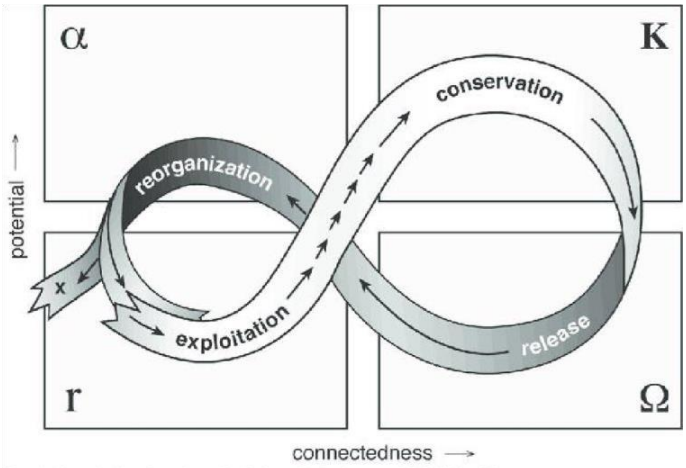
Ecological research prior to Holling's work had been focused on system equilibrium, but Holling argued that a system may have multiple equilibria that it shifts between during stress(Holling, C.S., and Gunderson 2002). In studying predator-prey relationships and population models, Holling noticed that there were multiple stable states possible (Folke 2006). This realization shifted ecological work from focusing solely around a single equilibrium to system unpredictability and more 6 variable behaviors.

Thus, from Holling's work, resilience is defined as a system's ability to cope with a stress or shock while preserving its existing function and organization; in other words, without shifting to a new equilibrium (Bahadur et al., 2013). This resilience perspective shifts the focus from attempting to isolate a system from change to attempting to build the capacity of a system to tolerate change; to quote Holling, "the relevant focus is not on constancy but on variability"(Folke 2006). Holling and his fellow researchers introduced work in 1995 that connected the organization and behavior of ecosystems with the organization and behavior of the people who live in and work with these ecosystems (Folke 2006). This work stressed the inevitability of uncertainty and began to push environmental management techniques away from the simple "command-and-control" tactics that try to avoid system change (Barrett 2014).

Holling argued that these tactics may provide the desired effect in the short term, but as they do not take all variables into account, they can leave systems more vulnerable to disturbances

in the long run. Holling's discovery of multiple stable states also led to his work on adaptive ecosystem management and the idea of the adaptive cycle. This section first outlines panarchy and the adaptive cycle, the building blocks of resilience theory. It then outlines different interpretations and definitions that have built on this work and adapted Holling's ideas outside of ecology. Panarchy and the Adaptive Cycle (Holling, C.S., and Gunderson 2002). The adaptive cycle is a cycle of disturbance and recovery that systems go through as they respond to stresses. Panarchy is the idea that these cycles are nested, rather than hierarchically or linearly organized (Holling & Gunderson, 2002). Panarchy describes adaptive cycles as complexly linked both spatially and temporally, often in ways which may cause "cascading" events where failure of one level can affect a variety of other levels (van Apeldoorn et al., 2011). For example, a failure at the field level of an agricultural system could cause changes affecting the regional-scale agricultural system (van Apeldoorn et al., 2011).

The adaptive cycle, as defined by (Holling, C.S., and Gunderson 2002), has four main stages: exploitation, conservation, release, and reorganization. Exploitation and conservation are the front of the loop, while release and reorganization are the back of the loop. The first stage, r, is the "exploitation" stage, characterized by rapid growth and high resiliency (Holling & Gunderson, 2002). For example, this could be the growth of a forest, when resources are allocated toward the rapid growth of trees. The cycle then shifts to the second stage, K. K is the "conservation" stage, characterized by efficiency rather than growth and buildup of system resources. This buildup and the increased connectedness that occurs during the K stage leaves the system inflexible, with a high potential for and vulnerability to change (Komarek, Pinto, and Smith 2020)). This would be when the forest is dominated by large, old-growth trees. There is no longer much room for growth.



The adaptive cycle (from Panarchy, edited by Lance H. Gunderson and C.S. Holling: Figure 2-1 (page 34). Copyright © 2002 Island Press.

A significant disturbance in the K stage will cause a release of the accrued resources and push the system into the third stage, Ω, the "release" stage. While the shift from r to K tends to be slow and gradual, the Ω stage is characterized by rapid change resulting from a system shock (Holling & Gunderson, 2002). An example would be a forest fire burning down the trees. In this stage, the resources that were previously stored in the trees would be released by the fire. After the disturbance, the system will move to α, the "reorganization" stage. Here, the system begins to rebuild, accumulating some basic resources again and likely reconfiguring into the same or at least a similar system. In the forest example, the resources that were released in the fire are now available in the soil for new growth. In some cases, if the disturbance was great enough or the system is unable to reorganize to its previous state, the system may become something new entirely. This is a shift from one state of equilibrium to another.

The adaptive cycle illustrates the degree to which change is an integral part of social ecological systems (Chillrud 2017)Thus, rather than defining resilience based on the ability to maintain a stable stasis, the natural cycle of change needs to be accounted for. The inevitability of changes to the system means that flexibility and adaptability are crucial to a resilient system. This is why definitions of resilience have evolved to incorporate cycles of change, as well as changes from one state of equilibrium to another. Resilient systems, including agro ecosystems, are able to cope with sudden shocks and effectively reorganize.

2.2 Adaptation finance mechanisms

Climate adaptation finance is a type of climate finance, which focuses on incorporating into the design of financial products the possible effects of climate change to its clients, trying this way to promote the implementation of adaptation measures. Finance has a critical role to play in enabling a transition to a low-carbon, climate-resilient economy (Bhandary, Gallagher, and Zhang 2021). Under the adaptation finance mechanisms, the study will focus on the roles of infrastructure and public-private partnership in influencing resilience. The Paris Agreement itself commits to aligning financial flows 'with a pathway towards low greenhouse gas emissions and climate resilient development' (Article 2.1(c)). The Paris outcome urges developed nations to mobilize US$100 billion per year by 2020 for climate action in developing nations; yet an estimated US$95 trillion investment in infrastructure (energy, transportation, water, telecommunications) will actually be required globally by 2030 to address climate change, of which 60–70% will be needed in developing countries (OECD, 2017 (Bracking 2021). It is claimed that the volume of private finance addressing climate

change is slowly rising in aggregate, particularly at the subnational level and by non-state actors, but that this still leaves a large investment gap (United Nations Conference on Trade and Development 2021).

However, numerous studies have established that a substantial financial gap exists to meet these goals (Buchner et al., 2019; (Savvidou et al. 2021);. A recent estimate of adaptation needs, for example, identified $1.8 trillion in potential investments that would result in $7.1 trillion in benefits (Global Commission on Adaptation, 2019, (Bhandary, Gallagher, and Zhang 2021)), yet the latest estimates only identify $30 billion in adaptation investments ((Barrett 2014); Buchner et al., 2019). To fix these financial gaps, more effectively mobilizing and steering public and private finance to climate-related purposes is of critical importance. Multiple barriers have impeded the mobilization of private finance to address climate change, including the lack of quantifiable incentives, the unwillingness of most for-profit firms to internalize environmental externalities, low or intangible returns to corporate social responsibility practices, perceptions of high risks of low-carbon technologies on the part of commercial banks and other mainstream financiers, a mismatch between long-term payback periods and the short-term horizons of most private investors, lack of information to evaluate projects and their climate-related consequences, and a shortage of bankable low carbon, adaptation, and resilience projects(Bhandary et al. 2021) Chawla & Ghosh, 2019; Jaffe et al., 2005; Leete et al., 2013; Pillay et al., 2017; Polzin, 2017; Wilson et al., 2012). There are also political, institutional, and legal barriers to private investments, which may be even more profound. These barriers may be further magnified when policy coordination is lacking. Nevertheless, some governments have begun to implement new policies to mobilize climate finance, accelerate decarbonization, and improve adaptation and resilience to climate change impacts (Bhandary et al. 2021).

2.2.1 Infrastructure

It should be noted that there are various categories or types of infrastructure. However, for this research, the study focused on agricultural infrastructure necessary to attain climate resilience. Agricultural infrastructure refers to the diverse systems and networks of resources that are vital to produce, procure, preserve, process, and trade agricultural products (Niagara Agriculture Municipal Network 2021). It plays a vital role in the productivity, competitiveness and sustainability of the agriculture sector. Notable dimensions of infrastructure for climate resilience in agriculture include: Hard infrastructure is the natural

and built assets, structures, facilities, equipment and networks that are essential for a competitive agriculture sector and resilient, sustainable food systems. Land, transportation, telecommunications, energy, and water systems, processing and storage facilities are examples of physical infrastructure essential to agriculture. Hard infrastructure is the backbone of the agriculture sector. The agriculture sector is grappling with competing demands related to global population growth, food security, climate change, and emerging technology. Ensuring adequate infrastructure that supports a competitive and sustainable agriculture sector requires input and engagement from a cross-section of stakeholders, including producers, processors, consumers, and policymakers at all levels of government (Canadian Foundation for Innovation 2018).

Another set of vital infrastructure necessary for climate resilience is soft infrastructure which includes intangible assets represented by human capital, services and social institutions needed to run the physical infrastructure and to maintain the economy and our quality of life. It includes financial, marketing, distribution and logistics, research, extension, education, healthcare, regulatory, governance and recreational services and human resources. These soft infrastructure assets provide the human expertise and ingenuity and social cohesion that drive a competitive and sustainable agriculture sector. Furthermore is the role of water infrastructure in facilitating climate resilience. Water infrastructure is a complex network of municipal water systems, treatment plants, pumping stations, wells, roadside gutters, stormwater drains, irrigation systems, and dams. Access to a reliable, safe water supply is essential to all agriculture production and critical to food security (The Canadian Federation of Agriculture 2021). Natural sources of water are increasingly inadequate in meeting needs of the agriculture sector. The anticipated increase in competition for water resources is expected to impact agriculture significantly. As the agriculture sector faces growing competition with other sectors for freshwater and the impacts of climate change, farmers are increasing looking to modern irrigation infrastructure as a solution (JAYEFF Partners n.d.). Additional water infrastructure, both hard and soft (e.g., evidence-based policy) is needed to meet the demands of a growing population for sustainable food production.

Investment in community infrastructure development initiatives is key in achieving climate resilience (Munyanyi 2013). Notably access to infrastructure financing remains limited especially to farmers in resettlement areas, mainly because they lack the required collateral and bankable business proposals. However infrastructure development can still be made possible through community initiatives. Instead farmers individually developing their areas,

they could achieve better results by working as communities on developmental projects. Pooling resources together could see farmers benefiting from the synergistic effects of working as a team. For example irrigation facilities require much more capital which an individual family may not be able to raise (Munyanyi 2013). However if farmers adjacent to each other pool resources together through a well-managed process, they could achieve desired results.

Long-term financial constraints have motivated governments to engage the private sector in public infrastructure development, including through public-private partnerships (The World Bank 2017). More recently, governments, researchers, and development practitioners have turned their attention to the importance of improving the resilience of infrastructure assets to natural disasters, as well as to the key role infrastructure plays in the resilience of communities, especially in the context of climate variability. During 1998–2017, disaster-hit countries reported direct economic losses of approximately US$2.9 trillion, of which 68 percent account for climate-related disasters. The reported losses from extreme weather events rose by 151 percent compared to the total reported losses of US$1.3 trillion during 1978–1997. Floods accounted for approximately 43 percent of recorded events affecting more than 2 billion people, followed by storms (28 percent) and earthquakes (8 percent). During this period, climate-related and geophysical disasters took the lives of 1.3 million people and left 4.4 billion people injured, homeless, displaced, or in need of emergency assistance. These enormous economic losses of human life have promoted attention to the importance of disaster risk management (DRM) and the impacts of climate change, particularly in countries most vulnerable to natural hazards. As such, governments are tasked with ensuring that sufficient funds and expertise are available to develop and supply quality infrastructure that can also (a) better withstand and recover from disasters and (b) adjust to changing conditions associated with climate change.

The above literature gives general insights about infrastructure in the agricultural sector. However, in this study, the researcher intends to study specific roles of infrastructure among rice farmers organised as a cooperative society in an irrigation scheme. Therefore, the study will give disaggregated findings on infrastructure in the context of rice growers in a cooperative society.

2.2.2 Public-private partnership

A public private partnership is a cooperative and collaborative arrangement between two or more public and private sectors, typically of a long-term nature (Hodge and Greve, 2007). Alternatively, a public-private partnership is a contractual agreement between a public agency (federal, state or local) and a private sector entity (Kharumnuid et al. 2023). Through this agreement, skills and assets of each sector (public and private) are shared in delivering a service or a facility for the use of the general public. In addition to the sharing of the resources, each party shares risks and rewards potential in the delivery of the service and/or the facility. The PPP approach supplements scarce public resources, creates a more competitive environment and helps to improve efficiencies and reduce costs. The rationale for public sector involvement differs between different kinds of services and influences the type of involvement required (Paul and Margaret, 2003).

In India, a 4 per cent growth rate in agriculture can be achieved by laying greater emphasis on the allied sectors (Kharumnuid et al. 2023). India's expenditure on agricultural Research & Development and education is currently about 0.6 per cent of the GDP from agriculture and allied activities which needs to be raised at least to 1.0 per cent (Huchaiah and Nayak 2019). It can be implemented in a number of areas like agricultural research, agricultural supply chain management, watershed management, agricultural extension management, Biotechnology, among others (Rai et al., 2017). Public Private Partnership is most preferred in developing countries for effective delivery of infrastructure facilities. In developing countries, rural-urban migration has increased urbanization at same time socio-economic developments have increased the demand for infrastructure and also pressure on maintaining and operating the existing infrastructure (Kharumnuid et al. 2023). Thus private sector could be attracted through mutually beneficial agreement for efficient use of resources, availability of modern technology, better project design and implementation and improved operation combine to deliver efficiency (Kharumnuid et al.

2023).

Some of the benefits of public and private sector coming together are discussed below:

PPP mechanism has the potential to mobilize fund from multiple sources, share costs, risks and benefits among different stakeholders, combine both scientific and local knowledge, and reduce uncertainty through formal and informal institutions. Benefited from these

advantages, PPP mechanism could improve project performance, thus increase farmers' adaptation options and resilience to drought(Zhang et al. 2018). Furthermore, PPP combines the best features of the public and private sector together (IMF 2004). The private sector can leverage its advantages in creative financing, greater operational efficiency, lower costs of distribution, more complex delivery systems, faster decision-making, management flexibility and innovation. The public sector can provide strategic direction – the choice, location and pricing of infrastructure; ensure transparency in procurement and above all, through capital or user fee subsidies, or commitments to purchasing agreements, enable private firms to enter large markets with guaranteed consumers. More still, there is reduced up-front public capital investment and mobilization of private capital. In addition to the above, PPPs encourage bundling design, construction and operations: Rather than there being separate design, construction, financing, operations and maintenance arrangements, as with traditional public sector procurement of infrastructure, involvement of the private sector encourages these functions to be combined under one contractor. Lastly, PPP is cost-saving, that is efficiency can be higher in the private sector, with greater opportunities for economies of scale, strong project management skills, response risk management, more attuned skills, innovative technologies and lower overheads.

With constrained public budgets and large infrastructure gaps, PPPs are growing in importance as an infrastructure delivery solution for many governments. The key features of a typical PPP project, which make them an attractive procurement solution for meeting public infrastructure needs, also lend themselves well to incorporating climate resiliency consideration: firstly, PPPs consider life-cycle costs (The World Bank 2017). PPPs require public officials to consider the longterm costs of infrastructure assets. This creates greater discipline in the infrastructure procurement process; private parties must look beyond just the construction phase to evaluate the costs over the life of the project (so 25-30 years). These private parties are incentivized to think about all potential risks and costs, including those related to climate change. As a result of this more lifecycle view of the project and its risks, PPPs may lead to better designed infrastructure projects which are more able to withstand climate events.

Secondly, PPPs offer innovative solutions (Frisari et al. 2020). Developing PPPs requires coordinating among many stakeholders (such as developer, government, financial investors, and operator), each bringing different perspectives and incentives. The result of this coordination and the negotiated effort to deliver a PPP project may lead to more innovative

infrastructure solutions in the face of climate related risks. Thirdly, PPPs include lender's due diligence. By their nature, PPPs bring in private finance and as a result they bring in an extra set of eyes performing due diligence. Lenders want to see that the project can perform well over its life and service its debt.

Climate risks, which materialize, can impact a project's ability to operate and generate revenue. As a result, many lenders to PPP arrangements are examining climate risks. Lastly, PPPs require robust risk assessment. At the heart of every good PPP project is a robust risk assessment that evaluates all possible risks to the projects and assigns them to the party best able to manage them. Including an analysis of climate and disaster risk as part of this existing process only makes sense, as PPP project developers are seeking to understand any/all risks which may disrupt services and undercut their returns (Frisari et al. 2020). However, weak motivation and distrust by farmers limit the engagement of private enterprises in supporting farmers to adapt to drought.

2.3 Climate resilience

Climate resilience is a fundamental concept of climate risk management. In this context, resilience refers to the ability of an agricultural system to anticipate and prepare for, as well as adapt to, absorb and recover from the impacts of changes in climate and extreme weather (Alvar-Beltrán et al., 2021) Resilience can be enhanced by implementing short and long-term climate mitigation and adaptation strategies, as well as ensuring transparent and inclusive participation of multiple actors and stakeholders in decision-making and management processes (Alvar-Beltrán etal., 2021). Some hydro-meteorological hazards are slow in their onset, such as changes in temperature and precipitation resulting in long-term altered temperature, rainfall patterns and agricultural droughts. On the other hand, some occur much more suddenly, such as tropical storms and floods. Both require robust risk preparedness informed by the assessment of climate risk.

According to the World Bank, Uganda is not adapting to climate change as needed(The World Bank 2020b). Uganda was ranked 155th out of 188 countries on the Notre Dame Global Adaptation Initiative (ND-GAIN) index8 in 2016, due to a combination of high vulnerability to climate change (14th most vulnerable country) and low readiness to improve resilience (48th least ready country).

Two elements drive Uganda's high vulnerability: (i) strong projected decrease in rice, wheat and maize yields; and (ii) low capacity to acquire and deploy agriculture technology (irrigation, machineries, and inputs). The impacts on the economy are striking: in 2010-11, Uganda experienced production losses (38 and 36 percent loss for beans and maize, respectively) totaling Ugandan Shilling (UGX) 2.8 trillion, which translated to 7.5 percent of GDP (The World Bank 2020b). Interestingly, annual rainfall over that period did not reveal any anomalies, but an analysis of monthly data showed that more than half of the months had below average rainfall, hinting to the need for investment and innovations to cope with intra-annual variability. Indeed, a third element defining Uganda's high vulnerability to climate change is lack of storage infrastructure.

In his review of climate resilience, the researcher will focus on production risks; flood risks, and livelihood risks. Hardaker (Izabela Lipińska 2016)) lists three common interpretations of risk: 1) the chance of a bad outcome, 2) the variability of outcomes (that is, the converse of stability), and 3) uncertainty of outcomes. Other words that characterize risk include robustness, vulnerability, and resilience (Urruty et al., 2016). In other words, risk can be defined as the possibility of adverse outcomes due to uncertainty and imperfect knowledge in decision making (Drollette 2009). Therefore, the above interpretations shall inform the literature review on climate resilience, taking into consideration the three fundamental risks under the proposed study.

2.3.1 Production risks

Production risk, in agriculture, refers to the uncertainty or variability that affects the quantity and quality of agricultural production (Alan Miller, Craig Dobbins and Ehmke 2015). It arises from various sources such as weather conditions, pests and diseases, production management practices, infrastructure malfunctions, and other environmental factors. To effectively manage production risk, farmers can employ a range of tools and methods for identifying, analyzing, and mitigating potential risks. Production risks stem from the uncertain natural growth processes of crops and livestock, with typical sources of these risks related to weather and climate (temperature and precipitation) and pests and diseases (Komarek et al. 2020). Production risks management under climate smart agricultural practices can improve farm performance and household well-being in developing countries, particularly through adapting new technologies against environmental change, better farming practices and using climate resilient seed varieties (Shahzad 2022). Many previous studies

have highlighted the significant effects of climate change on profits, farm income and farm productivity (Huang et al., 2015.). Studies conducted in Pakistan for instance have revealed that climate change adversely affects agriculture, while adaptation to climate change has had a shielding effect (Shahzad 2022; Batool et al. 2023)).

Climate-related environmental risks to agricultural production such as extreme temperature, erratic rainfall, floods, pest infestation, plant diseases, dust cyclones, drought, and weeds have significantly affected agricultural systems of Pakistan (Economic Survey of Pakistan, 2016; Abid et al., 2016b). The average global temperature has risen by about 0.6-0.8 ℃ during the last decade and is likely to continue increasing at a rapid rate (World Bank, 2013). The rainfall has become erratic and heavier for short periods (Khan, 2015) and in other months, farmers face water shortages and sometimes droughts. These variations in climate induce risks in farming activities, trigger ruin effects for geographic locations, and instigate floods and water scarcity, which consequently adversely affect agricultural activities (Shannon & Motha, 2015). Additionally, these variations have a significant impact on water resources, agricultural production, food supply, farmers' well-being and finally the global economy (FAO, 2011; IPCC, 2012). Climate-related risks not only affect crop yields but also have an impact on soil degradation, water logging, soil moisture interaction, soil nutrients and humidity (Anache et al., 2018).

In developing countries, small losses in agriculture production cause a greater loss of income because agriculture accounts for a greater share of GDP compared with industrial countries. Deterioration in agriculture productivity is causing persistent poverty in farming communities and food insecurity as a whole (Ali & Erenstein, 2017). Yield losses of agriculture crops ranging between 5 and 25 percent are alarming in terms of feeding the huge growing population (Schwarts & Randall, 2003). For a crop farmer, planting seeds does not guarantee a profitable yield at the end of the crop season. Output per acre likely varies by acre and year and can be suddenly devastated due to unforeseen weather factors such as drought, fire or frost. This is in tandem with the 2007/08 world food price crisis which was partly caused by production risk related to severe droughts although the impacts of the ensuing price spikes were exacerbated by some governments imposing export restrictions (Komarek et al. 2020). Wild animals, insects and other pests can negatively affect crop production levels and weeds can choke out growing crops. Crop disease can also be a significant source of risk in crop production. These and other unpredictable factors create a very real risk for crop producers. The presence of any of these unpredictable risk factors can significantly lower production

levels and lead to losses. Since production output is the main source of revenue for agricultural operations, it is crucial for farmers to recognize and manage production risk (Drollette 2009).

There are many tools available to help farmers manage production risk. Which tools a farmer uses should depend on his individual farm situation and risk-bearing willingness and ability:

Diversification; product diversification can help lower production risk for agricultural producers. By producing more than one crop or livestock product, farmers can reduce the risk of a total production loss. For example, a producer who operates a dairy and raises corn is not completely dependent on one product. Thus, his risk of a complete production loss due to an early frost would be less than a farmer who only grows corn. With diversification, choosing low-risk enterprises can also help reduce overall production risk. Given a farmer's specific location, some crops may have lower yield variability in general reducing the risk of production loss compared to a crop with high yield variability.

Production risk can also be reduced by maintaining excess production capacity. For example, in areas where weather conditions commonly postpone planting, a farmer with excess machinery or labor capacity will be able to catch up on planting to avoid that risk of production loss. Furthermore, having good and up-to-date information can greatly reduce the risk associated with agricultural production. Agricultural companies, as well -as universities, are constantly doing research to test and develop new and better ways of producing various agricultural commodities. A farmer who is well informed about and follows new and proven production practices can reduce his production risk (Izabela Lipińska 2016). Adopting new technologies can also help reduce production risk. For example, a crop producer who invests in new machinery or irrigation equipment may lower the risk of equipment or water problems reducing his yield (Owusu et al. 2020). Much as several studies have been conducted on production risks, little attention has been paid to the context of cooperative society and rice growers in particular. Therefore, this study intends to shed more light on the gaps regarding production risks in the context of rice growers under an irrigation cooperative society.

2.3.2 Flood risks

Flood refers to the temporary covering by water of land not normally covered by water (Sayers et al. 2013). The nature of the flood can vary significantly depending on the driving source, for example coastal floods (storm surge, wave overtopping and tsunamis), fluvial

floods (caused by rainfall – such floods can range from lowland floods that develop slowly to rapid-onset flash floods), pluvial floods (caused by rainfall directly on the urban area) and groundwater floods. The principles of FRM are common to all types of flood, but the specific tools and available management options may vary. Floods are the natural hazard with the highest frequency and the widest geographical distribution worldwide (Frisari et al. 2020). Although most floods are small events, monster floods are not infrequent (UNISDR 2017).

Flooding is an integral part of the natural rhythm of healthy rivers. Through seasonal periodic inundation, sediment and nutrients are exchanged between a river and its floodplains and transported downstream to nourish deltas and near shore coastal areas to form the most fertile lands on the planet for agriculture. These natural flood processes are crucial for freshwater biodiversity and migratory species that provide about 20 percent of the global fish catch. Flood-prone land is fertile and productive, which has drawn people for millennia to live and work on floodplains. Flooding, however, is also one of the most frequent and catastrophic climate-related hazards, severely impacting agriculture as well as other sectors. As the first ever quantification of the impact of disasters on agriculture at the global scale shows, natural disasters cause agricultural production losses of about USD 123 billion over the period 1991–2021. Floods inflict the second largest impact, after extreme temperatures and droughts (FAO, 2023a), with a responsible loss of around 16 to 20 percent (FAO, 2021b; FAO, 2023a). However, due to the limitations of data reporting and challenges in data disaggregation for particular hazard types, these figures are likely to be underestimations(FAO 2023).

Behind these losses lies a human story, since an estimated 1.8 billion people are exposed to a significant flood hazard (FAO 2023); Rentschler, Salhab and Jafino, 2022). The most socially vulnerable communities are often at greatest risk, including the rural poor. Those who rely on agriculture and food systems for their livelihoods are often the worst affected, potentially placing their livelihoods, food security and nutrition at serious risk. Loss of livestock and crop production, and damage to food storage facilities and distribution of the systems upon which agriculture and food depend (e.g. transport), can rapidly undermine fragile food systems and supply chains. This, coupled with limited financial resources to aid recovery, can make the impact of a flood on a rural community both acute and long lasting, continuing to undermine development for many years after the flood waters have receded.

Rural resilience challenges are often exacerbated by a legacy of poor development choices that increase flood risk, by creating environmental vulnerabilities, including fragmenting the longitudinal or lateral connectivity of the river. Such choices embed unnecessary fragility within the landscape, starving agricultural soils of nutrients and degrading freshwater ecosystems. Flood risk management has a pivotal position in promoting a more strategic development pathway and one that delivers desired societal, environmental, and economic outcomes (FAO 2023).

Managing rural flood risk is at the centre of the vision for climate resilient development pathways set out by the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (IPCC, 2023). The United Nations (UN) envisions a future where smallholder farmers, rural entrepreneurs, and industries across the agrifood system reap the benefits of available water and are adaptive, equitable, and equipped to thrive in the face of climate related hazards whilst protecting nature (UN, 2020). Making progress towards this goal will require a combination of mitigation and adaptation, as well as disaster risk reduction (DRR) actions in agriculture and food systems, water and natural resources systems, and infrastructures and services to manage climate related risks in rural territories (as set out in the Marrakech Partnership for Global Climate Action). The importance of prioritizing the poorest and most socially vulnerable (including rural communities in the poorest countries) must be increasingly recognised if we are to successfully reduce risks, adapt to climate change and promote resilience (IPCC, 2022) and the importance of adopting a long-term, strategic approach to flood risk management as part of these efforts (Sayers et al., 2014). However, it is important to recognise that rural areas have received disproportionately less attention, and current approaches to planning and management are less well established in rural areas compared to urban areas (The World Bank 2018); Asian Development Bank, 2018).

A small number of recommendations are set to help make more rapid progress towards flood resilience in rural settings: First, accept that absolute protection is not possible and plan for exceedance: An acceptance that some flooding will occur, regardless of steps made to reduce the risk to people, places a focus on building resilience into all aspects of the planning. This includes ensuring that early warnings trigger Anticipatory Action (AA), carried out before the forecast floods occur, with the goal to mitigate their direct impacts on lives and livelihoods. Further, humanitarian assistance should aid the timely and risk-informed recovery from a flood and act to underpin long-term resilience, addressing any underlying disaster risks.

Second, understand the resilience of agrifood systems at national and global scales: A lack of a global assessment focused on flood risks in agriculture and food systems, and rural areas is a brake on mobilizing investment to prevent flood risks, in early warning systems, proactive preparedness, AA, and capacities of rural communities. A strengthened risk assessment process would encourage investment and support timely action to reduce vulnerabilities and to prevent a hazard from triggering a disaster, saving lives and livelihoods.

Third work with natural processes as part of a whole system approach to managing risk: Working with natural processes as part of a flood risk management strategy implicitly encourages choices that support healthy freshwater and marine ecosystems, healthy soils, and the ecosystems and the services they provide: all are prerequisites for productive and resilient agriculture. Fourthly, assess the resilience of agrifood systems at a catchment and community scale to better understand and communicate any present-day risk and how it may change in the future: Understanding the flood hazard, as well as the exposure and vulnerabilities of agrifood systems and related livelihoods (including people's coping and adaptive capacities), and how they combine to generate the risk faced, is the starting point for any planning process. Communicating this risk using modern communication tools alongside traditional stories enhances risk awareness, which may be translated into interventions to reduce risk and help avoid disasters. Involve agriculture and rural communities in the process and promote socially just outcomes: Rural smallholder farmers, women and Indigenous Peoples have significant knowledge to contribute and a substantial role to play in flood risk management(FAO 2023). Inclusive planning processes encourage ownership and action. Align and integrate planning and policy within and across sectors to reduce risk and maximize co-benefits: Managing flood risk does not take place in isolation of other risks and development objectives. An active process of alignment (and, where necessary, integration) within and across sectors and in consideration of the multiple and often conflicting risks provides opportunities for delivering multi-objective solutions, helps manage trade-offs and maximize cobenefits, and avoid future conflicts, creating new risks or exacerbating existing ones. Good land use planning at catchment scale not only considers development but identifies appropriate areas to store flood water upstream to reduce flood magnitude downstream. Natural habitats should be conserved or restored. Mobilize increased investment to scale-up resilience of agrifood systems and rural communities: Scaling-up investment in the resilient agrifood systems and rural risk management through national adaptation planning and disaster risk management (and other mechanisms across sectors) will be critical

if adaptation is to be successful. Increasing international humanitarian support – including flexible and accessible resources to support emergency response and recovery – will also be needed to address the inevitable residual risk. Financing mechanisms that secure long term investment are needed to support the implementation of adaptation pathways that are clear on how future choices will be made, and who will make them. Take proactive action to adapt and promote an integrated approach to water: Building upon the shift in philosophy towards a more strategic, integrated approach to water management more broadly offers an opportunity for countries to slow and store flood waters in the landscape (rather than evacuating flood waters rapidly downstream where they may cause additional flooding) to help manage drought risks and develop system-based approaches to hydropower and agriculture1 that deliver multiple benefits for people, their livelihoods, economy, and nature.

2.3.3 Livelihood risks

Livelihood risk refers to the damage to the livelihood capital of farmers, leading to difficulties in their lives (Zeng et al. 2021). The definition of livelihood risk involves opportunities for injury, damage or loss (Zeng et al. 2021). The existence of livelihood risks will hinder the sustainable livelihoods of farmers and the sustainable development of rural society. Therefore, the issue of livelihood risks for farmers is regarded as the most important issue in rural society. There is no uniform standard for the division of livelihood risks. The Department for International Development (DFID) categorized farmers' livelihood risks into livelihood capital risk, livelihood strategy risk and livelihood outcome. Sarker et al based their study on the sustainability analysis framework and divided farmers' livelihood risk into human capital risk, natural capital risk, financial capital risk, physical capital risk, social capital risk and livelihood strategy risk (Sarker et al. 2019). Jin defined farmers' livelihood risks as including environmental risks, health risks, financial risks, social risks, and information risks (Jin et al. 2020). Nguyen et al. (2019) classified farmers' livelihood risks according to the source of livelihood risks, which were divided into natural risks, market risks, health risks, education risks, employment risks, economic risks, pension risks, and policy risks.

Livelihood risks are closely related to livelihood capital (Zhao and Lan 2023). Many empirical studies have proved that the improvement of farmers' livelihood capital can alleviate poverty and strengthen farmers' ability to cope with livelihood risks. On the contrary, the lack of farmers' livelihood capital causes farmers to fall into poverty, which

increases the risk to livelihoods, and livelihood capital has a significant positive impact on farmers' livelihood risks (Zhao and Lan 2023). For example, Addison and Brown used the sustainable livelihood method and found that the poorer a family, the more united its livelihood capital structure, and the weaker its ability to cope with livelihood risks. Papa (2020) believed that the financial and physical capital owned by farmers will affect their ability to cope with livelihood risk portfolio capital and play an important role in coping with livelihood risks (Sarker et al. 2019). Under the attack of multiple internal and external risks, farmers' pensions are extremely vulnerable, which may cause the elderly in rural areas to fall into the situation of no financial source, no one to take care of their life and lack of end-of-life escorts (Scoones 2014). Su and Shang believed that the increase in financial capital and human capital will help strengthen farmers' ability to resist risks. Establishing a sound risk aversion mechanism, improving the social security system, and reducing the risk of farmers' livelihoods is conducive to improving the living standards of farmers, promoting the sustainable development of farmers' livelihoods, and playing an important role in economic and social development. Climate change and environmental conditions in poverty-stricken areas will cause continuous livelihood risks and poor farmers are often in the first place to bear the brunt of natural disasters (Zeng et al. 2021).

2.4 Cooperative society

Cooperative society is a form of farmer organization. Traditionally, an agricultural cooperative is defined as a form of an economic organisation of a set of farmers (Tortia, Valentinov, and Iliopoulos 2013). A farmer organization (FO) refers to a voluntary collective action organization owned and controlled by farmers to pursue common interests. A FO can take different forms including cooperative, association, self-help group, and marketing group. These are forms of selforganization that may provide resources and services that help farms to become resilient. Currently, understanding of the nuanced role of FOs in supporting adaptation to climate change remains sketchy. Yet, FOs are critical in providing the farmer with learning, legitimacy, governance, diffusion of innovation, and information necessary in adapting to changes (Kangogo, Dentoni, and Bijman 2020).

Cooperatives play a prominent role in the agricultural sector, both in developed and developing countries. Historically, cooperatives have been the main institutional and organizational tool through which independent farmers were able to withstand the market power held by local and transnational retailers. They also serve to shorten the supply chain by

allowing producers to integrate most or all of the processing and marketing processes into one or few steps, thus allowing substantial savings on transaction and other intermediation costs. The agricultural sector accounts for 14.2% of total European Union manufacturing output, with 675 billion Euros worth of production. 38.5% of this output is generated by the cooperative sector (about €260 billion). In the EU there are about 40,000 cooperative enterprises employing over 600,000 persons; with 9 million members. The turnover is around €260 billion. These cooperatives represent over 50% of the shares of the supply of agricultural inputs and over 60% of shares of the collection, processing and marketing of agricultural products (Cooperatives E

urope 2008; Cogeca 2010). Cooperatives are recognised for their provision of technology services to farmers, encompassing activities such as the introduction of novel technologies, facilitation of information sharing among members, provision of technical consultations, access to market information and outlets, including input supply, product transportation, and marketing, as well as the provision of supportive services, such as credit service and collective resource management (Kangogo et al. 2020). (Tham-agyekum et al. 2024) indicated that access to cooperative services can positively impact cocoa productivity.

2.4.1 Group dynamics

To begin with, Samuel Ahado and his colleagues asserted that there are economic benefits of membership in producer groups (Ahado et al. 2024); that is a positive and significant impact of participation in groups on farm revenue and net returns. In the context of climate resilience and agriculture, farmer groups play a crucial role in implementing sustainable practices and adapting to the challenges posed by climate change. These groups often serve as platforms for knowledge sharing, resource pooling, and collective action to enhance the resilience of smallholder farmers. By working together, farmers can leverage their combined efforts to implement climate-smart agriculture techniques, access funding opportunities, and build community resilience (International Fund for Agricultural Development 2020). One key aspect of farmer groups in climate resilience is their ability to facilitate the adoption of climate-smart agriculture practices. These practices focus on sustainable land management, water conservation, crop diversification, and other strategies that help farmers mitigate the impacts of climate change. Through farmer groups, individual farmers can receive training and support to implement these techniques effectively on their farms.

Furthermore, farmer groups provide a forum for sharing experiences and best practices in climate resilience (ESAFF 2010). By exchanging knowledge and lessons learned, farmers can collectively identify innovative solutions to common challenges such as extreme weather events, droughts, or pests exacerbated by changing climatic conditions. This collaborative approach fosters continuous learning and adaptation within farming communities. Additionally, farmer groups enhance the access of smallholder farmers to financial resources for climate resilience. By organizing into formal or informal associations, farmers can improve their bargaining power when negotiating with financial institutions or government agencies for funding support. This increased access to finance enables farmers to invest in resilient agricultural practices, infrastructure improvements, or insurance mechanisms that protect against climate-related risks.

Investing in farmer groups and networks is crucial for enhancing climate resilience in agriculture. These groups play a significant role in building the adaptive capacity of farmers, particularly small and diversified farmers facing the challenges of climate change. Farmer networks serve as essential platforms for knowledge exchange, idea generation, resource access, and problem-solving within agricultural communities. By facilitating collaboration, information sharing, and mutual support, these networks enable farmers to learn about new practices, technologies, and innovations that can help them adapt to changing environmental conditions.

Cooperatives operate at collective economic models and play as a significant actor in addressing various difficulties of the household level. They contribute to changing members' awareness of climate change and its impacts by sharing and providing weather information, organizing training courses or acting as a bridge for members to participate in training courses organized by government and non-governmental organizations. Agricultural cooperatives choose scientific results such as new varieties, new farming techniques, and new technologies in accordance with their members' status to cope with climate change. They guide eco-friendly processes and support techniques for members and encourage members to pursue good agricultural practice, thereby contributing to changing production and business habits of each member that may be harmful to the environment. In addition, the cooperative also acts as a bridge to mobilize and attract financial and social resources from both public/ private institutions and NGOs to promote investment in climate-smart agricultural activities.

In addition, cooperatives through their extension services, facilitate exchange programs for learning between experienced and less experienced farmers. At farm level, the outcomes of extension services are changes in farming practices, for instance, crop rotation and the introduction of new crop varieties. FOs facilitate farmers to adopt new farming practices by providing access to technologies, finance, and technical backstopping during the adoption process. Additionally, FOs facilitate the marketing of farm produce through their bargaining role, enabling farmers to access lucrative markets. This has a direct impact on farmers' revenues, which can be reinvested in adaptation measures. (Raja and Nagasubramani 2018) concurred with Jung (2017) who showed that local organizations enhance actors' capacity to recover from catastrophic events through providing access to critical resources, information, and joint response planning.

The case of Kenyan potato farming highlights the importance of FOs for farm resilience. We observe that farmers are members of FOs mainly to access inputs and services which may help them adapt to climate change. In addition, FOs facilitate farmers to obtain access to resources and services from private businesses, non-governmental organizations (NGOs), and county governments. In Meru, for instance, we observed that small village-level farmer groups merged to form a potato cooperative, which provides member farmers with access to credit and certified potato seed in varieties demanded by specific buyers. Farmers are also able to insure their crops, to access extension and training through the cooperative field extension officers, and to enter into a contract farming arrangement. These resources and services have the potential to help farmers to invest in climate adaptation strategies thereby building farm resilience. This literature does not present information in the context of rice growers in a cooperative society. Therefore, in this proposed study, the researcher will address the gap by focusing rice growers in a cooperative society under an irrigation scheme.

In conclusion, farmer groups play a vital role in building the resilience of smallholder farmers to climate change by promoting the adoption of sustainable practices, fostering knowledge exchange, and enhancing access to financial resources. Through collective action and collaboration within these groups, farmers can better withstand the challenges posed by a changing climate and secure their livelihoods for future generations. By promoting collaboration, knowledge exchange, resource access, and problem-solving among farmers, these networks contribute significantly to building adaptive capacity and fostering innovation in response to the challenges posed by climate change.

2.4.2 Information sharing

The present age has been rightly called an Information age because information has become the most important element for progress in society (Acheampong et al. 2017). Information has been described as “the fifth need of man ranking after air, water, food and shelter”. Information sharing is considered a process that comprises the content, type, and frequency of the information shared between and among actors. The significance of information sharing depends not only on what information is shared, but also on when and how it is shared (Owusu et al. 2020). In other words, both the content and quality of the shared information must be considered. Everyone needs information about everything even in his day-to-day life. In agricultural production environment, relevant and timely information helps farming communities to take right decisions. Utilization of information in the agricultural sector enhances farming productivity in a number of ways. Providing information on weather trends, best practice in farming, new technologies developed by scientists, and timely access to market information helps the farmer make correct decisions about what crops to plant and where to sell their product and buy inputs.

Agricultural information is useful for farmers because it helps them to overcome their inadequacies in knowledge of certain basic practices that may include technical, marketing, social, and legal agricultural information(Acheampong et al. 2017). Farming is one profession that depends on the constant flow of information. However, most farmers find it difficult to identify when they have the need for information. Information source is an institution or individual that creates or brings about a message (Suresh et al.2016). The characteristics of a good information source are timelessness, accuracy, relevance, cost effectiveness, trustworthiness, usability, exhaustiveness and aggregation level. The selection of an information source depends on a number of factors, including level of income, farm size, age, geographical location, level of education. Studies also show that farmers use agricultural extensions officers, posters, televisions and radio as their source of their information. Other authors reported that sources of information used by rice farmers were personal experience, workshops and seminars, training sessions, friends and neighbors, Ministry of Agriculture, magazines of agriculture, extension officers, local Government officers, Non-Government Organization, libraries of agriculture and posters. Therefore, in view of the fact that each farmer prefers certain information sources or channels to others, it is important to do a thorough study before opting for an information source or channel to address their needs.

Farmers require different types of information for their day-to-day agricultural activities. Studies found that the important information needs for rice farmers were pest and disease management, pesticide and fertilizer application, best time to plant, planting method, storage and seed treatment.

Farmers face several challenges in accessing agricultural information (Suresh et al., 2016). For instance, identified that some of the challenges farmers face in accessing agricultural information were outdated information, language barrier, lack of awareness on existence of different information sources, lack of funds to acquire information and poor format of information carrier. It ought to be noted that the information needs of farmers change from time to time due to changing needs on emerging issue in agricultural technologies and innovations, environmental changes and agricultural policies.

In a study, Enoch Kwame Tham-Agyekum and colleagues underscored the crucial role of associative mechanisms, particularly cooperative societies, in bolstering the resilience of cocoa farmers. The ability of these mechanisms to serve as conduits for information dissemination, resource pooling, and collaborative problem-solving is highlighted as instrumental in mitigating the adverse impacts of natural hazards (Tham-agyekum et al. 2024). Associative mechanisms significantly contribute to cocoa farmers' awareness and understanding of climate change. Through farmer cooperatives and community-based organizations, information on climate patterns, sustainable farming practices, and weather-resistant crop varieties is disseminated. This awareness is pivotal in shaping farmers' resilience strategies, enabling them to proactively respond to changing climatic conditions (Tham-agyekum et al. 2024).

Cooperatives act as sources of information, learning platforms, and social support that farmers can rely on when dealing with climate change. This implies that farmer adaptive capacity emerges from organizational contexts where farmers meaningfully interact, learn, and collaborate. Cooperatives are flexible in responding to the complexity and dynamics of member needs, creating linkages with other actors, and providing space for knowledge generation and sharing. A typical example of how the services provided by Cooperatives may influence farmer adaptive capacity is through extension services, which provide farmers with learning opportunities that enhance their adaptive capacity for farm resilience. In this way, FOs provide farmers with a space to experiment and innovate as a group or individually. Particularly, experimentation enables farmers to adapt to the continuously changing

environment as it produces innovations and generates local knowledge that improves farmer adaptive capacity. Innovation relies on access to finance, information, and other resources, which can be accessed through participation in supportive institutions such as FOs, especially for resource-constrained smallholder farmers.

2.5 Climate finance mechanisms and climate resilience

Adaptation finance mechanism in terms of infrastructure plays a critical role in enhancing climate resilience. Agricultural infrastructure refers to the diverse systems and networks of resources that are vital to produce, procure, preserve, process, and trade agricultural products (Niagara Agriculture Municipal Network 2021). It plays a vital role in the productivity, competitiveness and sustainability of the agriculture sector. Notable dimensions of infrastructure for climate resilience in agriculture include: Hard infrastructure is the natural and built assets, structures, facilities, equipment and networks that are essential for a competitive agriculture sector and resilient, sustainable food systems. Land, transportation, telecommunications, energy, and water systems, processing and storage facilities are examples of physical infrastructure essential to agriculture.

Recently, governments, researchers, and development practitioners have increasingly focused on improving the resilience of infrastructure to natural disasters, highlighting the key role infrastructure plays in broader community resilience amid climate variability and extreme events (Hallegatte et al., 2019). Reported losses from extreme weather events increased by 151% when compared to the total reported losses of US$1.3 trillion during 1978–1997 (UNDRR, 2020). Floods accounted for approximately 43% of recorded events affecting more than 2 billion people, followed by storms (28%) and earthquakes (8%) (CRED, 2020). During this period, climaterelated and geophysical disasters caused the deaths of 1.3 million people and left 4.4 billion people injured, homeless, displaced, or in need of emergency assistance. These staggering losses underscore the importance of disaster risk management (DRM) and the growing emphasis on climate-resilient infrastructure (UNDP, 2021; World Bank, 2020).These enormous economic losses of human life have promoted attention to the importance of disaster risk management (DRM) and the impacts of climate change, particularly in countries most vulnerable to natural hazards. As such, governments are tasked with ensuring that sufficient funds and expertise are available to develop and supply quality infrastructure that can also (a) better withstand and recover from disasters and (b) adjust to changing conditions associated with climate change.

In terms of adaptation finance mechanisms, public private partnerships require robust risk assessment. At the heart of every good PPP project is a robust risk assessment that evaluates all possible risks to the projects and assigns them to the party best able to manage them. Including an analysis of climate and disaster risk as part of this existing process only makes sense, as PPP project developers are seeking to understand any/all risks which may disrupt services and undercut their returns (Frisari et al. 2020). However, weak motivation and distrust by farmers limit the engagement of private enterprises in supporting farmers to adapt to drought.

A study conducted in Lujiang Flatland in the Nu River (Upper Salween) valley, China entitled *public-private partnership in enhancing farmers' adaptation to drought* underscored the strong link between public-private partnership and climate resilience especially in regards to drought risks. Notably, they acknowledged diversified funding sources whereby private firms often provide initial investment, while governments contribute through subsidies and infrastructure co-financing, and farmers pay user fees. This pooled financing approach reduces the financial burden on any single actor (UNESCAP, 2019; Zhang et al., 2018). Secondly, shared risk and benefits: Through cooperative mechanisms, actors share risks and enjoy mutual benefits. Farmers gain reliable irrigation services; governments fulfill public service mandates; and private actors earn returns through service fees or land use arrangements (Garrido et al., 2019). Thirdly, there is reduced uncertainty. Legal frameworks, government oversight, and community engagement foster trust and transparency, enhancing PPP effectiveness (ITF 2017). Lastly, there is enhanced integration of scientific and local knowledge. Private firms bring technical expertise, while farmers contribute valuable indigenous knowledge, leading to more responsive and context-specific solutions (FAO, 2019; Zhang et al., 2018). For example, while solar-powered irrigation systems were initially proposed in Mangdan, farmers requested electric systems due to the need for nighttime irrigation. Such participatory adjustments are critical for ensuring sustainability and usability. Furthermore, embedding irrigation services within local customary institutions fostered smoother implementation and local ownership (Bird, Carter, and Meinzen-dick 2024). The performance of PPP irrigation projects demonstrated clear benefits: expanded irrigation coverage, reduced irrigation costs (by 50–500%), and decreased labor demands by 50% (Zhang et al., 2018). These outcomes substantially strengthened farmers' adaptive capacity to drought and variability in water availability.

Nonetheless, challenges persist. Farmers in remote mountainous areas often lack experience negotiating with companies, and transport and market access limitations hinder their involvement. While formal regulations exist, their enforcement and the protection of stakeholder interests remain uncertain (World Bank, 2021). Moreover, the inflexible nature of some PPPs, especially those focused solely on large-scale infrastructure, may limit their utility during years of adequate rainfall (Zhang et al., 2018; UNDP, 2022). Thus, more flexible and diversified models of PPPs, tailored to the unique endowments and social dynamics of communities, are needed. Each community should explore its endowment, and to develop diversified PPP project that best suit itself. It needs a lot of trying and learning processes to find the suitable way (Zhang et al. 2018)

2.6 Summary

In summary therefore, attempts to achieve climate resilience in agricultural context requires critical assessment of the major risks that farmers face, notably: production, flood, and livelihood risks. It is upon this that a feasible risk management plan and action can be formulated. In addition to risk assessment and planning, the literature underscores the need for an integrated approach involving application of appropriate adaptation finance mechanisms as well as maximum exploitation of all potential benefits that cooperative society presents such as information sharing, training, among others. Also from the above literature is the relevance of information sharing. A better understanding of farmers' information needs and information sources could help guide extension and other agricultural programs to better target specific groups of farmers for appropriate interventions. This implies the need for proper packaging of agricultural information, taking into account the nature of communication and channels used. Therefore, extension workers should harness all the potential benefits associated with training, information sharing, and supplies among others within farmer groups and cooperative at large.

In relation to Tochi Irrigation Scheme it should be noted that River Tochi and its catchment area will naturally keep on changing or evolving. Hence, the attempt to maintain its natural system static might be futile. Therefore, for the community in question to benefit from the River, flexible adaptation measures, tailored to specific climatic risks must be put in place so at to cope with the ever changing environment or ecosystem within which the project is located. This then will enhance climate resilience of the farmers in the project catchment area.

2.7 Literature gaps

The above literature presents gaps in a number of areas that this study seeks to address. For instance, the literature presented above does not provide adequate information on climate resilience among rice growers organised as a cooperative society under an irrigation scheme. It ought to be noted that different climatic situations are unique in terms of their features.

Furthermore, the literature does not provide adequate information on public-private partnership and climate resilience in the context of an irrigation scheme. Therefore, in this context the study will address gaps regarding adaptation finance mechanisms, production risks, flood risks, livelihood risks, group dynamics, and information sharing among rice growers in Tochi irrigation cooperative society. Additionally, the study will address the literature gap on the relationship between public-private partnership and climate resilience in the context of an irrigation project.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

This chapter consisted of the methods that the researcher used to collect and analyze data to ensure validity and reliability of findings. The chapter includes: introduction, scope of the study, research design, description of the population, ethical considerations, sampling strategies, data collection methods, instruments and procedures, data quality control, analysis, plan for dissemination of results, and limitations of the study

3.1 Research design

This study adopted a mixed methods research design, specifically integrating both quantitative and qualitative approaches, alongside a correlational study design. The use of mixed methods enabled the researcher to obtain a comprehensive understanding of the research problem by combining the strengths of both approaches. The quantitative component of the study was based on a correlational design, which sought to examine the nature and strength of relationships between the key study variables. In this regard, the study assessed the association between independent variables (adaptation finance mechanisms) and dependent variables (climate resilience indicators). The correlational design was appropriate because it allowed for statistical analysis of relationships without manipulating variables, thereby maintaining the natural setting of the study.

On the other hand, the qualitative component was employed to complement and enrich the quantitative findings by providing deeper insights into participants' experiences, perceptions, and contextual realities. Qualitative data were collected through key informant interviews, allowing participants to express their views in their own words. This helped to explain and interpret the statistical relationships identified in the quantitative phase. The integration of both methods occurred at the data interpretation stage, where qualitative findings were used to support, clarify, and expand upon the quantitative results. This triangulation enhanced the validity and reliability of the study findings by ensuring that different sources of data converged on similar conclusions.

3.2 Study Population

The study population involved members of Tochi Irrigation Cooperative Society who were approximately 100 rice farmers. These farmers hail from Acaba, Minakulu, and Ngai Sub counties in Oyam district, which are all within the project catchment area. It is from this study population that the samples were derived.

3.3 Sampling technique

Simple random sampling was used to sample farmers in the cooperative society. Here the researcher obtained names of famers from the three sub counties under the study so that the sample size is representative enough for all the farmers who hail from the three sub counties. Their names were picked randomly until the sample size was realized.

The researcher used purposive sampling to determine the samples of Agricultural extension staff, Environment focal person, Sub county chief, Community Development Officers, and private partners in the irrigation scheme. This category of respondents were deliberately picked on the basis of their few numbers and the qualities that are relevant for the study. In this case, the selected participants have the required knowledge and experience about Tochi irrigation project but particularly Tochi Irrigation Cooperative Society.

3.4 Sample size

The sample size for this study was determined using Cochran's (1977), followed by finite population correction (FPC). The Cochran Formula is provided by:

$$n_0 = \frac{Z^2 p(1-p)}{e^2}$$

Where:

n_0= initial sample size
Z = 1.96 (95% confidence level)
p = 0.5 (maximum variability)
e = 0.05 (margin of error)

$$n_0 = \frac{1.96^2 * 0.5(1-0.5)}{0.05^2}$$

$$n_0 = 384.16 \approx 384$$

Finite Population Correction (FPC)

$n = n_o / (1 + (n_o - 1) / N)$

$N = 100$

$n = 384 / (1 + 383 / 100)$

$n = 384 / 4.83$

$n = 79.5 \approx 79$

The final sample size of the farmers in the cooperative society for the study was therefore 79 participants for the survey.

Table 1: Sample size

S/N	Category of respondents	Population	Sample Size	Sampling technique
1.	Farmers in the cooperative society	100	79	Simple random sampling
2.	Agricultural extension staff	16	03	Purposive sampling
3.	Environment focal person	01	01	No sampling conducted
4.	Sub county chiefs	12	03	Purposive sampling
5.	Community Development Officers	12	03	Purposive sampling
6.	Private partners in the irrigation scheme	4	03	Purposive sampling
	TOTAL		**92**	

3.5 Data Collection methods

3.5 .1 Survey

The researcher used survey method of data collection. This method allowed the researcher to directly and quickly collect primary data from the respondents. More still, the survey method was used because it is more efficient, thereby allowing the researcher to collected data from a larger sample. Lastly, this method enabled the researcher to use standardized questionnaires, hence maintaining consistency in data collection thus, enabling easier data analysis and presentation by the researcher.

3.5.2 Interview

This is the second method of data collection that the researcher used during the study. This method involved direct interaction between the interviewer and the respondents. Therefore, researcher asked questions face to face with participants and recorded the responses, allowing for in-depth exploration of the respondents' through probing for experiences, perspectives, and insights regarding adaptation finance mechanisms and climate resilience, among.

3.6 Data collection instruments

The data collection instruments used in this study included questionnaires and interview guide.

3.6.1 Questionnaires

The questionnaires consisted of closed-ended questions. Close-ended questions were administered since they are simple to administer and analyze. Questionnaire was structured according to the research questions also considering all the key variables in the conceptual framework. Responses to the questions in the questionnaire included: The 5-Point Likert Scale; very high, high, moderate, low very low will be used in the section of risks. Lastly, the section of infrastructure was answered using yes and no.

3.6.2 Interview guide

In this data collection tool there was a set of questions that the researcher used to conduct interviews. The interview guide served as a roadmap for the interviewer, allowing him to cover important variables under the proposed study, thus facilitating a consistent and systematic data collection process. The researcher organized the structure and flow of the interview guide in a logical and coherent manner, taking into account the research questions.

3.7 Data quality control

For purposes of reliability and validity of data, the researcher was guided by the research objectives and questions throughout the study. Additionally, the data collected was reviewed to minimize errors and ensure validity. Lastly, the researcher used appropriate data collection instruments and probing was used for purposes of clarity during data collection. The two aspects of data quality were achieved as follows:

3.7.1 Reliability

The reliability of the instruments was improved through pretesting of pilot samples. This allowed for the re-phrasing of some questions. Furthermore, reliability of the scales was done with the application of the Cronbach's Alpha Coefficient for the computations so as to check for the internal consistency of the scales, Cronbach's alpha was used to determine the reliability of data. A Cronbach's alpha value of 0.7 and above was considered reliable as noted by (George and Mallery, 2003).

3.7.2 Validity

This entail the extent to which a test measures what the researcher actually is interested to measure. Therefore, the research instruments will be presented to the research experts to give their assessment of the items in the instruments from where content validity index (CVI) was computed using the formula below:

$$CVI = \frac{\text{Number of items considered relevant}}{\text{Total number of items in the instrument}}$$

Subsequently, the researcher then determined the validity using content validity index. According to Amin, (2005), the instrument with CVI of 0.7 and above will be acceptable and considered a valid instrument.

3.8 Data analysis

The data was transcribed verbatim. The researcher read all the transcripts to get an overall understanding. Secondly, the researcher used quantitative data analysis in which numbers were analyzed. Similarly, some data was converted into numbers without losing meanings. Both descriptive statistics and inferential statistics were analyzed under the quantitative analysis. Data from the field was sorted, edited and coded to have the required quality, accuracy and completeness. The Statistical Package for Social Sciences (SPSS) was used for analysis of data collected. Descriptive statistics was used to present the results in terms of mean, frequency and percentages. Inferential statistics was employed to analyze the relationship and effect that exist between or among the study variables by using correlation and regression analysis respectively.

For analysis of qualitative data, thematic analysis was used. This included data transcription, coding and categorization in to themes. The findings were then presented in a coherent and organized manner with narratives to support the analysis and reported verbatim.

3.9 Dissemination

This section includes different channels through which information in the report is distributed to various audience. As required, the report of this study was submitted to the Directorate of Graduate Studies of Gulu University. For purposes of reaching larger audience and easy of accessibility, the researcher may publish this report in a peer-reviewed journal, depending on availability of resources.

3.10 Ethical considerations

This report was approved by the Faculty of Business and Development Studies of Gulu University. Written informed consent was obtained of each respondent aged 18 years or more. Respect for participants was accorded, do no harm principle was applied so that harm would not be inflicted on the respondents and justice in terms of fair and equal treatment was given to the respondents or participants.

3.11 Constraints encountered

The researcher encountered late return of the questionnaires by some respondents such as Local Government officials, attributed to their busy schedules. However, the researcher addressed late return of questionnaires by engaging the respondents early enough so as to give them ample time to fill in and also extended dates for return of the questionnaires.

CHAPTER FOUR

DATA PRESENTATION, ANALYSIS AND INTERPRETATION

4.0 Introduction

This chapter presents the findings from the field survey and interviews involving 79 respondents. Data were analyzed using SPSS, and results are presented through descriptive statistics (frequencies, percentages) and visualizations using tables. The chapter is organized according to the thematic areas derived from the research objectives as follows:

4.1 Demographic characteristics of respondents

This section presents disaggregated statistics of the respondents in terms gender, age, and levels of education. It is upon these data that critical inferences are made regarding the research. The section includes the distribution of respondents by gender, hence significant in providing an overview of gender dynamics in the study. Table 2 presents the distribution of the respondents by their gender age group and education levels in which the total number of respondents was 79. The breakdown of the distribution is as follow.

Table 2: Distribution of the respondents by gender, age group and education levels

Gender	Frequency	Percentage (%)
Male	47	59.5
Female	32	40.5
Total	**79**	**100**
Education Level	**Frequency**	**Percentage (%)**
A level	14	17.7
Never attended formal education	14	17.7
Primary	21	26.6
Certificate	12	15.2
Master’s degree	1	1.3
O level	7	8.9
Degree	6	7.6
Diploma	4	5.1
Total	**79**	**100**
Age Group	**Frequency**	**Percentage (%**
25–35 years	27	34.2
36–45 years	26	32.9
46 years and above	14	17.7
Under 24 years	12	15.2
Total	**79**	**100**

4.1.1 Gender distribution

Table 2 shows that out of 79 respondents, 59.5% were male and 40.5% were female. This distribution indicates a male dominance in farming activities within TIS, likely influenced by cultural norms and traditional roles in resource control.

4.1.2 Age Distribution

Table 3 shows that the majority of respondents (67.1%) were aged between 25 and 45 years, with 34.2% aged 25–35 and 32.9% aged 36–45. Respondents under 24 accounted for 15.2%, while those above 46 made up 17.7%.

4.1.3 Education level

With reference to table 2 above, it can be noted that respondents' educational levels varied, with 29.2% holding tertiary qualifications (certificate and above), and 44.3% reporting primary or informal education. The rest held A-level (17.7%) or O-level (8.9%) qualifications. A relatively educated population can facilitate effective utilization of climate finance mechanisms, such as digital loan platforms, insurance schemes, and adaptation subsidies.

4.2 Adaptation finance mechanisms

This section presents both qualitative and quantitative results on adaptation finance mechanisms. Analysis of the interviews and surveys both revealed that adaptation finance mechanisms are operationalized through infrastructure investment and public–private partnerships. These mechanisms provide support that enables farmers to cope with climate variability.

4.2.1 Infrastructure

This section includes both qualitative and quantitative analyses of data obtained about the availability of specific infrastructure attributed to infrastructure grants. The findings of the interviews conducted concur with the results of the survey.

Table 3: Infrastructure

Infrastructure	Frequency (Yes)	(%)	Frequency (No)	(%)	Total (%)
Skilled extension services	54	68.4	25	31.6	100
Water reservoir	53	67.1	26	32.9	100
Roads	51	64.6	28	35.4	100
Storage	49	62.0	30	38.0	100
Bridges	49	62.0	30	38	100
Equipment	48	60.8	31	39.2	100
Information system	48	60.8	31	39.2	100
Agricultural machinery	47	59.5	32	40.5	100
Energy infrastructure	47	59.5	32	40.5	100
Land	46	58.2	33	41.8	100
Water canals	44	55.7	35	44.3	100
Transportation equipment	43	54.4	36	45.6	100
Dams	42	53.2	37	46.8	100

Table 3 presents findings on infrastructure disaggregated in terms of Yes and No responses with their corresponding percentages. The following include the infrastructure assessed during the study: Skilled extension services, water reservoir, roads, storage, bridges, equipment, information system, agricultural machinery, energy infrastructure, land, water canals, transportation equipment, and dams. The most frequently reported infrastructure includes skilled extension services (68.4%), water reservoirs (67.1%), and road networks (64.6%). These assets form the backbone for effective irrigation operations and provide a foundation for climate-resilient agricultural practices. In other words, it implies progress in physical and human capacity to support irrigation and agricultural activities. Other moderately reported infrastructures include agricultural machinery (59.5%), storage (62.0%), and information systems (60.8%). However, low reporting of dams (53.2%) and transportation equipment (54.4%) points to critical infrastructure gaps. Investment in these areas through targeted adaptation financing (e.g., climate bonds, government subsidies, donor funding) is vital to improve water regulation and logistics during extreme weather events.

From the interviews conducted; participants consistently highlighted infrastructure development as a major mechanism through which adaptation finance is implemented in the irrigation scheme. Participants reported that the irrigation scheme includes water canals, pumping stations, reservoirs, and water distribution channels that ensure continuous water supply to farmers. These infrastructures reduce reliance on rainfall and allow farmers to maintain agricultural production during dry periods. One agricultural extension officer explained: “The irrigation canals and pumping stations ensure that farmers have reliable

access to water even during prolonged dry seasons." The findings indicate that adaptation finance investments in irrigation infrastructure directly reduce climate-related agricultural risks.

Drainage and flood control infrastructure

Participants also identified drainage systems and water management channels as key infrastructures supporting climate resilience. Drainage systems regulate water flow, prevent waterlogging, and reduce flood damage. The environment focal person noted: "Drainage channels were constructed to control excess water and reduce flooding within the irrigation scheme." This suggests that adaptation investments are not limited to water supply but also address climate hazards such as flooding.

Farm accessibility and support infrastructure

Participants further identified supporting infrastructures such as farm access roads and demonstration plots. These infrastructures improve farmers' ability to transport produce and access agricultural training. Community development officers explained that demonstration plots serve as learning platforms for climate-smart agriculture practices. The findings suggest that adaptation finance at the irrigation scheme is primarily channeled into physical infrastructure that enhances agricultural productivity and reduces vulnerability to climate variability. These findings concur with the quantitative results presented in table 3.

4.2.2 Public-Private Partnership (PPP) mechanisms

This section includes both quantitative and qualitative analyses of the various PPP mechanisms adopted and used by the farmers at Tochi irrigation scheme so as to facilitate climate resilience.

Table 4: Public-Private Mechanisms

PPP Mechanism	Frequency (Yes)	Percentage (%)	Frequency (No)	Percentage (%)	Total (%)
Shared proceeds	49	62.0	30	38.0	100
Collaborative policy formulation	47	59.5	32	40.5	100
Sharing of resources	46	58.2	33	41.8	100
Sharing of labor	45	57.0	34	43.0	100
Market access	45	57.0	34	43.0	100
Shared risk management	44	55.7	35	44.3	100
Collaborative research & Innovation	44	55.7	35	44.3	100
Co-funding	43	54.4	36	45.6	100
Technology transfer	42	53.2	47	46.8	100
Farmer capacity building	41	51.9	38	48.1	100
Finance and investment access	41	51.9	38	48.1	100
Policy implementation	41	51.9	38	48.1	100
Gov't-private collaboration	39	49.4	40	50.6	100

Table 4 presents findings on the PPP mechanisms adopted. Thirteen PPP mechanisms were assessed during the study as presented in the following table. Table 4 shows that respondents indicated high levels of participation in shared proceeds (62.0%) and collaborative policy formulation (59.5%), suggesting that PPPs are playing a role in governance and resource management. Alternatively, the significant number of respondents acknowledging the presence of shared proceeds (62.0%) and collaborative policy formulation (59.5%), denoted active PPP involvement in strategic areas. Other mechanisms such as co-funding (54.4%), technology transfer (53.2%), and farmer capacity building (51.9%) show moderate development. However, finance and investment access (51.9%) and government-private collaboration (49.4%) remain weak, underlining a systemic gap in resource mobilization and institutional cooperation. Strengthening PPPs through inclusive financing models, risk-sharing arrangements, and innovation partnerships is crucial for enhancing adaptive capacity within TIS.

From the key informant interviews conducted, qualitative results indicated that the irrigation scheme operates under a public–private partnership (PPP) model, where government institutions collaborate with private sector actors and community organizations. Three key subthemes emerged.

Government investment and institutional support

Participants emphasized the critical role of government in initiating and financing the irrigation project in which they cited: construction of irrigation infrastructure; provision of agricultural extension services; institutional coordination and policy support; and capacity building for farmers A sub-county chief explained:

> *"The government financed most of the irrigation infrastructure and continues to support farmers through extension services."*

These findings indicate that government acts as the primary financier and facilitator of adaptation interventions.

Private sector investment and technical support

Under this subtheme, participants noted that private sector partners contributed the following: investment in irrigation technologies; supply of agricultural inputs; provision of technical expertise; and establishment of market linkages. In tehe same A private partner noted: "We provide improved farming technologies and link farmers to reliable markets so the irrigation scheme remains sustainable." This demonstrates that private sector participation strengthens economic viability and technological innovation within the irrigation scheme.

Complementary roles in climate adaptation

Participants highlighted that government and private actors perform complementary roles. Government provides infrastructure and institutional frameworks, while private actors enhance efficiency, innovation, and market integration. This collaboration increases the overall effectiveness of adaptation finance. The PPP model provides a multi-stakeholder financing structure that mobilizes both public and private resources to support climate adaptation.

4.3 Climate resilience

This section presents qualitative and quantitative results on climate resilience. The irrigation scheme has strengthened farmers' resilience against several categories of climate risks. This

section is presented under the following themes: production risk resilience; flood risk resilience; and livelihood resilience.

4.3.1 Production risks

In this section, the report presents findings on various production risk variables as shown in the table 5. Table 5 shows results of the survey, thereafter the section presents qualitative results obtained from the key informant interviews conducted.

Table 5: Production risks

Risk Item	1	2	3	4	5	Mean
Increased cost of inputs	0	4	10	30	35	4.22
Inadequate access to machinery	0	2	13	31	33	4.20
Delayed planting	1	4	11	33	30	4.10
Risk of yield reduction	0	5	15	31	28	4.04
Low prices for crops	5	2	14	29	29	3.95
Equipment failure	8	10	16	25	20	3.49
Delayed harvesting	5	9	23	25	17	3.51
Crop failure	10	11	34	15	9	3.03
Reduced storage space	31	30	15	2	1	1.89

Table 5 presents a summary of the findings on the 9 production risk variables that were considered during the research. Table 5 summarizes the perceptions of farmers on nine production-related risks. The results highlight which risks are considered most pressing and the average severity assigned to them. From the analysis of production risks reveals a high level of concern among farmers regarding several key aspects of agricultural productivity as indicated below: Increased cost of inputs was rated as a high or very high risk with a mean of 4.22 equivalent to 82.3% of respondents (38.0% scored it 4, while 44.3% scored it 5). Inadequate access to farm machinery was similarly considered a major constraint, with a mean score of 4.20. Delayed planting was also a prominent issue scoring a mean of 4.10 which is approximately 79.8% of respondents. Risk of yield reduction was rated at a mean score of 4.04%, reflecting widespread concern about production instability. Low crop prices were perceived as a considerable risk with mean score of 3.95. Equipment failure (3.49) and delayed harvesting (3.51) were viewed as moderate to high risks. Crop failure received more moderate scores, with the highest mean score of 3.03, indicating a perceived moderate level of risk. Reduced storage space was not considered a serious concern with the lowest risk. The findings suggest that production-related risks are a central concern among farmers in the

scheme. High scoring on cost-related and timing-related variables indicates systemic production challenges, particularly those related to access to essential inputs, mechanization, and optimal planting periods. Conversely, risks such as storage space appear to be less pressing within the local context.

Participants described production risks as uncertainties affecting agricultural productivity. Common climate-related risks identified during the interviews include drought; erratic rainfall; and extreme weather events. The environment focal person explained: "Production risks arise mainly from unpredictable rainfall and drought conditions that affect crop growth." Additionally, participants also identified high costs of agricultural inputs, crop failure due crop diseases, and declining soil fertility as major threats to agricultural productivity. Irrigation sometimes increases pest prevalence due to improved moisture conditions.

Participants indicated that irrigation reduces production risks mainly through reliable water supply; increased cropping seasons; and crop diversification. An extension officer explained: *"Farmers are now able to grow crops more than once in a year instead of relying on seasonal rains."* Irrigation improves resilience by reducing dependence on climate-sensitive rainfall patterns and stabilizing agricultural production.

4.3.2 Flood risks

Under flood risks, this section includes presentation of findings on flood risk variables that were considered during the study as indicated in table 6. This section also includes qualitative results on flood risks, obtained from interviews.

Table 6: Flood risks

Risk Item	1	2	3	4	5	Mean
Destruction of crops	0	0	1	18	60	4.75
Destruction of road infrastructure	0	0	1	23	55	4.68
Displacement of farmers	0	1	13	35	30	4.19
Flood frequency	0	6	15	28	30	4.04
Destruction of storage infrastructure	2	3	30	20	24	3.77
Flood severity	30	24	15	10	0	2.06
Destruction of farm equipment	38	25	9	6	1	1.82
Death of farmers	68	10	1	0	0	1.15

Table 6 presents a summary of the findings on the eight flood risk variables that were considered during the research. Flood risks were evaluated to understand their impact on

infrastructure, production, and livelihoods. From table 6 flood risks were assessed based on their perceived impact on agricultural operations, infrastructure, and livelihoods. Destruction of crops and destruction of road infrastructure were perceived as severe, with mean scores of 4.75 and 4.68, respectively, scoring these risks as very high. Displacement of farmers was also seen as significant, with mean scores of 4.19. Flood frequency had a mean score of 4.04, indicating that flooding is a recurring challenge. Destruction of storage infrastructure received a wider distribution, with 3.77 mean score, indicating a moderate to high level of concern. Flood severity was not perceived as a major issue, scoring only 2.06. Destruction of farm equipment and death of farmers had the lowest scores of 1.82 and 1.15 respectively, indicating very low risk. Therefore, these findings highlight that while flood-related impacts on crops, roads, and farmer displacement are critical issues, the perceived severity and fatality of flood events remain low. This suggests that although floods are frequent and damaging to infrastructure and production, they are not typically life-threatening within the study area.

Participants noted that flooding occasionally occurs within the irrigation scheme, especially during heavy rainfall. Findings indicate that flooding mainly occurs due to heavy rainfall events and overflow of irrigation canals. However, participants reported that flood severity has reduced compared to the period before the irrigation infrastructure was established.

Flooding creates several risks, including crop destruction, soil erosion, and damage to farm infrastructure. These risks disrupt agricultural production and reduce farmers' incomes. Participants identified several flood management strategies, notably: Drainage infrastructure, water regulation systems, maintenance of irrigation canals, and farmer training on water management. These strategies help minimize the negative impacts of flooding. Flood management systems within the irrigation scheme represent an important climate adaptation measure that reduces disaster-related agricultural losses.

4.3.3 Livelihood risks

This section presents the findings on livelihood risks at Tochi Irrigation scheme. The section starts with quantitative results on livelihood risks and concludes with qualitative findings as shown in table 7:

Table 7: Livelihood risks

Risk Item	1	2	3	4	5	Mean
Decline in income	3	6	12	28	30	3.96
Financial distress (debts)	1	3	18	22	35	4.10
Food shortage	7	12	15	20	25	3.56
Increased unemployment	11	18	10	22	18	3.23
Decline in crop production	11	14	25	19	10	3.04
Inadequate access to information	8	10	35	17	9	3.11
Loss of financial capital	12	12	30	17	8	2.96
Decline in prices	20	25	15	10	9	2.53

Table 7 presents a summary of the findings on the eight livelihood risk variables that were considered during the research. It includes livelihood risks encompassing economic and social consequences of climate change for the farmers. From the findings, the following can be noted: Financial distress (debts) was perceived as a serious risk, with a mean score of 4.10. Decline in income followed a similar pattern, with a high mean score of 3.96. Food shortage scored 3.56 indicating a moderate to high concern among farmers. Increased unemployment had 3.23 mean score, suggesting possible labor market vulnerability. Decline in crop production was rated moderately, with 3.04, indicating perceived long-term decline in agricultural output. Inadequate access to information received mixed responses, with mean score of 3.11. The data indicate that economic insecurity particularly in the form of indebtedness and declining income is a major livelihood risk for farmers in the scheme. Moderate concern over food access and unemployment also points to the broader socio-economic vulnerabilities affecting household resilience. Information access and price fluctuations, though relevant, appear to be of secondary concern.

Participants reported that the irrigation scheme has strengthened farmers' livelihoods through increased agricultural productivity; improved food security; and employment and economic opportunities. These have minimized risks associated with food shortage, crop production, and unemployment.

Improved water availability allows farmers to increase crop yields and expand production. Higher productivity contributes to increased household income. However, financial distress and high debt burden was reported. Participants noted that the irrigation enabled moderately consistent food production throughout the year, hence reducing seasonal food shortages.

The irrigation scheme has created employment opportunities in: Farming activities, input supply, and produce marketing. Private partners noted that market linkages have helped farmers earn higher incomes. The irrigation scheme enhances livelihood resilience by improving economic stability, food security, and income diversification.

4.3.4 Cooperative governance

Table 8: Descriptive statistics on cooperative governance

Governance Element	Percentage (%)
Active participation in decision-making	65.8
Transparency in financial reporting	63.3
Accountability structures in place	61.0
Member satisfaction with leadership	59.5
Timely communication and meetings	58.2

Descriptive statistics were first computed to assess the prevalence of key governance elements among agricultural cooperatives within the scheme. Table 8 summarizes findings on the key elements of cooperative governance, namely: Active participation in decision-making, transparency in financial reporting, accountability structures in place, member satisfaction with leadership, and timely communication and meetings. From table 8, active participation in decision making and transparency in financial reporting scored highest with 65.8% and 63.3% respectively while accountability structures in place had a moderate score with 61% of the 79 respondents acknowledged the presence of accountability structures. Lastly, member satisfaction with leadership, and timely communication and meetings had 59.5% and 58.2% respectively. The results indicate a moderate to high prevalence of effective cooperative governance, providing a suitable foundation to examine its moderating effect on AFMs and climate resilience.

The cooperative society was identified as an important institutional mechanism for organizing farmers and facilitating adaptation. Participants reported that multiple farmer groups operate under the Tochi Irrigation Cooperative Society.

Findings show that farmer groups facilitate coordination of irrigation activities; access to agricultural inputs; and participation in training programs. Community development officers noted that farmer groups help mobilize farmers for collective action.

From the interviews conducted, results indicate that farmer groups are governed through: Elected leadership committees, cooperative bylaws, and regular meetings. This governance structure promotes accountability and efficient resource management. Collective organization enables farmers to manage shared irrigation resources and strengthen their bargaining power.

Participants emphasized that information sharing within the cooperative society supports climate adaptation. This is achieved through trainings, meetings and timely communication. Findings show that information commonly shared includes: weather and climate forecasts; pest and disease management; agricultural best practices; and market price information

From the key informant interviews conducted, findings show that key sources of information included: agricultural extension services; government agencies; private sector partners; and farmer group meetings. Additionally, findings show that timely information enables farmers to plan planting seasons, adopt climate-smart agriculture practices, and respond quickly to emerging risks.

An extension officer explained: “Access to reliable information allows farmers to prepare for climate changes and manage their crops better.” Therefore, it is evident that information sharing strengthens farmers’ adaptive capacity by improving knowledge, decision-making, and responsiveness to climate risks.

4.4 Relationship between adaptation finance mechanisms and climate resilience

This section presents results on the relationship between adaptation finance mechanisms and climate resilience. The section includes correlational analyses between infrastructure and climate resilience; and public-private partnership and climate resilience.

4.4.1 Correlation analysis between infrastructure and climate resilience

This section includes presentation of correlation analysis between infrastructure and climate resilience as indicated in table 9. The section includes the indicators under infrastructure component versus production risks, flood risks, and livelihood risks.

Table 9: Correlation Analysis between infrastructure and climate resilience

Infrastructure Component	Production Risks (r)	Flood Risks (r)	Livelihood Risks (r)
Skilled extension services	-0.68***	-0.54**	-0.61***
Water reservoir	-0.65***	-0.51**	-0.57**
Roads	-0.70***	-0.63***	-0.60***
Storage	-0.59**	-0.52**	-0.50**
Bridges	-0.60***	-0.61***	-0.58**
Equipment	-0.58**	-0.53**	-0.52**
Information system	-0.60***	-0.57**	-0.55**
Agricultural machinery	-0.61***	-0.56**	-0.59**
Energy infrastructure	-0.58**	-0.50**	-0.53**
Land	-0.57**	-0.49*	-0.50**
Water canals	-0.55**	-0.51**	-0.47*
Transportation equipment	-0.54**	-0.53**	-0.49*
Dams	-0.53**	-0.52**	-0.48*

Notes: *** = Significance at 0.1%; ** = Significance at 1%; *= Significance at 5%

Table 9 illustrates the correlations between various infrastructure components and indicators of climate resilience. The findings reveal statistically significant negative correlations across all infrastructure variables and resilience risks, suggesting that greater availability and functionality of infrastructure contributes to reducing production, flood, and livelihood risks. From table 9 the infrastructure component most strongly correlated with reduced production risks is roads ($r = 0.70$, $p < 0.001$), followed by skilled extension services and water reservoirs. These results highlight the importance of transport and technical infrastructure in supporting agricultural productivity and resilience. Overall, the correlation results show a strong negative correlation between infrastructure availability and both production risks ($r = -0.613$) and flood risks ($r = 0.575$). This indicates that as infrastructure improves (such roads, water reservoirs, machinery), the perceived production and flood risks decrease. Additionally, the correlation with livelihood risks is slightly lower ($r = -0.541$), but still statistically significant ($p < 0.01$), suggesting that infrastructure positively impacts income stability, access to markets, and reduces vulnerability.

4.4.2 Correlation Analysis between PPP mechanisms and climate resilience

This section includes presentation of correlation analysis between PPP mechanisms and climate resilience as indicated in table 10. It includes the indicators under PPP mechanism versus production risks, flood risks, and livelihood risks.

Table 10: Correlation Analysis between PPP mechanisms and climate resilience

PPP Mechanism	Production Risks (r)	Flood Risks (r)	Livelihood Risks (r)
Shared proceeds	-0.66***	-0.59**	-0.62***
Collaborative policy	-0.62***	-0.55**	-0.60***
Sharing of resources	-0.59**	-0.51**	-0.57**
Sharing of labor	-0.57**	-0.49*	-0.55**
Market access	-0.58**	-0.50**	-0.56**
Shared risk management	-0.61***	-0.54**	-0.59**
Collaborative R&D	-0.59**	-0.53**	-0.57**
Co-funding	-0.60***	-0.52**	-0.58**
Technology transfer	-0.57**	-0.50**	-0.55**
Farmer capacity building	-0.56**	-0.51**	-0.53**
Finance & investment access	-0.55**	-0.49*	-0.52**
Policy implementation	-0.54**	-0.50**	-0.51**
Government-private collaboration	-0.52**	-0.47*	-0.50**

Notes: *** = Significance at 0.1%; ** = Significance at 1%; * = Significance at 5%; R & D – Research and Development

Table 10 presents the correlation analysis results between public-private partnership (PPP) mechanisms and climate resilience indicators. Each PPP mechanism shows a negative correlation with production, flood, and livelihood risks, implying that improvements in collaborative efforts between the public and private sectors are associated with reduced climate-related vulnerabilities. From table 10, the results demonstrate that strong and consistent public-private partnerships are crucial for reducing the impacts of climate risks. Key observations include shared proceeds with strong negative correlations across all risks, especially with production risks (-0.66) and livelihood risks (-0.62). Collaborative policy formulation and shared risk management also stand out, with correlations around -0.60, reinforcing the importance of inclusive governance. Mechanisms such as co-funding, collaborative R&D, and technology transfer similarly show moderate to strong inverse correlations. Relatively lower correlations are noted for government-private collaboration, pointing to possible gaps in institutional synergy that need strengthening. Overall, Table 10 underscores that strengthening PPPs across financial, technological, policy, and labor areas is essential for mitigating climate-induced production delays, infrastructural breakdowns, and socioeconomic disruptions.

4.5 Influence of cooperative governance on the relationship between adaptation finance mechanisms and climate resilience

This section presents results of a moderation analysis that evaluates the influence of cooperative governance (CG) on the relationship between adaptation finance mechanisms (AFMs), comprising infrastructure and public-private partnerships (PPP), and climate resilience risks, namely: production, flood, and livelihood risks. The analysis aims to determine whether cooperative governance strengthens or weakens the impact of AFMs on reducing climate risks.

Table 11: Consolidated moderation results for cooperative governance, adaptation finance mechanisms and climate-related risks

Predictor	Production risks B (SE)	t	p	Flood risks B (SE)	t	p	Livelihood risks B (SE)	t	p
Adaptation finance mechanism (AFM)	-0.55 (0.12)	-4.58	< .001	-0.41 (0.10)	-4.10	< .001	-0.48 (0.11)	-4.36	< .001
Cooperative governance (CG)	-0.30 (0.13)	-2.31	.025	-0.29 (0.12)	-2.42	.019	-0.26 (0.12)	-2.17	.034
AFM × CG interaction	-0.22 (0.09)	-2.44	.018	-0.18 (0.08)	-2.25	.027	-0.19 (0.08)	-2.38	.021

Notes: B = unstandardised regression coefficient; SE = standard error; t = t-statistic; p = significance level; AFM = adaptation finance mechanisms; CG = cooperative governance.

All p-values are two-tailed. Values reported as p = .000 in the original tables are presented as p < .001, consistent with statistical reporting conventions. The production-risk model uses infrastructure as the AFM indicator, the flood-risk model uses public–private partnerships (PPP), and the livelihood-risk model uses combined adaptation finance mechanisms. The table retains the coefficients reported in the original tables.

The results indicate that adaptation finance mechanisms are negatively and significantly associated with production risks ($B = -0.55$, $p < .001$), flood risks ($B = -0.41$, $p < .001$), and livelihood risks ($B = -0.48$, $p < .001$). These findings suggest that greater adaptation finance support is associated with lower levels of climate-related risks among farmers at Tochi Irrigation Scheme.

Cooperative governance also has statistically significant negative associations with production risks (B = −0.30, p = .025), flood risks (B = −0.29, p = .019), and livelihood risks (B = −0.26, p = .034).

Importantly, the interaction terms are statistically significant across all three models: production risks (B = −0.22, p = .018), flood risks (B = −0.18, p = .027), and livelihood risks (B = −0.19, p = 0.021). The negative interaction coefficients indicate that, assuming higher outcome scores represent greater risk, the negative association between adaptation finance mechanisms and climate-related risks becomes stronger as cooperative governance increases.

Overall, the findings support the conclusion that cooperative governance significantly moderates the relationships between adaptation finance mechanisms and all three climate-related risk outcomes. However, confirmation that governance strengthens these relationships in practice would ideally be supported by conditional-effects analysis or interaction plots. These findings were based on the following model-fit R^2=0.526 and F(3,75)=36.87).

CHAPTER FIVE

DISCUSSION OF FINDINGS

5.0 Introduction

This chapter critically discusses the findings presented in Chapter Four in relation to the study's objectives, theoretical framework, and existing literature. The aim is to contextualize the results within the broader discourse on climate finance, resilience building, and cooperative governance, specifically in the context of the Tochi Irrigation Scheme (TIS). The chapter is organized thematically to reflect the research objectives and key areas explored: demographic characteristics, infrastructure availability, and public-private partnerships (PPPs) as adaptation finance mechanisms.

5.1 Adaptation Finance Mechanisms at TIS

5.1.1 Infrastructure

The infrastructure profile at TICSillustrates both strengths and challenges. The relatively high availability of skilled extension services (68.4%), water reservoirs (67.1%), and access roads (64.6%) underscores the presence of foundational structures necessary for agricultural productivity and climate resilience. These infrastructural elements support timely information dissemination, efficient water management, and market access all of which are pivotal in mitigating the impacts of climatic hazards such as prolonged droughts and erratic rainfall (FAO, 2019; World Bank, 2020). However, the relatively lower availability of critical components such as dams (53.2%) and transportation equipment (54.4%) reflects systemic infrastructural gaps. Dams are essential for buffering seasonal water variability, while reliable transport infrastructure enables efficient movement of inputs and produce, especially during adverse weather events (IPCC, 2022). These deficiencies risk undermining the potential gains of existing infrastructure and highlight the need for more targeted climate finance interventions.

The moderate presence of energy infrastructure and agricultural machinery signals a missed opportunity for scaling adaptive technologies. In line with global best practices, decentralized renewable energy systems such as solar-powered irrigation have been identified as low-cost and scalable solutions in off-grid agricultural regions (IRENA, 2021). The establishment of machinerysharing schemes through cooperatives could also address capital constraints

commonly faced by smallholder farmers (Arbuckle et al., 2017). The findings point to the importance of complementing physical infrastructure with innovative financing instruments such as climate bonds, green credit lines, and blended finance models to sustain infrastructure development (Nakhooda et al., 2014). Without such financial vehicles, the long-term maintenance and expansion of infrastructure may remain constrained, thereby limiting adaptive capacity. These findings align with global trends showing that well-resourced infrastructure significantly enhances adaptive capacity (The World Bank 2020a).

5.1.2 PPP Mechanisms

The role of PPPs in climate adaptation is increasingly recognized for their potential to pool resources, share risks, and deliver context-specific solutions. At TIS, the study identified shared proceeds (62.0%) and collaborative policy formulation (59.5%) as the most prominent PPP mechanisms. These approaches foster inclusivity and shared responsibility among stakeholders, enhancing legitimacy and ensuring that adaptation initiatives align with local needs (Bryson, Crosby, & Bloomberg, 2014). However, moderate uptake in technology transfer (53.2%) and farmer capacity building (51.9%) reveals a gap in innovation diffusion. The integration of climatesmart technologies and practices is central to long-term adaptation, and PPPs offer a viable pathway for this through co-financing and knowledge sharing (UNFCCC, 2018). Capacity building is equally crucial, as it empowers farmers with the skills and information needed to adopt adaptive practices (Fisher et al., 2015).

The study also identified weak engagement in finance and investment access (51.9%) and government-private collaboration (49.4%), suggesting institutional bottlenecks and limited private sector incentives. This mirrors broader findings in sub-Saharan Africa, where unclear policy frameworks and poor coordination between stakeholders often hinder the scaling of PPPs (OECD, 2020). Enhancing PPP effectiveness at TICSwill require greater policy coherence, transparent contractual arrangements, and innovative financing mechanisms such as impact investing and performance-based subsidies. Strengthening PPPs in areas such as joint investment planning, risksharing, and value chain financing can catalyze resilient agricultural development. This approach is supported by empirical evidence that effective PPPs can leverage private sector capital and expertise to complement public adaptation initiatives (World Economic Forum, 2019). Therefore, institutional reforms to enhance stakeholder trust, streamline regulatory processes, and foster joint accountability are essential.

5.2 Climate resilience risks

5.2.1 Resilience to production risks

The analysis of production risks reveals that farmers at TICSface significant challenges in sustaining agricultural productivity under climate variability. Key production concerns such as the increased cost of inputs (mean = 4.22), inadequate access to machinery (mean = 4.20), and delayed planting (mean = 4.10) highlight systemic inefficiencies that heighten vulnerability. These findings resonate with the Sustainable Livelihoods Framework (SLF), which identifies physical and financial capital as essential assets for resilience. The predominance of cost and timing-related constraints suggests that production vulnerability is not solely a function of climate events, but also of infrastructural and institutional gaps that hinder timely farming operations. The relatively lower concern for reduced storage space (mean = 1.89) may reflect coping strategies or adaptive practices already in place (e.g., informal storage networks or reliance on just-in-time sales). These insights echo studies by (Mulinde et al. 2021) and Antwi-Agyei et al. (2018), which highlight that without access to affordable inputs and timely mechanization, climate adaptation remains largely aspirational for smallholder farmers. From the discussion, it can therefore be asserted that production risks are a central challenge to agricultural resilience.

5.2.2 Resilience to flood risks

Flood-related risks, particularly the destruction of crops (mean = 4.75) and road infrastructure (mean = 4.68), emerged as the most pressing environmental threats. These findings underscore the compounding nature of climate extremes, where infrastructural damage exacerbates production losses and disrupts market access. Interestingly, flood severity (mean = 2.06) and destruction of farm equipment (mean = 1.82) were rated significantly lower, while death of farmers (mean = 1.15) was the least concerning. This indicates that while floods are frequent and destructive, their intensity and direct human toll are perceived as manageable. Such localized perceptions of flood risk are supported by (Adger, Arnell, and Tompkins 2005), who argue that vulnerability is socially constructed and mediated by context-specific adaptive capacities. The moderate risk attributed to displacement of farmers (mean = 4.19) further points to a reality where floods disrupt but do not necessarily uproot livelihoods completely perhaps due to community-based coping mechanisms or the spatial characteristics of floodwaters within the TICSarea. Therefore the study revealed that although flood risk is severe, it has non-lethal impacts.

5.2.3 Resilience to livelihood risks

Livelihood risks such as financial distress (mean = 4.10) and decline in income (mean = 3.96) reflect the socio-economic dimensions of climate vulnerability. These outcomes emphasize the indirect but profound impact of climate shocks on household welfare, supporting the assertion that climate change is as much an economic as it is an environmental crisis. The moderate concerns around food shortage (mean = 3.56) and unemployment (mean = 3.23) highlight latent threats to food and job security. These findings align with literature on rural livelihoods under stress, such as the work of (Scoones 2014) and IPCC (2022), which link environmental variability to chronic poverty and livelihood degradation. The relatively lower concern for price volatility (mean = 2.53) suggests either adaptive marketing behaviors or a normalization of market fluctuations. This interpretation aligns with Sen's entitlement theory, which postulates that food and income insecurity arise not solely from supply shocks but from disrupted access to economic resources and opportunities.

5.3 Correlation between adaptation finance mechanisms and climate resilience

The results demonstrate a consistent and significant inverse relationship between adaptation finance mechanisms and the three indicators of climate-related risk. This suggests that improvements in infrastructure and PPP mechanisms are instrumental in mitigating the adverse effects of climate variability and change. The correlation coefficients, all of which are negative, imply that increased investment in these adaptation mechanisms is associated with reduced vulnerability in agricultural production, flood exposure, and household livelihoods.

5.3.1 Correlation between Infrastructure and Climate Resilience

The study findings indicate that robust and well-distributed infrastructure serves as a vital pillar in enhancing the adaptive capacity of communities. Among the infrastructure components analyzed, road infrastructure showed the strongest negative correlation with production risks (-0.70), suggesting that improved road networks significantly ease market access, enhance timely delivery of agricultural inputs, and reduce post-harvest losses. This aligns with the findings of (Dansoabbeam et al. 2021) and Alhassan & Kuwornu (2014), who highlighted the central role of road access in improving agricultural productivity in Sub-Saharan Africa. Skilled extension services (0.68) and water reservoirs (-0.65) also emerged as crucial factors in reducing production risks. Skilled extension officers provide technical

guidance, introduce adaptive technologies, and build farmer capacity, which collectively enhance preparedness and response to climate variability. Likewise, water reservoirs provide critical support in buffering rainfall variability, ensuring steady water supply during dry spells.

Furthermore, bridges, information systems, and agricultural machinery displayed notable negative correlations with both flood and livelihood risks, indicating their role in enhancing physical and socio-economic resilience. For example, bridges improve connectivity during floods, reducing isolation and ensuring access to markets and services. Information systems aid in early warning dissemination and timely response, while machinery contributes to production efficiency even under adverse weather conditions. Although dams, transportation equipment, and water canals showed comparatively weaker correlations, their roles should not be overlooked. These components provide long-term resilience benefits, particularly in irrigation, storage, and logistical support. However, the moderate strength of their relationships suggests the need for more targeted and integrated investment strategies in these areas. The findings affirm that infrastructure is not merely a supporting mechanism but a core determinant of community resilience. Strategic investments in climate-smart infrastructure can simultaneously reduce production bottlenecks, minimize flood risks, and sustain livelihoods in climate-sensitive sectors.

5.3.2 Correlation between PPP Mechanisms and Climate Resilience

The analysis also reveals that public-private partnerships (PPPs) are integral to building climate resilience, particularly through collaborative and inclusive approaches. Shared proceeds stood out with the highest negative correlations across all risk indicators especially production (-0.66) and livelihood risks (-0.62). This suggests that equitable distribution of resources and returns incentivizes participation, builds trust, and reduces the economic vulnerability of farming households. Other notable PPP components included collaborative policy formulation (-0.62) and shared risk management (-0.61), emphasizing the need for participatory governance and joint decision-making in climate adaptation. These mechanisms facilitate stakeholder alignment, ensure responsive policies, and promote collective investment in adaptation infrastructure and technologies.

Co-funding, collaborative R&D, and technology transfer demonstrated moderately strong correlations with reduced climate risks, underscoring the importance of knowledge co-creation, innovation, and joint financing in sustaining adaptive capacity. These findings echo

the conclusions of (Owusu et al. 2020) and Vincent & Cull (2021), who assert that innovation partnerships enhance the diffusion of climate-resilient technologies and practices. Interestingly, government-private collaboration recorded the weakest correlations among PPP indicators (e.g., 0.52 with production risks), hinting at possible institutional and operational bottlenecks. This suggests that while partnerships exist on paper, their implementation may be hindered by bureaucratic inefficiencies, limited coordination, or unequal power dynamics. Strengthening institutional synergy, therefore, remains a key area for policy reform and capacity development. Overall, the results validate the argument that PPP mechanisms are not supplementary but essential in climate resilience planning. By combining public oversight with private sector efficiency and innovation, these partnerships enhance the reach, relevance, and sustainability of adaptation initiatives.

The cumulative evidence from this study points to the interdependence between infrastructure and PPP mechanisms in advancing climate resilience. Infrastructure provides the physical and technological foundation, while PPPs supply the financial, institutional, and knowledge-based support necessary to operationalize and scale adaptation interventions. For instance, infrastructure such as roads and water reservoirs are more effective when complemented by policies that promote shared investment and resource governance. This interdependence highlights the importance of adopting a systems-thinking approach to climate adaptation wherein infrastructure planning, policy-making, and stakeholder engagement are integrated rather than fragmented. It also calls for multi-level governance, involving local governments, private actors, civil society, and community members in adaptation finance decisions.

5.4 Cooperative Governance

5.4.1 Key governance characteristics

The descriptive analysis reveals a moderately strong presence of good governance practices within the agricultural cooperatives at the Tochi Irrigation Scheme. Key governance indicators such as participatory decision-making (65.8%), transparency in financial reporting (63.3%), and accountability structures (61.0%) reflect a functional internal governance environment. These findings suggest that cooperative societies at TICSpossess foundational attributes necessary for the effective implementation of adaptation finance mechanisms (AFMs). Participation in decisionmaking is especially crucial in cooperative settings, where member engagement underpins organizational legitimacy and performance. As noted by Birchall (2014), member-driven governance is a cornerstone of cooperative resilience,

ensuring that policies and resource allocations align with grassroots needs. The relatively high level of reported participation (65.8%) at TICSthus indicates that these institutions are not only democratic in structure but also inclusive in practice.

Transparency in financial reporting (63.3%) is another critical indicator of institutional integrity. As emphasized by Wanyama (2009), financial transparency strengthens trust, minimizes corruption, and enhances the cooperative's ability to attract external funding including climate adaptation finance. This finding aligns with the cooperative principles endorsed by the International Co-operative Alliance (ICA, 2015), which stress the importance of openness and accountability in sustaining cooperative operations. Accountability mechanisms (61.0%) and member satisfaction with leadership (59.5%) further support the notion of moderate governance functionality. According to Ostrom (1990), the success of collective action in managing shared resources such as irrigation water depends significantly on locally enforceable rules and accountable leadership. In this context, cooperatives with fair levels of accountability are better positioned to coordinate and oversee the implementation of AFMs, including infrastructure maintenance and resource allocation. Timely communication and regular meetings (58.2%) also indicate that cooperative leadership maintains consistent interaction with its members. This supports findings by Francesconi and Heerink (2011), who argue that regular communication fosters transparency, conflict resolution, and timely adaptation to external challenges, including climate variability.

The observed governance practices are not merely procedural—they play an instrumental role in enabling or constraining the success of adaptation finance mechanisms. Cooperatives serve as key intermediaries in the mobilization, distribution, and oversight of climate finance in rural areas (Shiferaw et al., 2006). Thus, the presence of participatory governance structures enhances collective agency and ensures that climate finance is not only received but effectively translated into resilience-building interventions. Moreover, good governance strengthens the absorptive and adaptive capacities of cooperative members. For instance, when financial decisions are made transparently and communicated effectively, members are more likely to trust and engage with programs involving cost-sharing, loan repayment, and co-investment in resilient infrastructure. As highlighted by Agrawal and Lemos (2007), institutions that foster trust and participation are more likely to achieve successful adaptation outcomes.

The findings align with the Institutional Analysis and Development (IAD) framework, which underscores the importance of institutional arrangements in shaping collective outcomes (Ostrom, 2005). Cooperative governance functions as the "action arena" where actors negotiate, monitor, and enforce adaptation strategies. The moderately strong presence of governance indicators at TICSsuggests that these action arenas are sufficiently structured to facilitate effective adaptation.

In policy terms, these results resonate with Uganda's National Irrigation Policy (2018), which advocates for strengthening farmer institutions and cooperatives as key vehicles for sustainable irrigation and climate resilience. Similarly, global adaptation frameworks such as the Green

Climate Fund's (GCF) Enhanced Direct Access modality emphasize the need for strong local institutions to ensure that climate finance reaches and benefits local communities (GCF, 2020).

5.4.2 Moderation effect of cooperative governance

The moderation analysis conducted using PROCESS Macro Model 1 revealed a statistically significant interaction between adaptation finance mechanisms and cooperative governance ($B = 0.21$, $p = .004$). This finding provides empirical support for the hypothesis that governance structures enhance or constrain the effectiveness of financial interventions aimed at climate resilience. Specifically, the results show that the positive impact of AFMs on resilience outcomes is significantly amplified in the presence of strong governance systems. This aligns with institutionalist perspectives in climate adaptation research, which argue that adaptation outcomes are not solely determined by financial inputs but are mediated by the quality of local institutions and governance arrangements (Adger, 2003; Huq et al., 2004). For example, when irrigation infrastructure is installed in well-governed cooperatives, proper maintenance, equitable access, and conflict resolution are more likely enhancing the long-term resilience of farming communities (IPCC, 2014; Deininger & Byerlee, 2011). On the contrary, weak governance often leads to mismanagement, elite capture, and reduced collective benefits, ultimately diluting the effectiveness of even well-funded adaptation interventions (Meinzen-Dick, 2009).

The statistical significance of the main effects of both AFMs ($B = 0.62$, $p < .001$) and cooperative governance ($B = 0.28$, $p = .013$) further corroborates their individual

contributions to resilience. These results echo findings from earlier studies that emphasize the importance of bundling financial mechanisms with institutional support systems (Jones et al., 2010; Linnerooth-Bayer &

Hochrainer-Stigler, 2015). The model's R-squared value of 0.526 reinforces this synergy, indicating that more than half of the variability in climate resilience among the respondents can be attributed to the interaction of these variables. Such a high explanatory power is commendable in social science research, where multifactorial influences and contextual diversity often limit predictability (Bryman, 2016). The high F-value (36.87, $p < .001$) further validates the model's robustness, suggesting that the relationship under investigation is not only statistically significant but also of practical relevance.

The results underscore the necessity of integrating governance strengthening efforts into climate finance programs targeting smallholder farmers. Simply channeling adaptation finance into cooperatives without reinforcing transparency, participation, and accountability may lead to suboptimal outcomes. Development actors and policymakers must therefore design AFM interventions that are embedded within or contingent upon governance benchmarks (UNDP, 2011; FAO, 2017). This study highlights the need for continuous capacity building for cooperative leaders, mechanisms for member feedback, and routine audits all of which foster institutional trust and enable adaptive decision-making (Pretty, 2003; World Bank, 2010). Given the increasing climate variability affecting Sub-Saharan Africa, including Uganda, such integrative approaches are not optional but essential.

CHAPTER SIX

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

6.1 Summary of findings

This study investigated the relationship between adaptation finance mechanisms (AFMs) and climate resilience at the Tochi Irrigation Cooperative Society, with cooperative governance as a moderating factor. The research specifically explored two key adaptation finance mechanisms: infrastructure and public-private partnerships (PPPs), and their influence on three dimensions of climate resilience: resilience to production risks, resilience to flood risks, and resilience to livelihood risks. The study also assessed demographic characteristics to understand their influence on participation in climate-resilient agriculture.

The findings revealed a male-dominated respondent profile (59.5%), yet with a significant proportion of female participation (40.5%), indicating increasing gender inclusivity in irrigation farming. The age distribution skewed towards youth and middle-aged respondents (67.1% aged 25–45), suggesting a promising demographic for uptake of technological and financial innovations. Although only 29.2% held tertiary education, the general educational background supported potential engagement with financial tools and agricultural extension services.

In terms of adaptation finance mechanisms, infrastructure components such as skilled extension services, water reservoirs, and roads were relatively available, whereas dams and transportation equipment were moderately accessible. PPPs at TICS showed moderate implementation, with shared proceeds (62.0%) and collaborative policy formulation (59.5%) being the most practiced, while technology transfer and joint investment strategies were underutilized.

The findings showed a statistically significant inverse relationship between adaptation finance mechanisms and climate risks. Infrastructure showed the strongest negative correlations with production risks (e.g., roads at $r = -0.70$, skilled extension at $r = -0.68$), while PPPs such as shared proceeds ($r = -0.66$) and collaborative policy formulation ($r = -0.62$) also exhibited significant correlations with reduced climate vulnerabilities.

The moderation analysis revealed that cooperative governance significantly strengthens the relationship between adaptation finance mechanisms and climate resilience (interaction effect

B = 0.21, $p = 0.004$), with an overall model fit of $R^2 = 0.526$, $F(3, 75) = 36.87$, $p < 0.001$. Governance indicators such as transparency, accountability, and participatory leadership were moderately prevalent and essential for enhancing adaptation outcomes.

6.2 Conclusions

Based on the research objectives and empirical findings, the following conclusions were drawn:

Infrastructure and climate resilience: Well-developed infrastructure significantly contributes to improved climate resilience by reducing production, flood, and livelihood risks. Roads, skilled extension services, and water reservoirs were particularly effective. The availability and accessibility of these resources directly influenced farmers' capacity to respond to climate stressors.

Public-private partnerships (PPPs) as enablers: PPPs offer a strategic pathway for mobilizing resources and fostering inclusive climate adaptation. However, their effectiveness is constrained by limited implementation in areas such as technology transfer, investment access, and farmer capacity building. Stronger alignment between public institutions and private actors is required.

Cooperative governance as a moderating force: Cooperative governance significantly enhances the effectiveness of adaptation finance mechanisms. Where governance structures are transparent, participatory, and accountable, the benefits of infrastructure and PPPs are maximized. Weak governance, conversely, undermines climate resilience efforts.

Demographic leverage: The relatively young, moderately educated population at TICS presents a unique opportunity to promote climate-resilient agriculture through digital finance, mobile-based services, and youth-centered policies. Gender dynamics also suggest a need for more inclusive financing mechanisms that empower women.

Integrated approaches yield greater impact: Adaptation finance mechanisms do not operate in isolation. Their effectiveness depends on supportive institutional frameworks, governance quality, and local participation. A systems-thinking approach is essential to building long-term resilience in climate-vulnerable irrigation schemes.

6.3 Recommendations

Drawing on the study's conclusions, the following recommendations are proposed for policy, practice, and future research:

6.3.1 Policy recommendations

- **i** Enhance climate-smart infrastructure investment: Government and development partners should prioritize the expansion and maintenance of roads, water storage facilities, and mechanization tools within TIS. Blended finance models and climate bonds should be explored to address funding gaps.
- **ii** Institutionalize cooperative governance standards: Establish national or regional governance benchmarks for agricultural cooperatives, with specific criteria for transparency, participation, and accountability. These standards can serve as prerequisites for accessing adaptation funds.
- **iii** Promote gender-sensitive adaptation finance: Introduce gender quotas in cooperative leadership, establish microfinance schemes targeting women, and design educational programs that address socio-cultural barriers to women's participation in climate-resilient agriculture.

6.3.2 Programmatic recommendations

- **i** There is need to strengthen PPP frameworks: Incentivize private sector participation through risk-sharing instruments, tax rebates, and co-financing arrangements. Facilitate platforms for joint policy dialogue and farmer-business linkages.
- **ii** Invest in farmer education and digital tools: Scale up digital agricultural extension, financial literacy campaigns, and training in climate-smart agriculture, especially for youth and women. Integrate local languages and visual aids to reach semi-literate farmers.
- **iii** Foster innovation through cooperative-based initiatives: Support cooperatives to implement shared equipment models, energy-efficient technologies (for example solar irrigation), and community-managed early warning systems. This will enhance ownership and sustainability of adaptation solutions.

6.3.3 Recommendations for future research

i There is need to undertake longitudinal studies. Conduct longitudinal assessments of adaptation finance interventions to evaluate their sustained impact on resilience over time.

ii Comparative analysis should as well be conducted. Expand the scope to include other irrigation schemes across Uganda and Sub-Saharan Africa to compare adaptation finance performance and contextual influences.

iii Lastly, focus should be laid on climate finance access pathways. Investigate how farmers navigate formal and informal financial systems to access adaptation resources, with a focus on institutional and behavioral factors.

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APPENDICES

Appendix I: Self-Administered Questionnaire

Hello respondent,

My name is **Ojok Michael**, a student of Gulu University, pursuing Master of Development Studies. I am currently conducting a study to ascertain how adaptation finance mechanisms are influencing climate resilience at Tochi Irrigation Cooperative society, in Oyam district. You are hereby requested to participate in the research by filling in this brief questionnaire. This research is purely academic and your responses shall be kept confidential. Thank you for your time and kind cooperation.

Section one: Personal Information (*kindly tick the appropriate response/answer*)

a) Gender

Male ☐ Female ☐

b) Age

Under 24 years ☐ 25-35 years ☐ 36 – 45 years ☐ 46 years and above ☐

c) Educational level

Primary education ☐ O level ☐ A level ☐ Certificate ☐ Diploma ☐ Degree

Master's degree ☐ Others _____

d) Occupation: _____

Responses (5-Point Likert Scale)

Strongly agree: SD = 1 Disagree: D = 2 Neutral: N = 3 Agree: A = 4 Strongly Agree: SA = 5

The scales for responses to the questions on risks are as follows:

Very low: VL = 1; Low: L = 2; Moderate: M = 3; High: H = 4; Very high: VH = 5

Section two: Adaptation finance mechanisms (***kindly tick the appropriate box***)			
	Infrastructure **Which of the following infrastructures have installed and are accessible and functional at Tochi Irrigation scheme?**	**YES**	**NO**
i.	Storage		
ii.	Roads		
iii.	Dams		
iv.	Water reservoir		
v.	Equipment		
vi.	Skilled extension services		
vii.	Transportation equipment		
viii.	Agricultural machinery		
ix.	Information system		
x.	Land		
xi.	Bridges		
xii.	Water canals		
xiii.	Energy infrastructure like electricity, solar, generator, etc		
	Public-private partnership **There is existence of PPP at Tochi irrigation scheme in the following aspects**		
i.	There is collaboration between the government of Uganda and private entities at Tochi Irrigation Scheme		
ii.	Co-funding at Tochi Irrigation scheme		
iii.	Sharing of labor at Tochi irrigation scheme		
iv.	Farmer capacity building through skilling		
v.	Market access; that is linking farmers to markets, and facilitating trade		

vi.	Sharing of resources at TICS		
vii.	Risks		
viii.	Proceeds		

ix.	Shared risk management strategies like crop insurance and weather-based insurance		
x.	Technology transfer		
xi.	Finance and investment for example in form of grant, credit facilities and venture capital among others		
xii.	Collaborative formulation policy and regulation at TICS		
xiii.	Implementation of policy and regulation		
xiv.	Collaborative research and development in terms of innovation in agricultural technologies, crop varieties, and best practices.		

Section Three: Climate resilience
In this section, the following responses apply: Very low: VL = 1; Lo w: L = 2; Moderate: M = 3; Hig h: H = 4; Very high: VH = 5

	Production risks **How do you rate the following risks at Tochi irrigation scheme**	**VL**	**L**	**M**	**H**	**VH**
i.	Risk of yield reduction					
ii.	Risk of equipment failure					
iii.	Crop failure					
iv.	Low prices for the crops produced					
v.	Increased cost of inputs like seeds, fertilizers, pesticides and insecticides, etc					
vi.	Inadequate access to farm equipment and machinery					
vii.	Reduced storage space					
viii.	Delayed planting					
ix.	Delayed harvesting					
	Flood risks **How frequent or sever is flood at Tochi irrigation scheme?**					
i.	Frequency					
ii.	Severity					

	How do you rate the following risks associated with flood at the irrigation scheme?					
i.	Destruction of crops					
ii.	Destruction of road infrastructure					
iii.	Displacement of farmers					
iv.	Destruction of storage infrastructure					
v.	Destruction of farm equipment					

vi.	Death of farmers					
	Livelihood risks					
i.	Increased unemployment					
ii.	Decline in income of the farmers					
iii.	Food shortage					
iv.	Decline in crop production					
v.	Financial distress for example due to debts					
vi.	Loss of financial capital					
vii.	Inadequate access to information					
viii.	Decline in prices					
Section Four: Cooperative society governance						
	Group dynamics ***Which of the following exist in your group?***	**YES**		**N O**		
i.	Elections					
ii.	There is adequate financial accountability					
iii.	Bank account					
iv.	Routine meetings are held					
v.	Pooling of financial resources					
vi.	Disciplinary measures are effectively applied					
vii.	Records are effectively kept					
viii.	Rules governing our group are observed by the members					
ix.	Co-management					
	Information sharing **Being a member of the cooperative society, to what extent do you agree with the following statements?**					
i.	I receive more information on climate change adaptation					
ii.	I receive more information on weather patterns					
iii.	Sufficient information on sustainable farming practices					

iv.	I receive more information on weather-resistant crops					
v.	The cooperative has enhanced my linkages with external actors through information sharing					
vi.	The cooperative has improved my access to extension services					
vii.	The cooperative society provides me with information on the best time to plant					
viii.	I receive more information regarding pesticide and fertilizer application					
ix.	The cooperative society has improved my productivity through information sharing					

Appendix II: Interview Guide

Introduction and consent

Hello respondent,

My name is Ojok Michael, a student of Gulu University, pursuing Master of Development Studies. The purpose of this engagement with you is to ascertain the influence of adaptation mechanisms on climate resilience at Tochi Irrigation Scheme, Oyam District. This study is purely for academic purposes and your responses shall be kept confidential. Can we briefly share for 15 minutes?

SECTION ONE: ADAPTATION FINANCE MECHANISMS

Infrastructure

1. Which agricultural infrastructure have been installed or provided under the irrigation scheme?
2. Have the infrastructures enhanced your climate resilience as a farmer? If Yes, how?

Public-private partnership

3. What are the different dimensions of public-private partnership adopted here at Tochi Irrigation scheme?
4. How has the government contributed to this irrigation project?
5. How has the private sector contributed this irrigation project?

SECTION TWO: CLIMATE RESILIENCE

Production risks

6. What is your understanding of production risks in agriculture?
7. What are the different dimensions of production risk here at Tochi irrigation scheme?
8. How has the irrigation project improved farmers' resilience against production risks?

Flood risks

9. Can you comment on the level of frequency and severity of flood here at Tochi irrigation scheme?
10. What are the major risks associated with flooding here?

11. Which flood risk management strategies are in place and how have they improved farmers' resilience against flood?

Livelihood risks

12. What are the major livelihood risks that farmers here are exposed to?
13. How has the irrigation scheme enhanced the resilience of farmers against risks associated with their livelihood?

SECTION THREE: COOPERATIVE SOCIETY

Group dynamics

14. Are there active farmer groups, and how many are they under Tochi Irrigation cooperative society?
15. How are those farmer groups governed?

Information sharing

16. What are the different forms of information shared within the cooperative society and how are they shared?
17. What are the major sources of information shared within the cooperative society?
18. How has information sharing facilitated climate resilience of farmers in the cooperative society?

Thank you for participating in this study. The report shall be shared as soon as it is ready.

THE END