

# Climate change adaptation, intersectionality, and institutional support for smallholder farmers in the Guinea Savannah of Ghana

### by Seth Opoku Mensah

Thesis submitted in fulfilment of the requirements for the degree of

#### **Doctor of Philosophy**

under the supervision of Associate Professor Brent Jacobs and Dr. Rebecca Cunningham

University of Technology Sydney Institute for Sustainable Futures

April 2025

# **Certificate of Original Authorship**

#### Required wording for the certificate of original authorship

CERTIFICATE OF ORIGINAL AUTHORSHIP

I, Seth Opoku Mensah, declare that this thesis is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the Institute for Sustainable Futures at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

This research is supported by the Australian Government Research Training Program.

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#### List of Acronyms and Abbreviations

AC Adaptive Capacity

AEZ Agro-ecological Zone

AGRA Alliance for Green Revolution in Africa

APPs Area Programme Plans

AU African Union

AUC African Union Commission

CSA Climate-Smart Agriculture

DMTDP District Medium Term Development Plan

DoA Department of Agriculture

EPA Environmental Protection Agency

FAO Food and Agriculture Organization

FGDs Focus Group Discussions

FMNR Farmer Managed Natural Regeneration

FTC Farmer Training Centre

GCA Global Commission on Adaptation

GHG Green House Gas

GMet Ghana Meteorological Agency

GSS Ghana Statistical Service

HREC Human Research Ethics Committee

IPCC Intergovernmental Panel on Climate Change

ISO International Organization for Standardization

KDC Kundok Development Consult

KIIs Key Informant Interviews

LEAN Landscape and Environmental Agility across the Nation

MA Millennium Ecosystem Assessment

MoFA Ministry of Food and Agriculture

ODK Open Data Kit

PPS Probability Proportional to Size

RDMP Research Data Management Plan

SDGs Sustainable Development Goals

SES Socio-ecological Systems

SLF Sustainable Livelihood Framework

SPSS Statistical Package for Social Science

SSA Sub-Saharan Africa

TDA Talensi District Assembly

UN United Nations

UNDP United Nations Development Programme

UNEP United Nations Environmental Programme

UNEP FI United Nations Environmental Programme Finance Initiative

UNFCCC United Nations Framework Convention on Climate Change

UTS University of Technology Sydney UTS

VIF Variance Inflation Factor

WFP World Food Programme

WMO World Meteorological Organization

WOM Widows and Orphans Movement

WRI World Resources Institute

WVG World Vision Ghana

#### **Abstract**

Ghana exemplifies the challenges that smallholder farmers in Sub-Saharan Africa face. Ghana's significant vulnerability primarily stems from its rain-fed agrarian dependency, over-dependence on natural resources and the prevalence of smallholder farmers. Extreme weather events which are linked to climate change, including changes in precipitation, floods, heat waves and droughts, have significantly damaged agricultural production in Ghana. Ghana's agricultural sector is largely based on exploiting natural resources, with extensive crop and livestock production systems, rain-fed agriculture, hunting, and fishing from natural water bodies. The sector directly absorbs 36 per cent of Ghana's labour force—albeit highly informal, composed of 80 per cent smallholder farmers. Climate change is projected to adversely affect Ghana's agricultural sector stability with the country's millions of smallholder farmers particularly vulnerable and least empowered to address climate impacts. These farmers are dependent on rain-fed agriculture and are highly exposed and vulnerable to climate-related hazards, yet they possess limited capacity to adapt.

This thesis examines the complex dynamics of climate change adaptation among smallholder farmers in the Talensi district, a climate-vulnerable district in Ghana's Guinea Savannah agroecological zone. Using mixed methods, including focus group discussions, institutional interviews and household surveys, the research explores the interplay of factors influencing farmers' adaptation decisions, the role of intersectionality in shaping adaptive capacities, and the effectiveness of institutional interventions. Findings reveal that all farmers employ at least one adaptation action to mitigate climate risks, with planting improved crop cultivars being the most common (89%) and raising additional livestock the least adopted (19%). Adaptation decisions are shaped by a complex web of variables, including farmers' perceptions, livelihood capitals, and institutional support.

The thesis also highlights the unequal adaptive capacities within communities, driven by the intersection of socio-demographic identities (e.g., age, gender, and education) with livelihood resources. This intersectional lens uncovers deep-seated inequalities in climate adaptation, underscoring the importance of addressing the diverse vulnerabilities of heterogeneous farmer groups. Institutional interventions play a critical role in enhancing adaptation, with institutions providing training, technology transfer, input supply, and marketing support. However,

challenges such as resource constraints, donor priorities, and inadequate policy frameworks limit the sustainability and effectiveness of these interventions. The thesis advocates for coordinated and context-specific strategies that integrate complementary adaptation actions, adopt an intersectional approach and leverage cross-institutional synergies to ensure inclusive and equitable adaptation outcomes. By addressing the interconnections between farmer adaptation behaviours, socio-economic realities, and institutional support, this thesis provides actionable insights to strengthen adaptive capacity in smallholder farming systems in Ghana.

**Keywords**: Climate change adaptation, Ghana, institutions, intersectionality, smallholder farmers, Talensi district.

#### **Chapter One**

#### **Background and problem formulation**

#### 1.1 Introduction

This thesis examines the complex dynamics of climate change adaptation among smallholder farmers in the Talensi district, a climate-vulnerable district in Ghana's Guinea Savannah agroecological zone. Using mixed methods, including focus group discussions, institutional interviews and household surveys, the research explores the interplay of factors influencing farmers' adaptation decisions, the role of intersectionality in shaping adaptive capacities, and the effectiveness of institutional interventions.

Climate change—"a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean or the variability of its properties and that persists for an extended period, typically decades or longer" (Intergovernmental Panel on Climate Change [IPCC], 2022a, p. 2902)—and climate change-induced phenomena, including climate variability<sup>1</sup> and extreme weather events<sup>2</sup> have been labelled as the most systemic threat to humankind (United Nations Secretary-General, 2018; Talanow et al., 2021), which poses a pressing global challenge (Amoah & Simatele, 2021; IPCC, 2023) that is an unequivocal and consolidated fact (Romm, 2020). According to the World Meteorological Organization (WMO) (2021), climate change is not only about temperature. It is bringing multiple different changes in various geographical regions across the globe. For example, it intensifies the water cycle and brings more intense rainfall, associated flooding, and drought in many areas. It also affects rainfall patterns, with precipitation likely to increase in high latitudes and projected to decrease over significant parts of the subtropics. Changes to monsoon precipitation are expected to vary by region. Climate change also leads to significant climatic extremes. For instance, extreme precipitation events can result in high runoff, flooding, and soil erosion, while low precipitation can cause persistent drought and reduce agricultural productivity (Kogo et al., 2021; Sedata et al., 2025).

<sup>&</sup>lt;sup>1</sup> "Deviations of some climate variables from a given mean state (including the occurrence of extremes, etc.) at all spatial and temporal scales beyond that of individual weather events" (IPCC, 2022a, p. 2903).

<sup>&</sup>lt;sup>2</sup> "An event that is rare at a particular place and time of year" (IPCC, 2022a, p. 2908).

Every region on Earth is facing the reality of climate change in multiple ways (IPCC, 2023; Adil et al., 2025). Changes to the climate system have already occurred in every region across the globe at an unprecedented scale. These changes are unavoidable and will increase with additional warming in a rapidly warming climate (WMO, 2024a; United Nations Environmental Programme Finance Initiative [UNEP FI], 2024). Under future climate change, such changes will occur more frequently (WMO, 2024a). The impacts on societies and economies caused by changes to temperature and rainfall differ, with developing countries disproportionately affected (Figure 1) despite the fact that developed countries contribute more to global climate change (IPCC, 2023; Bergman, 2025).

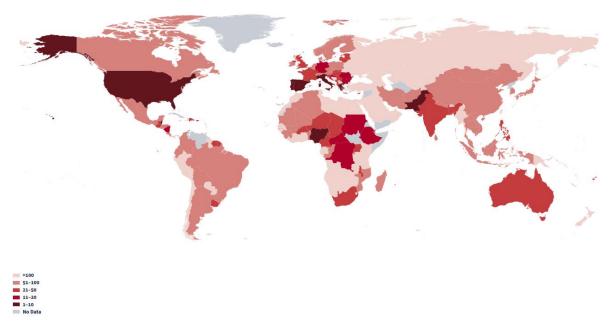


Figure 1: Climate Risk Index: Overall ranking 2022

Source: Adil et al. (2025, p. 49-50)

The IPCC (2022b) asserts that Africa is particularly vulnerable to climate change impacts because of widespread poverty, governance challenges, limited access to essential services and resources, frequent violent conflicts, and a high dependence on climate-sensitive livelihoods. Africa is at a tipping point (IPCC, 2014; WMO, 2024b). It is home to some of the world's harshest climates and most vulnerable populations (Global Commission on Adaptation [GCA] & World Resources Institute [WRI], 2019; United Nations Environmental Programme [UNEP], 2021; Overland et al., 2022). The rate of temperature increase across Africa exceeds the global

average and is likely to bring devastating impacts, including drought, increased average temperatures and hot extremes. There is also a projected increase in extreme rainfall in Africa (UNEP, 2021; WMO, 2024b; Getachew et al., 2025). For millions of people across Africa, climate change means intense and more frequent floods, storms and droughts. These account for up to 90% of all climate-related disasters annually (World Food Programme [WFP], 2021). Water availability, agriculture, food security, human health and well-being across Africa are being and will continue to be adversely affected. These climate change impacts are also anticipated to result in the spread of pests and diseases and the loss of fauna and flora (Atanga & Tankpa, 2021). Climate change and extreme weather events, therefore, are pressing concerns in Africa (Omondi et al., 2014; Getachew et al., 2025) because the well-being of most households depends on land-based activities, negatively affecting peoples' livelihoods (Epule et al., 2018; WMO, 2024b).

In Africa, Ghana is a climate change hotspot, ranking high among countries most vulnerable to climate change impacts (Antwi-Agyei & Nyantakyi-Frimpong, 2021; World Bank, 2022; Asante et al., 2024). Ghana has, for example, experienced increased temperatures, extreme rainfall regimes and major catastrophic events, including floods, droughts and wildfires, over the past decades (Environmental Protection Agency [EPA], 2020; World Bank, 2021; Smits et al., 2024). Temperature trends between 1989 and 2015 have increased by about an average of 1.0°C across the country (Asare-Nuamah & Botchway, 2019; Klutse et al., 2020). Also, Ghana's annual rainfall trends have changed with significant average rainfall reductions (EPA, 2020; Bessah et al., 2021; Lente et al., 2024). The implication is that farmers should expect more extreme events, including floods, droughts and wildfires in the future, with negative consequences for Ghana's agricultural systems (Kyere-Boateng & Marek, 2021). This situation is particularly worrying as erratic precipitation patterns have severe consequences for agricultural production, and only two per cent of Ghana's irrigation potential has been tapped (World Bank, 2021).

#### 1.2 Impacts of climate change on agriculture

Globally, it is well-documented that agricultural systems contribute to climate change while simultaneously suffering drastically from its impacts (Abdollahzadeh et al., 2023; FAO et al., 2024; Liao et al., 2023; Shaffer-Morrison et al., 2025). Extreme weather events linked to climate change, impact every aspect of agriculture and affect the local populations and communities

dependent on it for their livelihoods (United Nations Framework Convention on Climate Change [UNFCCC], 2023; FAO, 2023; Tong et al., 2024). For example, extreme weather events can disrupt planting seasons, reduce water availability, and damage crops. Additionally, rising temperatures stress plants and decrease yields (Gwambene et al., 2023; Baffour-Ata et al., 2025). Globally, smallholder farmers<sup>3</sup>, who often lack resources and depend on rain-fed agriculture, are particularly vulnerable to climate change (United Nations Development Programme [UNDP], 2021; Food and Agriculture Organization [FAO] et al., 2024). For example, resource limitations can increase smallholder farmers' vulnerability<sup>4</sup>— discussed further in Chapter 2—to climate-exacerbated weather events because they lack the resources needed for recovery. This lack of resources further constrains their ability to invest in adaptive practices that could mitigate vulnerability in the short and long term (Berry et al., 2011; Ojumu et al., 2020; Ali et al., 2025). Their limited capacity to adapt<sup>5</sup>—adaptation is discussed further in Chapter 2—to changing weather patterns and absorbing financial losses from production failures exacerbates their vulnerability (FAO et al., 2024; Gwambene et al., 2023).

While climate threats to agriculture are global, Africa remains the most affected region (Epule et al., 2023; Alliance for Green Revolution in Africa [AGRA], 2023). The exposure of Africa's agriculture is exacerbated by persistent poverty, limited infrastructure development, and weak capacity to adapt (AGRA, 2023; African Union [AU], 2023). For example, since 1961, climate change has reduced total agricultural productivity growth in Africa by 26% to 34%. This reduction is more than in any other region of the world (Ortiz-Bobea et al., 2021). In Africa, Sub-Saharan Africa (SSA) has been recognised as one of the most climate-vulnerable regions (Campbell et al., 2023; WMO, 2024b). Climate change is a significant challenge to SSA agriculture where agricultural production relies heavily on rainfed systems and adaptive capacity<sup>6</sup> remains limited (Olsson et al., 2014; IPCC, 2023). One-fifth of SSA's economic output and 60% of its labour force depend on agriculture (Woetzel et al., 2020; IPCC, 2022b).

<sup>&</sup>lt;sup>3</sup> Smallholder farmers account for approximately 90% of the world's farmers and 80% of all farms in SSA. These farmers typically own less than two hectares of land, with farming often serving as their primary, and sometimes only, source of income (UNDP, 2021; FAO et al., 2024).

<sup>&</sup>lt;sup>4</sup> Vulnerability refers to the degree to which a system, community, or individual is susceptible to and unable to cope with the negative impacts of climate change, shaped by sensitivity, exposure and adaptive capacity (IPCC, 2022a).

<sup>&</sup>lt;sup>5</sup> Adaptation is the process of adjusting to actual or expected climate change and its impacts to moderate harm or take advantage of beneficial opportunities (IPCC, 2022a).

<sup>&</sup>lt;sup>6</sup> Adaptive capacity refers to the ability of a system, community, or individual to adjust to climate change impacts, moderate potential damages, take advantage of opportunities, or respond to consequences (IPCC, 2022a).

However, with 97% of agricultural production systems relying on rain-fed agriculture, the sector remains particularly vulnerable (Mafongoya & Ajayi, 2017; AGRA, 2023).

Figure 2 shows that countries in SSA, along with South Asia, are exposed to high agricultural risks from a range of climate hazards. In summary, the economies of SSA are largely driven by a growing population of smallholder farmers. Smallholder farmers in SSA are increasingly exposed to climate risks, including reduced rainfall, rising temperatures, and more frequent extreme weather events (Ayanlade et al., 2022; Azine et al., 2025). Climate change impacts disproportionately affect these farmers, who form 80 per cent of the labour force in the agriculture sector but are the least empowered to address climate impacts (AGRA, 2023). They depend almost exclusively on rain-fed agriculture in largely subsistence production systems with constrained adaptive capacities (FAO & the African Union Commission [AUC] 2022; AGRA, 2023).

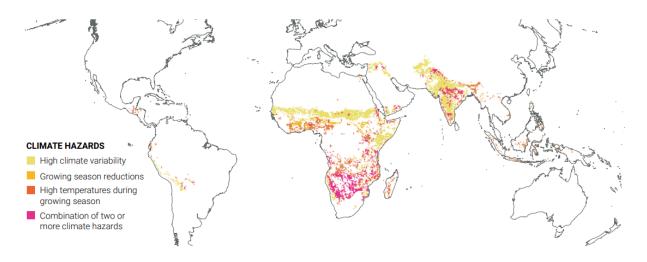


Figure 2: High agricultural risk for different climate hazards in SSA

Source: GCA & WRI (2019, p. 24)

#### 1.3 Adapting to the impacts of climate change

Climate change is a global crisis with localized impacts that require context-specific solutions (Wang et al., 2023; Talha et al., 2025). The current magnitude and pace of climate change are unprecedented. As climatic changes amplify the vulnerability of farming communities, farmers must adapt their production systems to cope with climate risks and opportunistically utilise prevailing conditions to secure agricultural productivity and livelihoods (Füssel, 2007b; IPCC,

2023; Nondlazi et al., 2025). The promotion of Climate Smart Agriculture is viewed as central to responses to climate change throughout the Global South. While this thesis focuses primarily on adaptation, it is imperative to recognize that Climate-Smart Agriculture (CSA) encompasses both adaptation and mitigation strategies (Lipper et al., 2014; Kabato et al., 2025).

While adaptation in agriculture refers to the strategies that enhance smallholder farmers' ability to cope with climate variability and change, mitigation efforts in agriculture focus on reducing greenhouse gas emissions (Maraseni et al., 2021; Kabato et al., 2025). Although CSA integrates both approaches, this research prioritizes adaptation because smallholder farmers in Ghana's Guinea Savannah agro-ecological zone are highly vulnerable to climate change impacts (Antwi-Agyei & Nyantakyi-Frimpong, 2021; Abunyewah et al., 2024). Their immediate concern is securing food production and livelihoods rather than mitigating emissions, which, while important, is often a secondary consideration in resource-constrained farming communities (Thornton et al., 2018). Therefore, this thesis situates CSA primarily within an adaptation framework, acknowledging that while mitigation has long-term global benefits, adaptation remains the most urgent need for smallholder farmers facing immediate climate risks.

Climate adaptation—defined as adjusting human or natural systems to actual or expected climate impacts, to moderate harm or exploit beneficial opportunities (IPCC, 2022a)—is critical for advancing global socio-economic development under current climatic changes (O'Neill et al., 2014; Nondlazi et al., 2025; Callahan, 2025). Adaptation has thus become imperative, requiring further action in the short term to anticipate and prepare for future climate change (IPCC 2022b; Morrison et al., 2022; Zorita et al., 2025).

Adaptation is happening globally, especially in Africa and Asia, where the most commonly documented area of adaptation focuses on the agricultural sector (Berrang-Ford et al., 2021; Haque et al., 2023). Since there is no "silver bullet" solution for climate change (Pinkse & Kolk, 2010; p. 261), adaptation is the best possible strategy for minimizing climate impacts (Füssel & Klein, 2006; IPCC, 2014; Nondlazi et al., 2025). While smallholder farmers in SSA have historically demonstrated the ability to adapt to climatic risks (Gbegbelegbe et al., 2018; Baffour-Ata et al., 2025), without appropriate farm-level interventions and responses, climate change will continue to impact the agricultural sector and increase poverty levels in SSA (Derbile et al., 2022; Nondlazi et al., 2025). Consequently, adaptation in the agriculture sector

has become a priority in SSA (FAO & AUC, 2022; Gudina & Alemu, 2024). Adaptation occurs across multiple scales, both national and local, spanning various sectors and involving a diverse range of actors, including individual farmers, households and communities, policymakers, and institutions (IPCC, 2022b; Buzási et al., 2024; Maskell et al., 2025).

Adaptation efforts exhibit regional variations and are shaped by multiple, interrelated factors, including socio-demographic and psycho-social attributes, livelihood capitals, and institutional support mechanisms (e.g. Adeagbo et al. 2023; Asante et al. 2024; Ali et al., 2025). Therefore, this thesis investigates the dynamics of climate change adaptation among smallholder farmers, emphasizing three interconnected themes: (1) factors influencing smallholder farmers' adaptation actions, (2) the role of intersectionality in shaping farmers' adaptive capacity, and (3) the influence of institutions in enhancing climate adaptation. The overarching goal is to provide evidence-based insights for fostering inclusive and sustainable adaptation strategies in climate-vulnerable communities.

In the following section, I discuss the problem formulation that shapes the focus, scope, and direction of the research, and demonstrate why the research matters, how it fills critical gaps, and its broader implications for climate adaptation, intersectionality, and institutional support.

#### 1.4 Problem formulation

Ghana exemplifies the challenges that smallholder farmers in SSA face. Smallholder farmers are farmers engaged in agricultural activities on a small scale, typically characterised by limited land holdings, often less than two hectares. These farmers primarily rely on family labour and traditional farming methods, and their production is primarily for subsistence, with any surplus sold in local markets (United Nations Development Programme [UNDP], 2021; Swanepoel et al., 2025). In Ghana, smallholder farmers constitute over 80% of the agricultural workforce and play a crucial role in food security by producing the majority of staple crops and livestock, which enhances nutritional quality and increases resilience to climate change and market volatility. Their importance extends beyond production to employment generation, rural livelihoods, and the preservation of indigenous agricultural knowledge (Ministry of Food and Agriculture [MoFA], 2022; Yeboah et al., 2025).

However, this group of farmers is also among the most vulnerable to climate change. Their vulnerability stems from multiple interlocking factors, including their dependence on rain-fed agriculture, limited access to irrigation, inadequate extension services, insecure land tenure arrangements, poor infrastructure, and restricted access to credit and insurance schemes. Furthermore, their exposure to increasingly erratic rainfall patterns, prolonged droughts, and extreme weather events—combined with constrained adaptive capacity—undermines their ability to respond effectively to climate shocks (EPA, 2020; Incoom et al., 2025).

In common with SSA generally, Ghana's significant vulnerability primarily stems from its rainfed agrarian dependency, over-dependence on natural resources and the prevalence of smallholder farmers (EPA, 2020; MoFA, 2022; Alhassan et al., 2025). Ghana's agricultural sector is largely based on exploiting natural resources, with extensive crop and livestock production systems, rain-fed agriculture, hunting, and fishing from natural water bodies (Ghana Statistical Service [GSS], 2020).

While climate change is a global issue, its impacts are manifested differently across regions. The severity and nature of these impacts are influenced by the agro-ecologies of specific geographical zones (Jamshidi et al., 2019; Sedata et al., 2025). Due to Ghana's diverse agro-climatic conditions and production systems, its agriculture sector faces climate change effects whose causes, frequency, and severity vary between regions, commodities, and years, with strong implications for localized risk management strategies (EPA, 2021). Thus, climate change in Ghana is spatially and socially differentiated (Gyamerah et al., 2024). The level of vulnerability varies depending on the Agro-ecological Zone (AEZ) (Adonadaga et al., 2022) (see Section 3.4.1 for details on Ghana's agro-ecological zones). Ghana's Guinea Savannah zone constitutes one of the climate change vulnerability hotspots in SSA (Asare-Nuamah & Botchway, 2019)—with projections of intense and frequent droughts, coupled with rising temperatures and rainfall variability (World Bank, 2020).

The Guinea Savannah zone, where significant agricultural production is centred and poverty is most severe, disproportionately experiences increased impacts of climate change, including increasing extreme weather conditions, higher incidences and more prolonged periods of flooding and droughts (Abunyewah et al., 2024)). The zone covers over 40 per cent of Ghana's total surface area, with approximately six million hectares of arable land with great potential for

commercial crop and livestock production (World Bank, 2017). However, the semi-arid climate as well as its overdependence on the production of crops and livestock, which are sensitive to climate change, make the region particularly vulnerable (GSS, 2020; MoFA, 2022). The zone is projected to experience total crop failure approximately once every five years due to delayed or diminished rains (World Bank, 2021).

As climate change and extreme weather events become unpredictable and more frequent, climate change adaptation has become a key priority in Ghana (EPA, 2021; Opoku Mensah et al., 2023; Antwi-Agyei et al., 2025). There are calls to support communities whose livelihoods depend on natural and agricultural ecosystems to reduce their vulnerability (Dapilah & Nielsen, 2020; Dapilah et al., 2020; Antwi-Agyei & Nyantakyi-Frimpong, 2021). Consequently, a number of strategies to build the adaptive capacity of communities in Ghana have been concentrated in the Guinea Savannah zone's agricultural sector (Adu et al., 2018; Dazé & Echeverría, 2016) and for smallholder farmers (Opoku Mensah et al., 2023). Numerous measures have been initiated to support smallholder farmers to adapt to climate change impacts (EPA, 2020, 2021; Abunyewah et al., 2024).

Adaptation actions employed by Ghanaian smallholder farmers can be bifurcated into on-farm and off-farm adaptation actions (Opoku Mensah et al., 2023; Quarshie et al., 2023). On-farm adaptation actions primarily involve crop management, soil/land management, water management, livestock/poultry management, improved technology, and the enhancement of social capital. These actions fall into two sub-categories: agricultural intensification and agricultural extensification. Intensification actions include crop diversification, irrigation, disease or drought-resistant crops, inorganic and organic fertilizer application, agroforestry, and natural regeneration. Extensification actions involve farm relocation, fallow farming, and land rotation (Opoku Mensah et al., 2023; Quarshie et al., 2023). Off-farm adaptation actions focus primarily on livelihood diversification and migration (Opoku Mensah et al., 2023; Quarshie et al., 2023).

In this thesis, I explore the adaptation actions adopted by smallholder farmers. I identify these actions, examine the determinants of smallholder farmers' choices of action, and analyze the factors that constrain their adoption. While recognising the difficulty of capturing the full complexity of adoption decisions and limited consideration of technological and structural drivers (Rodríguez-Barillas et al. 2024; Ricart et al., 2025), I investigate the relative influence of

perception, livelihood capitals and institutional interventions on smallholder farmers' adoption of a range of common adaptation actions to reduce their climate vulnerability. Also, informed by the local and contextual nature of adaptation (Adger et al., 2004), I examine how multiple social characteristics interact to shape adaptive capacities rather than considering them in isolation (Thompson-Hall et al., 2016; Opoku Mensah et al., 2025).

This approach allows for a more nuanced understanding of vulnerability to climate extremes and the identification of vulnerable groups. Additionally, it helps prevent the overshadowing of complex local realities that could misguide policy formulation (Ravera et al., 2016; Puig et al., 2025). Such consideration is critical because adaptation actions are not uniformly available or equally effective for all farmers. Social identities such as gender, age, education, and access to livelihood capitals intersect to determine who has access to adaptation opportunities and who faces constraints (Nyantakyi-Frimpong, 2020; Opoku Mensah et al., 2025). Such a deeper understanding of the interconnections between socio-cultural categorisations (such as race, class and gender) applied to actors (such as smallholder farmers) that create interdependent and overlapping systems of discrimination, disadvantage or exclusionary practices is an essential aspect of adaptive capacity assessment (Nyantakyi-Frimpong, 2020; Puig et al., 2025).

Some determinants of adaptive capacity are primarily local (e.g., strong local networks), while others reflect broader socio-economic and political factors as well as the prevailing enabling environment (e.g., institutional support) (Smit & Wandel, 2006; Atampugre, 2018). Therefore, the research described in this thesis recognises that adaptation does not take place in an 'institutional vacuum' (Agrawal, 2008, p. 19). Instead, institutions are viewed as critical in enabling, constraining, and shaping adaptation actions (IPCC, 2022b; Madaki et al., 2025) as they can contribute to conditions that guide households and collectives to adopt specific actions (Azhoni et al., 2024; UNFCCC, 2020). They play a vital role not only in shaping adaptation but also in enhancing the capabilities of the most vulnerable social groups within society (Agrawal, 2008). Institutional involvement in adaptation encompasses changes in formal institutional arrangements and informal routines and norms in response to climate change (Patterson, 2021; Birchall et al., 2025).

In this thesis, I focus on the adaptation actions fostered by formal institutions because they are tangible and can be empirically compared across cases (Liu & Fan, 2023). Also, because Ghana

is regarded as having a well-established rural governance infrastructure, mainly dominated by formal institutions that promote practices to reduce farmers' vulnerability and maintain sustainable livelihoods (Yomo et al., 2020).

While previous studies in Ghana have examined, in isolation, aspects of climate change adaptation (e.g., Antwi-Agyei & Nyantakyi-Frimpong, 2021; Opoku Mensah et al., 2023), adaptation and intersectional analysis (e.g. Lawson et al., 2020; Nyantakyi-Frimpong, 2020; Alare et al., 2022) and institutional support (e.g. Yomo et al., 2020; Musah-Surugu et al., 2019; Tahiru et al., 2019), research is limited that seeks to integrate these dimensions to understand their interconnections and implications for smallholder farming systems. Therefore, I aim to fill this research gap by offering an integrated analysis of the factors that shape farmers' adaptation decisions and the broader institutional and socio-economic landscapes that influence these processes.

In the following section, I discuss the research gaps further to highlight the need for the research and establish its contribution to academic knowledge and practical applications. I aim to place this thesis within the broader academic discourse, demonstrate its theoretical, methodological, and practical significance, and justify the research questions.

#### 1.5 Research gaps

Despite the increasing scholarly attention on climate change adaptation, significant research gaps remain in understanding how smallholder farmers in ecologically vulnerable regions like Ghana's Guinea Savannah zone navigate climate risks. Existing literature has primarily focused on isolated aspects of climate change adaptation, often neglecting the complex interactions between adaptation actions, adaptation and intersectional analysis and institutional support. I provide a holistic perspective by exploring the relationships between adaptation actions, social inequalities, and institutional interventions to emphasize the need for policies that recognize the interconnected nature of adaptation and institutional dynamics. Accordingly, I address three key research gaps as they relate to knowledge of adaptation among smallholder farmers in the Guinea Savannah zone of Ghana.

#### 1.5.1 Limited understanding of the determinants of climate change adaptation

While previous studies in the Guinea Savannah zone of Ghana have explored the factors influencing smallholder farmers' adaptation actions, they have largely examined these factors in silos. Although these studies provide rich insights into the factors that influence the adoption of adaptation actions, significant research gaps remain (Asante et al., 2024). These gaps arise because most existing research concentrates on specific factors influencing farmers' adoption decision-making even though the factors that influence agricultural technology adoption are varied. Such concentration results in a lack of comprehensive research that examines the multifaceted factors influencing the adoption of climate change actions (Tong et al. 2024). For example, there is a critical gap in understanding smallholder farmers' latent climate perception factors and how these perception factors influence agricultural technology adoption (He et al., 2022; Gudina & Alemu, 2024; Azine et al., 2025).

While climate perception is a central feature of farmers' adaptation decisions (Grothmann & Patt, 2005; Azine et al., 2025), the adaptation literature, especially in the developing world often focuses on the significance of resources available to farmers to develop strategies within a specific institutional context to achieve sustainable livelihood outcomes (He et al., 2022; Azine et al., 2025). Also, the IPCC (2022b) posits that with more countries and regions prioritising adaptation in the face of increasing severity of climate change, the role of institutions in climate change adaptation warrants greater attention.

Another major gap is that previous studies often assume that farmers adopt only one action at a time on their farms. Hence, such studies focus on individual adaptation actions (Asante et al., 2024). However, farmers are more likely to adopt a combination of adaptation actions to address their production challenges, highlighting complementarity among these actions—an analysis often overlooked in adaptation studies (Adeagbo et al., 2023). Therefore, there are calls to further investigate and understand the factors influencing smallholder farmers' adoption of multiple adaptation actions and their complementarity (Gudina & Alemu, 2024). Also, smallholders' lived experiences and their unique contexts shape their adaptation behaviours (Llewellyn & Brown, 2020). However, these factors are often overlooked in studies of practice adoption in Ghana (Asante et al., 2024) and other regions (e.g. Aqib et al., 2024). Consequently, there are research

and knowledge gaps in understanding how perception, livelihood capitals, and institutional interventions—both individually and in combination—influence smallholder farmers' adaptation choices in Ghana.

While recognising the difficulty of capturing the full complexity of adoption decisions and limited consideration of technological and structural drivers (Rodríguez-Barillas et al., 2024; Ricart et al., 2025), I investigate the relative influence of perception, livelihood capitals and institutional interventions on smallholder farmers' adoption of a range of common adaptation actions to shape their adaptation decisions and reduce their vulnerability (see Chapter 4). I also assess whether adaptation actions complement each other, providing deeper insights into farmers' decision-making processes.

#### 1.5.2 Lack of intersectional analysis in climate change adaptation studies

Adaptation research has often treated smallholder farmers as a homogeneous group, overlooking the diversity of experiences within farming communities. Simply put, adaptation research and policy still fail to reflect the priorities of many people (Puig et al., 2025). In Ghana, most studies of agriculture's vulnerability focus on farm-level, technical adaptation strategies (e.g. Opoku Mensah et al., 2023), with limited research conducted on smallholder farmers' adaptive capacity (e.g. Abdul-Razak & Kruse, 2017). While existing research has significantly advanced our understanding of climate impacts and adaptation, few studies have focused on specific aspects of adaptation and intersectional analysis in Ghana. For example, Lawson et al. (2020) focused on understanding intersectional perceptions and adaptation actions of women farmers. Also, Alare et al. (2022) examined how inter-gender dynamics influenced access to social networks. Such vulnerability analyses based on gender, class, religion, and other factors are inadequate as they risk homogenising entire groups. Ensuing interventions may, therefore, miss the actual needs of countless individuals (Nyantakyi-Frimpong, 2020). Thus, existing studies in Ghana have largely overlooked intersectional analysis examining the nuanced vulnerabilities to climate extremes, the varying impacts on diverse yet equally exposed groups, and how such dynamics shape adaptive capacities among diverse yet equally exposed groups (Nyantakyi-Frimpong, 2020).

Echoing earlier studies in Ghana (e.g. Abdul-Razak & Kruse, 2017), I operationalised adaptive capacity based on the five capitals—human, social, natural, physical and financial—of the

Sustainable Livelihood Framework (SLF) (Chapter 5). These capitals influence farmers' actions to mitigate climate change impacts within an existing enabling environment of policy and institutional frameworks (Scoones, 1998). I adopted the SLF to define the components contributing to smallholder farmers' adaptive capacity, as outlined by Ellis (2000) and Scoones (1998). The SLF evaluates livelihoods by considering people's access to various capitals, how they combine and use the capitals to build capacity and create livelihoods, and how they can expand their capitals through interaction with other actors and institutions (Scoones, 1998). Such studies have been termed first-order capacity assessments (Elrick-Barr et al., 2022).

I seek to enhance this first-order adaptive capacity assessment by applying an intersectional approach to adaptation, analysing how indicators of smallholder farmers' stocks of capital and other socio-demographic characteristics intersect to support or constrain adaptive capacity. This analysis is important to reveal how inequalities influence adaptation opportunities and vulnerabilities. Nyantakyi-Frimpong (2020) qualitatively demonstrated how farmers' social characteristics intersected to deepen their vulnerability. He highlighted the need for more intersectional analysis to better understand vulnerability to climate extremes in Ghana. To advance this research, I align with the growing calls for empirically grounded intersectional research to understand the diversity of actors pursuing adaptation, how intersecting identities shape their adaptation in a highly diverse context, and what policies could promote more equitable adaptation within and across heterogeneous communities (Agrawal & Gibson, 1999; Erwin et al., 2021). Such intersectional research fosters a more nuanced and critical analysis of climate change and inequality dynamics (Arora-Jonsson, 2011; Hopkins, 2018; Puig et al., 2025).

#### 1.5.3 Institutional constraints and the sustainability of adaptation interventions

Although institutions have been recognised to play important roles in enabling smallholder farmers' adaptation, corresponding research in this area is largely under-explored (He et al., 2022; Azhoni et al., 2024), especially in developing countries such as Ghana (the location of this research) (Yomo et al., 2020; Tahiru et al., 2019). IPCC (2022b) recommended intensifying smallholder farm-level research to understand how institutions shape farmers responses to climate impacts and support their adaptation behaviours (IPCC, 2022b; Petzold et al., 2023), particularly in climate-sensitive areas (He et al., 2022). Such a focus has significant implications for developing climate change actions to address farmers' vulnerability (He et al., 2022).

Realising complex and ambitious goals, such as effective adaptation (UNFCCC, 2020), climate equity and justice (Kerr et al., 2022), and the Sustainable Development Goals (SDGs) (United Nations [UN], 2015; Pradhan et al., 2025), requires institutions to continue to be active in promoting adaptation (IPCC, 2022b; Witinok-Huber et al., 2025).

In this thesis (Chapter 6), I highlight the interfaces between institutional interventions and farmer adaptation behaviours. I investigate how institutions influence the adaptation behaviours of smallholder farmers to navigate climate-related risks and effectively adapt. In Ghana, there is a lack of empirical research on various institution-led adaptation actions, their outcomes, and the challenges limiting the implementation of adaptation actions. I focus on the institutional landscape (nature and goals of the identified institutions), institutional accessibility (how adaptation actions are facilitated) and institutional linkages (coordination among institutions and connection to communities) for vulnerable smallholder farmers (identified by Agrawal, 2008). I also document the challenges that limit the effectiveness and sustainability of institutional adaptation support to smallholder farmers. To understand the role and influence of institutions in adaptation, I consider three dimensions of their operations: scale, scope and sustainability.

By addressing these research gaps, I contribute to a more comprehensive understanding of smallholder farmers' adaptation to climate change. I provide novel insights into how adaptation actions are shaped by social identities and institutional constraints and offer recommendations for developing more inclusive and sustainable adaptation policies.

In the next section, I reframe these gaps as a specific research objective and a series of research questions that provide direction, coherence, and academic rigour to my thesis. The research questions then guide the choice of methodology, structure the analysis, and ensure practical relevance to help shape academic discourse and policy interventions discussed later in the thesis.

#### 1.6 Research objective and questions

The overall objective of this thesis is to examine the dynamics of climate change adaptation among smallholder farmers by analyzing the factors that shape their adaptation actions, the role of intersectionality in determining adaptive capacities, and the effectiveness of institutional interventions.

To address the research objective, I designed the following research questions structured around key themes and sub-themes to fill the identified research gaps.

**Research question 1:** Which factors influence climate change adaptation by smallholder farmers?

#### Sub-research questions:

- i. How do perception, livelihood capitals and institutional intervention, individually and in combination, influence smallholder farmers' adoption of a range of common adaptation actions to reduce their vulnerability to climate change?
- ii. Is smallholder farmers' adoption of multiple adaptation actions complementary?
- iii. What rationale—based on smallholder farmers' lived experiences of unique contexts explains smallholder farmers' practice adoption?

**Research question 2:** What role does intersectionality play in shaping adaptive capacity of smallholder farmers?

#### Sub-research questions:

- i. How do indicators of smallholder farmers' stocks of capital and other socio-demographic characteristics intersect to either support or constrain their climate adaptation efforts?
- ii. What smallholder farmers' narratives about their lived experience provide insight into social categories and their intersections?

**Research question 3:** What roles do institutions play in enhancing climate change adaptation by smallholder farmers?

#### Sub-research questions:

- i. What are the various institution-led adaptation actions and their outcomes for smallholder farmers?
- ii. What challenges limit the implementation of institutional adaptation actions?

In the next section, I discuss the structure of my thesis to serve as a roadmap to guide readers through the research, ensuring clarity, coherence, and logical flow. By clearly outlining the thesis

structure, readers—including examiners, researchers, and policymakers—can navigate the study, understand its organization, and grasp how different sections contribute to the overall argument. For a hybrid thesis, where my chapters are structured as journal articles, explaining the thesis structure is important to show how the papers contribute to addressing the overarching research questions.

#### 1.6 Structure of the thesis

I adopted a thesis by compilation model and structured the thesis as a combination of chapters with publications and manuscripts under review. Overall, the thesis is organized into eight (8) chapters.

Chapter 1 provides the foundation for my thesis. I introduce the research background and outline the problem formulation. I define the research objectives and questions, highlighting the significance of the research within the broader discourse on climate change adaptation, intersectionality, and institutional support for smallholder farmers. Finally, I present the thesis structure and conclude by linking to the theory review in Chapter 2.

Chapter 2 provides a literature review of theories underpinning climate change vulnerability and adaptation, intersectionality, and institutional support. I critically examine vulnerability and adaptation frameworks, situating them within social-ecological systems thinking. Also, I explore the role of institutions in shaping adaptation pathways, providing the theoretical lens through which the empirical findings are interpreted. Again, I set the stage for the subsequent empirical chapters by highlighting key debates in existing literature.

Chapter 3 outlines the research methodology and context. I outline the research design, methodology, and data collection techniques used in the thesis. I explain the mixed-methods approach I employed, including focus group discussions, institutional interviews and household surveys. I describe the study context—the Talensi district in Ghana's Guinea Savannah agroecological zone—in detail, focusing on its climatic challenges, livelihood systems, and institutional landscape. I also discuss the ethical considerations and data analysis methods used in the research.

Chapter 4 examines the factors which influence adaptation among smallholder farmers. Here, I present the first set of empirical findings in the form of a manuscript submitted to a peer-reviewed journal for publication. It examines how smallholder farmers' perceptions, livelihood capitals, and institutional interventions influence their adoption of various adaptation strategies. I explore the complementarity of adaptation actions and the rationale—farmers' lived experiences—behind farmers' adaptation behaviours and choices.

Chapter 5 is an article published in the peer-reviewed journal, Climate and Development. It explores the role of intersectionality in shaping adaptive capacity. I delve into the intersectional dimensions of climate adaptation, investigating how socio-demographic factors, including gender, education, age and wealth intersect with livelihood capitals to influence farmers' adaptive capacity. I highlight the unequal adaptation opportunities within farming communities and underscore the need for policies that address social differentiation in climate adaptation planning.

Chapter 6 investigates the role of institutions in supporting adaptation. This chapter is presented as a manuscript submitted to a peer-reviewed journal for publication. I examine institutional interventions aimed at supporting smallholder farmers' adaptation efforts. I analyze the types of adaptation support provided by institutions and their sustainability. Additionally, I identify key institutional barriers that hinder the implementation of adaptation initiatives.

Chapter 7 integrates findings from the three empirical chapters to provide a general discussion. I synthesize insights on adaptation actions, intersectionality, and institutional support. I reflect on how these factors interact and influence smallholder farmers' adaptive capacities, highlighting the broader implications for climate adaptation policy and practice. I synthesis empirical findings to theoretical debates, emphasizing the need for multi-scalar and intersectional approaches to adaptation planning.

Chapter 8 concludes the thesis with reflections on key findings, limitations, and recommendations for future research. In this final chapter, I synthesize the key contributions of my thesis, reflecting on its methodological, empirical, and theoretical significance. I revisit the research questions and discuss how the study's findings contribute to climate adaptation literature. Also, I acknowledge the study's limitations and suggest directions for future research,

particularly in exploring the long-term impacts of adaptation strategies and institutional interventions.

## 1.7 Conclusion

In this chapter, I introduced the research focus, framed the key problem areas, and outlined the objectives and significance of the study. I established the necessity of examining climate change adaptation through an integrated lens that considers adaptation actions, intersectionality, and institutional support. In the next chapter (Chapter 2), I build on this foundation by undertaking a literature review of theories that guide this research, offering insights into how vulnerability, adaptation, and institutional mechanisms shape smallholder farmers' responses to climate risks. I critically engage with existing theories and applications to build the theoretical foundation for the research.

# **Chapter Two**

# Conceptualising climate change vulnerability, adaptation, intersectionality and institutional support: A theory review

#### 2.1 Introduction

This chapter presents a review of the main themes and concepts related to this research. It critically analyses the key concepts underpinning this research and their interconnectedness. The chapter explains how vulnerability and adaptation are positioned within existing theoretical discourses, particularly concerning the impacts of climate change on social-ecological systems. The chapter adopts a multi-theoretical approach (e.g. Quinlan et al., 2016; Khalil, 2021) to provide in-depth insights into relevant literature and develop an understanding of the contextual issues of climate change vulnerability and adaptation, intersectionality, and institutional support as they relate to and are shaped by three conceptual areas of this thesis: 1. factors influencing climate change adaptation by smallholder farmers, 2. the role of intersectionality in shaping adaptive capacity of smallholder farmers, and 3. the role of institutions in enhancing climate change adaptation.

In the following section, I discuss the conceptualizations and definitions of vulnerability. I aim to provide theoretical clarity and scope for the study. How vulnerability is understood directly influences how it is measured, interpreted, and addressed. By clearly defining and contextualizing vulnerability within the scope of my thesis, I ensure consistency in analysis and enhance the validity of my findings.

## 2.2 Conceptualizations and definitions of vulnerability

Theoretical traditions from geography, environmental science, hazard studies, food security, economics, sociology, health and anthropology in the geophysical sciences have significantly shaped vulnerability research (Eakin & Luers, 2006; Paul, 2014). These traditions focus on addressing risks, responses and their associated welfare outcomes (Paul, 2014). However, debates, internal tensions and disciplinary integration within the vulnerability research community remain highly diverse (Miller et al., 2010; Adger, 2006). Vulnerability is a complex concept that varies depending on multiple factors, including environmental, social, economic,

geographic, institutional, governance, demographic and cultural factors (Thornton et al.; 2006; Ford et al., 2018; IPCC, 2022b).

While there are multiple interpretations of vulnerability (Thornton et al., 2006; Reed et al., 2013), there is no consensus on its precise definition (Gallopín, 2006; Fellmann, 2012). Despite this diversity, there is a consensus on the key attributes of the concept of vulnerability—it is multi-dimensional, site-specific, scale-dependent and dynamic (O'Brien et al., 2007; Turner et al., 2003). As a foundational stage of planning for climate change, understanding climate vulnerabilities involves responding to climate change by assessing its impacts <sup>7</sup> and risk <sup>8</sup>; planning and implementing adaptation (adaptation is further discussed in Section 2.6); making contingency arrangements for when impacts occur; addressing losses; and monitoring and evaluating climate change adaptation efforts (UNFCCC, 2021).

Vulnerability is defined as a state of susceptibility to harm arising from exposure to stresses associated with social and environmental change, coupled with a lack of capacity to adapt (Smit & Wandel, 2006; Adger, 2006). Nelson et al. (2007, p.396) defined vulnerability as the "susceptibility of a system to disturbances determined by exposure to perturbations, sensitivity to perturbations, and the capacity to adapt". Vulnerability has also been defined by the IPCC (2022a, p. 2927) as the "propensity or predisposition to be adversely affected. It encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt". The state of vulnerability is closely linked to the capacity to respond—an individual, community, or nation is considered vulnerable if it is open to harm as a result of climate change due to its limited capacity to respond to the threat (Eriksen & Kelly, 2007).

The source of vulnerability lies in the nature of properties and activities within interconnected Socio-ecological Systems (SES)—complex adaptive systems that enable interactions between environmental and social agents and factors, facilitating change (Anderies et al., 2004; Ostrom,

<sup>7</sup> 

<sup>&</sup>lt;sup>7</sup> "Effects on lives, livelihoods, health and well-being, ecosystems and species, economic, social and cultural assets, services (including ecosystem services) and infrastructure. Impacts may be referred to as consequences or outcomes and can be adverse or beneficial" (IPCC, 2022a, p. 2912).

<sup>&</sup>lt;sup>8</sup> "The potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from potential impacts of climate change as well as human responses to climate change" (IPCC, 2022a, p. 2921).

<sup>&</sup>lt;sup>9</sup> "In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects" (IPCC, 2022a, p. 2898).

2009; Schlüter et al., 2019)—(Turner et al., 2003). With consideration of these definitions, vulnerability refers to the following:

- a. The nature of properties and activities within interconnected SES (Turner et al., 2003).
- b. The state of susceptibility of SES (Schlüter et al., 2019); and
- c. Harm arising from exposure to stresses linked to social, environmental, economic, cultural, and ecological changes that is compounded by limited adaptive capacities (Berrouet et al., 2018).

In this section, I established the foundational conceptualizations and definitions of vulnerability, highlighting its complexity and multidimensional nature. However, understanding vulnerability to climate change requires more than just definitions; it demands a nuanced exploration of how vulnerability is interpreted within different analytical frameworks. To build on this foundation and deepen the analytical perspective, in the next section, I explore two general interpretations of vulnerability: the end-point (or outcome) approach and the starting-point (or contextual) approach. I aim to elucidate their theoretical underpinnings and demonstrate their implications for climate change adaptation.

#### 2.3 General interpretations of vulnerability

There are two general interpretations of vulnerability: the end-point approach and the starting-point approach (Kelly & Adger, 2000; Füssel & Klein, 2006). These interpretations of vulnerability are more succinctly summarised as outcome vulnerability and contextual vulnerability (O'Brien et al., 2007) (see Figure 3). The distinction between outcome vulnerability and contextual vulnerability interpretations roughly corresponds to the first- and second-generation studies defined by Burton et al. (2002). They are not simply about the different interpretations of vulnerability but fundamentally different framings of climate change (O'Brien et al., 2007).

Framings influence the questions asked, structure the kind of knowledge produced and determine what is included or omitted within the domain (Forsyth, 2003; O'Brien et al., 2007; Kanarp et al., 2025). For example, the definition of vulnerability used in the IPCC Third Assessment Report defined the concept as "the degree to which a system is susceptible to, or unable to cope with,

adverse effects of climate change, including climate variability and extremes" (IPCC, 2001, p. 225). This definition sees vulnerability as a "function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity" and is an example of outcome vulnerability (IPCC, 2001, p. 225). Conversely, Nelson et al.'s (2007, p. 396) definition of vulnerability as the "susceptibility of a system to disturbances determined by exposure to perturbations, sensitivity to perturbations, and the capacity to adapt" is an example of contextual vulnerability. Outcome and contextual vulnerability are further elaborated upon in the following section.

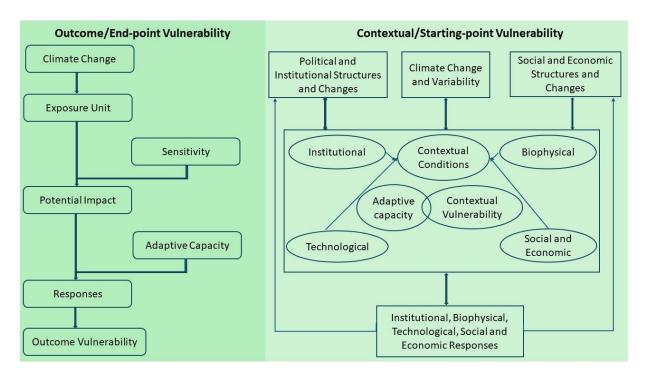


Figure 3: Frameworks for depicting outcome and contextual vulnerability to climate change

Source: Adapted from Smit et al., 1999; Allen Consulting Group, 2005; O'Brien et al., 2007; Pearson & Langridge, 2008

The theoretical and disciplinary foundations of outcome vulnerability are rooted in the physical sciences (Pearson & Langridge, 2008; Okpara et al., 2016). Outcome vulnerability adopts a positivist (reductionist) epistemological perspective<sup>10</sup> and focuses on a single or well-defined

<sup>&</sup>lt;sup>10</sup> It focuses on quantifiable impacts of climate hazards, emphasizing measurable cause-and-effect relationships while largely excluding social, cultural, and contextual factors.

group of hazards<sup>11</sup> or drivers of change (Okpara et al., 2016). Outcome vulnerability represents a linear approach to conceptualising vulnerability. It emphasizes the future impacts of climate change on SES and the corresponding responses to these pressures (O'Brien et al., 2007; see Figure 1). This perspective prioritizes the susceptibility of SES to the net effects of climate change after accounting for potential (future) adaptation measures (Kelly & Adger, 2000; Okpara et al., 2016). In essence, it views vulnerability as the residual risk remaining after the implementation of adaptive responses (O'Brien et al., 2007).

The outcome interpretation of vulnerability aligns with risk-hazard and integrated vulnerability approaches. It is particularly relevant for informing mitigation and compensation policy options aimed at estimating and reducing the costs of climate-related hazards (Füssel & Klein, 2006; Bennett et al., 2016). This framing primarily emphasizes mitigation strategies and technological solutions for adaptation (Räsänen et al., 2016; Fellmann, 2012). Analyzing outcome vulnerability involves projecting future emission trends, developing climate scenarios, evaluating biophysical impacts, and identifying response options (Kelly & Adger, 2000). To reduce outcome vulnerability involves reducing exposure through mitigation or developing adaptations to limit negative outcomes (O'Brien et al., 2007).

Outcome vulnerability studies, which define vulnerability in terms of net impacts, tend to frame adaptive options as fixes, often technological, aimed at minimizing specific projected impacts. Consequently, policy recommendations focus on sector-specific measures, such as introducing drought-resistant seeds or implementing infrastructure changes tailored to projected climate changes, thus, restricting the nature and scope of adaptive measures that are likely to be considered (Eriksen & Kelly, 2007; Atampugre, 2018). The outcome vulnerability approach often overlooks the role of human systems in shaping the outcomes of such events (Žurovec et al., 2017) and frames affected people as passive victims in the face of active threats and hazards (Wisner, 2004). It emphasizes outcome indicators rather than the state of a system before a hazard event occurs (Žurovec et al., 2017).

The contextual vulnerability interpretation has its theoretical and disciplinary foundations rooted in the social sciences (Pearson & Langridge, 2008; Okpara et al., 2016). It adopts a constructivist

<sup>&</sup>lt;sup>11</sup> "The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources" (IPCC, 2022a, p. 2911).

epistemological perspective<sup>12</sup> (Miller et al., 2010; Pearson & Langridge, 2008). The contextual vulnerability approach conceptualizes vulnerability as a state determined by the inherent characteristics of a system before it encounters a hazard event. Social vulnerability, which results from the social and economic characteristics of a system, is considered an inherent characteristic (Adger & Kelly, 1999; Žurovec et al., 2017). The contextual interpretations view people as active agents who are adaptive and possess the capacity to withstand and respond to climate change (Wisner, 2004). Thus, it is specific to context, purpose, place, and time, ensuring the active involvement and perspectives of assessors in identifying stressors<sup>13</sup>, impacts, and adaptive options (Adger, 2006; Fellmann, 2012).

It has been noted that a common question that emerges from contextual interpretations is "what can be done to strengthen people's own capacity to respond and adapt?", rather than "what can be done to protect the population?" as emerges from the outcome interpretation. Such an analysis focuses on the fundamental causes and drivers of vulnerability, thereby enabling the identification of a broader range of adaptive options and policy interventions (Eriksen and Kelly, 2007, p. 505). Contextual vulnerability conceptualizes vulnerability as a pre-existing condition within society, emphasizing the importance of understanding climate change experiences by examining the interplay between sensitivity, exposure and adaptive capacity (Smit & Wandel, 2006). This approach highlights how socio-economic, cultural, and political factors interact across time and space to shape diverse experiences of climate change. It offers a more nuanced theoretical foundation for understanding the human–environment dynamics that shape lived experiences of climate change (Ribot, 2010; Hanly & McDowell, 2025).

Contextual vulnerability frames vulnerability within the broader dynamics of SES (Bennett et al., 2016). It focuses on the underlying processes that shape vulnerability through human-environment interactions and the specific socio-ecological contexts in which these relationships occur (Naylor et al., 2020). This approach assesses risk by examining the cyclical interactions between social and biophysical factors, emphasizing how systemic conditions contribute to vulnerability. Contextual vulnerability analyzes vulnerability from the perspective of individuals or groups within society (Pearson & Langridge, 2008). This analysis is critical as the underlying

<sup>&</sup>lt;sup>12</sup> It considers vulnerability as socially constructed, shaped by dynamic interactions between social, political, and environmental factors, emphasizing subjective experiences and contextual realities.

<sup>&</sup>lt;sup>13</sup> Events and trends, whether climate-related or not, that have an important effect on the system exposed and can increase its vulnerability to climate-related risks (IPCC, 2022a)

causes of vulnerability are not attributed solely to climate change but rather to the interactions between contextual conditions and multiple processes of change (O'Brien et al., 2007). Also, contextual vulnerability focuses on the historical factors or current characteristics of individuals, households, communities, sectors, nations, etc. that determine their differential susceptibility to harm (Bennett et al., 2016). This approach also emphasizes the importance of mitigating climate change based on principles of equity and justice (Athanasiou & Baer, 2002; Adger et al., 2006).

Furthermore, in the context of climate change, contextual vulnerability refers to a system's current susceptibility to climate variability and change, shaped by multiple interacting processes and factors (O'Brien et al., 2007; Okpara et al., 2016). It emphasizes present-day vulnerability and the capacity for adaptation to existing climate impacts (Atampugre, 2018). This perspective highlights the potential for social systems to reduce vulnerability by transforming contextual conditions that enable effective adaptation (Atampugre, 2018). Lastly, it adopts "a multidimensional and processual view of climate-society interactions" (O'Brien et al., 2007, p. 76). In this context, contextual conditions shape both exposure to climate change and variability<sup>14</sup>, as well as the potential responses to these challenges. In turn, these responses can influence the very processes and conditions in which they occur (O'Brien et al., 2007). Reducing contextual vulnerability, therefore, involves transforming the underlying context in which climate change unfolds, thereby enabling individuals and groups to respond more effectively to changing conditions (O'Brien et al., 2007).

Building on the discussion of the general interpretations of vulnerability—outcome and contextual vulnerability—it is essential to delve deeper into the specific approaches to vulnerability assessment. By examining the risk-hazard approach, entitlement and livelihoods approach, and the integrative approach, I can better illustrate how different perspectives shape our understanding of vulnerability as either an exposure to hazards, a social condition, or a dynamic integration of exposure and societal resilience. With this exploration, I provide a comprehensive framework to contextualize the empirical findings of this thesis, thereby enriching the analytical lens through which I examine vulnerability and adaptation.

<sup>&</sup>lt;sup>14</sup> "Deviations of some climate variables from a given mean state (including the occurrence of extremes, etc.) at all spatial and temporal scales beyond that of individual weather events" (IPCC, 2022a).

#### 2.4 Approaches to vulnerability assessment

"Vulnerability manifests in specific places at specific times" (Adger, 2006, P. 276). This manifestation underscores its context-specific and dynamic nature, as it is tied to particular places, times, and the perspectives of those assessing it (Smit & Wandel, 2006; UNEP, 2021). Vulnerability assessment should, therefore, be an on-going process to highlight its spatial and temporal scales of a particular region or community and offer valuable information to help reduce risk (Luers, 2005; Eriksen & Kelly, 2007). Accordingly, the development of any one-size-fits-all solution or general-purpose approach to asses vulnerability is problematic (Pearson & Langridge, 2008). Theoretically, there are three approaches to vulnerability assessment (see Füssel & Klein, 2006; Füssel, 2007a; Ribot, 2011; Tesso et al., 2012; Opiyo et al., 2014):

- 1. Risk-hazard approach—vulnerability as exposure to hazard;
- 2. Entitlement and livelihoods approach—vulnerability as social condition; and
- 3. Integrative approach—vulnerability as the integration of potential exposures and societal resilience.

The risk-hazard approach is rooted in a positivist orientation <sup>15</sup>, employing a biophysical vulnerability assessment to evaluate the extent of damage that a given environmental stress causes to both biological and social systems (Tesso et al., 2012). This approach is associated with outcome vulnerability (O'Brien et al., 2007; Kelly & Adger, 2000). It is generally a quantitative impact assessment approach that evaluates multiple outcomes of a single climate event (Ribot, 2011; Adger, 2006). The risk-hazard approach attributes the causes of risk and vulnerability to the hazard itself, often tracing a linear causal relationship back to the hazard (Atampugre, 2018). The risk-hazard approach employs theoretically developed measurable indicators or characteristics to establish indices that represent the vulnerability of a system (Welle & Birkmann, 2015).

The risk-hazard approach has proven valuable in providing a clear basis for comparing vulnerability situations among ecological and human systems (Osman, 2023). However, this approach has been criticized for failing to adequately incorporate the social dimensions of

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<sup>&</sup>lt;sup>15</sup> The theoretical perspective of positivism is objectivism and relies on deterministic philosophy in which causes determine effects (Crotty, 2020; Creswell & Creswell, 2023)

climate risks and vulnerabilities (Adger, 2006) but focusing on evaluating and abating the costs of climate impacts (Bennett et al., 2015). Omari (2018) explains this limitation in relation to farmers, noting that they are vulnerable to factors affecting their livelihood options, such as climate change, water stress and soil degradation, among others. Socioeconomic factors that shape farmers' adaptive capacity are considered irrelevant and assumed to remain constant. However, two farming households may experience the same environmental or climatic conditions but vary in their socioeconomic factors. The limitation of the risk-hazard approach lies in its reliance on indicators developed primarily from expert knowledge, with minimal input from vulnerable communities directly affected by hazards (Adger, 2006). Additionally, it depends on data from national or regional censuses, which are computed at a broader scale and can obscure the real vulnerability situations in micro-level systems (Morse & Fraser, 2005).

The entitlement and livelihoods approach is oriented towards social constructivism<sup>16</sup> (Adger, 2006; Füssel & Klein, 2006; Ribot, 2011). It locates causality in society, tracing the causes of vulnerability to multiple environmental, socio-economic and political factors, which can make exposure meaningful or not (Füssel & Klein, 2006; Ribot, 2011). This approach emphasizes the dispositions of social systems (households, communities, and sectors) that make them susceptible to stressors (Bennett et al., 2015). Here, vulnerability is primarily attributed to the social system (O'Brien et al., 2007; Smit & Wandel, 2006). The entitlement and livelihoods approach depicts vulnerability as a lack of livelihood assets or entitlements necessary to sustain a group or an individual in the face of climate-related hazards (Adger, 2006). Thus, this approach highlights that groups or individuals within a community or household differ in their vulnerability due to their differences in various factors, including gender, age, education, income, access to credit, health status, access to information and technology, social networks, political power and land ownership.

In essence, socio-economic vulnerability reflects socio-economic inequalities (Omari, 2018). A key criticism of this approach is that it often overlooks or reduces the significance of environmental factors which distorts the measurement of vulnerability (Adger, 2006; Omari, 2018). This approach assumes that all other factors, such as climatic and environmental conditions remain constant and have no significant influence on vulnerability. However, in

<sup>&</sup>lt;sup>16</sup> The theoretical perspective of constructivism is the belief that meaning is constructed through subjective interrelationships with the world—there is no existence of reality without consciousness (Creswell & Poth, 2018; Creswell & Creswell, 2023).

reality, this assumption is not the case. Communities and households are influenced by environmental and socio-economic factors (Deressa et al., 2008).

The integrative approach adopts a pragmatist perspective<sup>17</sup> (Füssel, 2007a). This approach seeks to address the limitations of the risk-hazard and entitlement and livelihoods approaches by integrating both to determine vulnerability (Füssel, 2007a; Opiyo et al., 2014). It defines vulnerability as an inherent property of socio-ecological systems (Adger, 2006; Birkmann et al., 2013). The integrative approach views vulnerability as a function of anthropogenic and biophysical factors, focusing on the interactions between them. Thus, it integrates both external biophysical factors, such as exposure, and internal social dimensions, including a system's sensitivity and adaptive capacity (Füssel & Klein, 2006). It assesses the combined effects of biophysical and socio-economic factors (Ribot, 2011; Birkmann et al., 2013). There is however no standard method for combining the biophysical and socio-economic indicators (Tesso et al., 2012). An example of a successful methodology may be found in the work of Opiyo et al. (2014). They incorporated environmental factors, such as rainfall, temperature, drought and flooding with socioeconomic factors, including gender, age, access to credit, marital status and remittances to assess the vulnerabilities of rural households in Kenya.

The integrative approach emphasizes the involvement of local communities in identifying and analyzing context-specific experiences and information regarding local perceptions and climate impacts on communities and individuals affected (Ayantunde et al., 2015; Agrawal et al., 2020). It relies on participatory methods such as focus group discussions and interviews to collect data on the causes, timing, and frequency of hazards, the severity of their impacts, and the strategies, resources and institutional support available for reducing vulnerability (Janssen et al., 2006; Ayantunde et al., 2015). From the perspective of the integrative approach, vulnerability is viewed as the biophysical, socio-economic, and political advantages and disadvantages of an individual or group that shape their capacity to anticipate, cope with, withstand, and recover from a previous state of well-being after experiencing the impacts of hazards (Janssen et al., 2006). This view acknowledges the multiple and complex sources of vulnerability, including physical, natural, social, and cultural factors, as well as those resulting from decision-making, policy formulation, and implementation (Freduah, 2016). Failure to consider these multiple and

<sup>&</sup>lt;sup>17</sup> A pragmatist perspective combines both biophysical and social dimensions of vulnerability, emphasizing practical, context-specific solutions that bridge positivist and constructivist viewpoints.

complex sources of vulnerability within a socio-ecological system can result in misguided response strategies, potentially leading to significant unintended results or surprises (Adger, 2006; Puig et al., 2025).

## 2.5 Vulnerability and intersectionality

This thesis adopts an intersectional lens to understand how vulnerability to climate change is coproduced by overlapping social identities and structural inequalities. Central to this framing is the foundational work of legal scholar and critical race theorist Kimberly Crenshaw (1989, 1991), who first coined the term 'intersectionality' to capture the unique and compounded forms of discrimination experienced by Black women in the United States of America. Crenshaw's work has since become foundational in the social sciences, emphasising that experiences of marginalisation cannot be fully understood through single-axis analyses of identity such as gender or race alone (Hankivsky & Cormier, 2011; Ahlborg & Nightingale, 2018). In the context of climate change, this perspective offers critical insights into how intersecting factors including gender, class, age, ethnicity, and spatial location—shape differentiated experiences of vulnerability and access to adaptation resources (Ravera et al., 2016; Singleton et al., 2021). Building on this tradition, this thesis engages intersectionality as an approach to explore how power relations and structural constraints interact to shape smallholder farmers' adaptive capacities. This approach allows for a more nuanced understanding of vulnerability that avoids oversimplification and ensures that adaptation interventions are responsive to the complex realities on the ground (Thompson-Hall et al., 2016; Erwin et al., 2021).

The multiple and complex sources of vulnerability acknowledge that individuals' experiences with climate change vulnerability are influenced by intersectionality (Yimam & Holvoet, 2023; Opoku Mensah et al., 2025)—how social identities, including gender, race, class, age, ability and geography interact to create complex experiences and unique meanings within and between social groups (Hankivsky & Cormier, 2011). This interaction shapes adaptation processes and outcomes and enables a more accurate assessment that addresses inequalities and promotes equitable programmes and policies to address such inequalities (Erwin et al., 2021). Thompson-Hall et al. (2016) assert that intersectionality delves deeply into the multi-faceted identities of farmers. It illuminates how these attributes coalesce to influence the vulnerability of diverse individuals. Intersectionality facilitates the development of more nuanced understandings of the

dynamic interplay between power structures and institutions and how they shape adaptive capacity.

Intersectionality clarifies how social, economic, and political factors limit certain positionalities' access to adaptation resources and participation in institutions, making them multiplicatively vulnerable to social-ecological change (Ahlborg & Nightingale, 2018). Therefore, to attain a more nuanced understanding of vulnerability to climate extremes and vulnerable groups, it is vital to consider how multiple social characteristics such as gender, age, disability, religion, and class in combination instead of in isolation (Thompson-Hall et al., 2016) shape adaptive capacities and, subsequently, farmers' level of vulnerability (Ravera et al., 2016).

In the next section, I delve into the components of vulnerability—exposure, sensitivity, and adaptive capacity—to fully understand how these elements interact to shape the vulnerability of SES. By unpacking these components, I provide a more nuanced analysis of vulnerability to inform targeted adaptation actions and set the stage for a comprehensive examination of climate change impacts and responses.

## 2.6 Components of vulnerability

In the context of the integrative approach to vulnerability assessment, the vulnerability of any system, regardless of scale, depends on its exposure and sensitivity to harmful conditions, and capacity (biophysical, social, economic, and political) to respond and adapt (Smit & Wandel, 2006; IPCC, 2014; 2022a). Thus, vulnerability is a function of the character, magnitude, and rate of climate variations to which a system is exposed, its sensitivity to these changes (i.e., susceptibility to harm), and its adaptive capacity (i.e., the preconditions that enable adaptation) (IPCC, 2014; 2022a). Vulnerability, therefore, has both external—a system's exposure to climate variations and other environmental factors—and internal—a system's sensitivity to stresses and adaptive capacity—dimensions (Adger, 2006; Füssel & Klein, 2006).

As shown in Figure 4, exposure, sensitivity, and adaptive capacity are interrelated, dynamic, and variable, with broad applicability to climate change (Weis et al., 2016). For example, manifestations of climate change—such as seasonal temperature shifts, rainfall variability, and extreme events including prolonged droughts and floods—pose significant risks to the SESs of rural communities and households (Tong et al., 2024). These systems are exposed to a myriad of

risks and changes that affect nearly every aspect of agriculture and the local communities that depend on it for their livelihoods (United Nations Framework Convention on Climate Change [UNFCCC], 2023). Enhancing adaptive capacity empowers socio-ecological systems, enabling them to safeguard livelihoods and reduce vulnerability under extreme climatic stressors (Abdollahzadeh et al., 2023). Accordingly, vulnerability assessment necessitates integrating socioeconomic and biophysical approaches (Smit & Wandel, 2006).

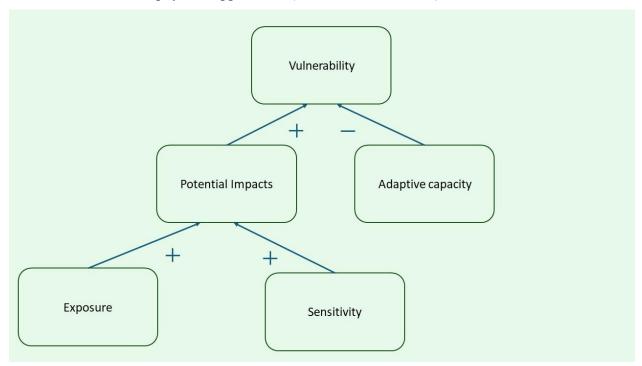


Figure 4: Components of vulnerability and their interactions

Source: Locatelli et al. (2008, p. 6)

**Note:** The signs under the arrows indicate that high exposure, high sensitivity and low adaptive capacity contribute to high vulnerability.

## 2.6.1 Exposure

Exposure is the extent to which people, livelihoods, ecosystems or species, environmental services, infrastructure, functions, resources and socio-economic and cultural assets are at risk of being adversely affected (Adger, 2006; IPCC, 2014; 2022a). According to Ericksen (2008), a system must be first exposed to be vulnerable. Exposure is the extent to which a system comes into contact with or is confronted with stressors, including people affected in a particular area by

the size, rate and duration of climatic stressors (Adger, 2006; Smit & Wandel, 2006). Birkmann et al. (2013, p. 200) succinctly put exposure as "the extent to which a unit of assessment falls within the geographical range of a hazard event". Exposure is conceptualized in terms of spatial and temporal patterns, encompassing fixed physical attributes of social systems (e.g., infrastructure) and human systems (e.g., livelihoods) that are spatially tied to specific resources and practices, which may also be subject to exposure (Birkmann et al., 2013).

Exposure is associated with variations in rainfall and temperature. An increase in exposure—such as seasonal temperature changes, rainfall variability and extreme events, including protracted droughts and floods—heightens vulnerability, particularly among farmers (Ide et al., 2014; Teshome, 2016). Exposure is viewed as biophysical risks and household exposure to stressors—including changes in meteorological conditions, such as rainfall and temperature, and extreme events like floods, droughts and storms (O'Brien et al., 2004; Baffour-Ata et al., 2024) and the broad range of social, economic, political, institutional, technological, environmental, and demographic factors that affect farmers' access to and availability of resources, opportunities, services and markets (Füssel & Klein, 2006; Antwi-Agyei et al., 2017) as these risks and stressors hinder agricultural productivity and sustainability (Baffour-Ata et al., 2024).

# 2.6.2 Sensitivity

Sensitivity refers to the predisposition of SESs to be affected by environmental risks (Birkmann et al., 2013). It is determined by the inherent characteristics of a system being exposed and the extent of stress exerted on a particular system (Smit & Wandel, 2006). Sensitivity is the extent to which a species or system is either beneficially or adversely affected by climate change or variability. This effect is influenced directly or indirectly by the degree of the species or system's dependence on natural and climate-related resources or ecosystems, such as agriculture (Adger, 2006; IPCC, 2022a). It can serve as a gateway to exposing a system to stressors. However, an insensitive system may close the system to adaptation and limit access to potential benefits or new opportunities (Gallopín, 2006). Generally, sensitivity increases the impacts of exposure on people and systems, leading to more adverse impacts (Omari, 2018).

Sensitivity is defined by human-environmental conditions. Specifically, the five capitals—human, social, natural, physical and financial of the SLF, as further explained in Section 2.6.3

Adaptive capacity either influences the adaptive responses of households and communities to climate-related hazards or is adjusted (created or diminished) as a result of exposure to such hazards. It highlights the degree to which livelihood capitals are susceptible to climate hazards (see Atampugre, 2018). The main components of the SLF are the vulnerability context, stocks and flows of livelihood assets, and institutions (processes and structures) which mediate access to and use of assets in building livelihood strategies aimed at achieving livelihood goals (Scoones, 1998). The vulnerability context encompasses the risk factors affecting a livelihood, represented by shocks/hazards, trends, and seasonality (Chambers & Conway, 1992). According to Osman, (2023), the livelihood assets, along with the institutional structures and processes, are the primary causal factors influencing households' sensitivity to shocks where institutional processes and structures of the SLF shape the risk context of vulnerable people (see Osman, 2023).

#### 2.6.3 Adaptive capacity

The concept of adaptive capacity, along with adaptation, has gained significant prominence in recent years (Fidelman et al., 2017). For farmers, while models to describe and predict the adoption of innovations abound (Montes de Oca Munguia et al. 2021), studies of climate change adaptation have largely occurred through the lens of adaptive capacity. Adaptive capacity has been particularly advancing within the vulnerability framework. The adjustments made to address exposure and sensitivity are a reflection of adaptive capacity (Smit & Wandel, 2006). It is considered a critical property of a system for reducing vulnerability by modulating exposure and sensitivity (Engle, 2011) (Figure 4). It is closely related to or synonymous with several commonly used concepts, including adaptability, coping ability, resilience, stability, management capacity, robustness and flexibility (see Smit & Wandel, 2006). Adaptive capacity reflects the ability of a system to adjust to sustain and reduce stressors from environmental change (IPCC, 2014).

The Millennium Ecosystem Assessment ([MA], 2005) defines adaptive capacity as the ability of a system to adjust to potential damage, exploit opportunities or respond to consequences. It has been referred to as a system's ability to adjust to or cope with the real or anticipated climate impacts while maintaining or improving its conditions (Gallopín, 2006; Engle, 2011). According to IPCC (2022a), adaptive capacity is the ability of humans, systems, institutions, and other

organisms to adjust to potential damages, take advantage of opportunities, or respond to consequences. The central role of adaptive capacity is widely recognized as an integral and positive attribute or desirable property of a system to reduce vulnerability (Engle, 2011; Elrick-Barr et al., 2022). Low adaptive capacity relative to exposure and sensitivity contributes to high vulnerability. In contrast, high adaptive capacity mitigates the effects of exposure and sensitivity, thereby reducing vulnerability (Thomas et al., 2019).

The core of vulnerability lies in a system's susceptibility to adapt to socio-ecological risks, primarily due to deficiencies in adaptive capacity (Smit & Wandel, 2006). Individuals, groups, or systems with low adaptive capacity often struggle to manage continued changes or capitalize on opportunities arising from climate change (Cinner et al., 2012). It presupposes that limited access to assets, indicative of weak adaptive capacity among, for example, smallholder farmers as examined in this thesis, leads to higher levels of vulnerability (Appiah & Guodaar, 2022; Ferdous & Mallick, 2019). According to Adger (2003), the factors that influence the ability of a socio-ecological system to adapt to hazards are considered the determinants of adaptive capacity. Fidelman et al. (2017) identify these determinants as broad categories, including resources and infrastructure, information and technology, organization and social capital, wealth and financial capital, political capital, and institutions and entitlements.

The adaptive capacity of a household depends on its ability to utilize local resources and develop short-term adjustments or long-term transitions to address crises which affect the availability and access to resources (Nath & Arrawatia, 2025). These capitals influence farmers' actions to mitigate the impacts of climate change within an existing enabling environment of policy and institutional frameworks (Scoones, 1998). These capitals are conceptualized as stocks that households can store, accumulate, exchange, allocate and transform to develop different livelihood strategies (Rakodi, 1999; Nath & Arrawatia, 2025). Adaptive capacity highlights how farming households combine resources to develop livelihood strategies, emphasizing the importance of using multidimensional measures, such as adaptive capacity, to assess human agency (Quandt, 2018). Additionally, focusing on these capitals provides pathways to reducing vulnerabilities and mitigating risks in all forms (Scoones, 1998; Nath & Arrawatia, 2025).

Institutional structures and processes are critical in building adaptive capacity (IPCC, 2022b). Institutions act as anchors and scaffolding to reinforce adaptive capacity (Agrawal, 2008). In this

context, adaptive capacity can be defined as the institutional preconditions that enable adaptation to socio-environmental changes (Fidelman et al., 2017). These institutional preconditions comprise the inherent characteristics of institutions that empower social actors to respond to short- and long-term impacts (Gupta et al., 2010) (see Section 2.6.3). Here, Fidelman et al. (2017), drawing on the vulnerability framework, define institutional capacity in terms of knowledge, financial, and technical resources that enable effective response mechanisms dealing with adaptation and risk management.

Adaptive capacity aligns with the need to address the core thematic dimensions of vulnerability—social dimension, economic dimension, physical dimension, cultural dimension, environmental dimension and institutional dimension—within a holistic assessment process (Birkmann et al., 2013). The social dimension of vulnerability is the propensity for human well-being to be adversely affected by disruptions to individual and collective social systems and their characteristics (e.g., gender disparities and marginalization of social groups). The economic dimension refers to the propensity for loss of economic value resulting from damage to physical assets or disruptions of productive capacity. The physical dimension discusses the potential for damage to physical assets, such as infrastructure (Birkmann et al., 2013).

Within the cultural dimension of vulnerability, the potential for damage to intangible values, such as the meanings attributed to customs, habitual practices, and natural landscapes is discussed (Birkmann et al., 2013). The environmental dimension is used to refer to the potential for damage to biophysical and ecological systems and their various functions, including specific environmental services and ecosystem functions. Finally, the institutional dimension of vulnerability discusses the potential for damage to governance systems, organizational structures and functions, as well as the formal and informal rules that guide them (Birkmann et al., 2013; Renaud, 2006). Most systems and assets exposed to hazards will exhibit more than one dimension of vulnerability (Birkmann et al., 2013).

Exposure and sensitivity of socio-ecological systems create impacts that highlight the perturbations exerted on these systems. It is possible to be exposed without being vulnerable. However, to be sensitive—and thus vulnerable—exposure is a necessary precondition (Atampugre, 2018). Together, they determine the potential impacts a species or system may experience, which are moderated by its adaptive capacity (Turner et al., 2003). Neither

sensitivity nor exposure accounts for a system's capacity to adapt. A system may be highly sensitive or exposed but that does not necessarily mean it is vulnerable (Adger et al., 2007; Fellmann, 2012). Reidsma et al. (2007) differentiated between the potential and actual impacts of climate change on a particular system. The potential impact is a function of exposure and sensitivity without considering adaptive capacity. The actual impact is when adaptive capacity is considered. Vulnerability is, therefore, the net impact that remains after adaptive capacity is accounted for. The extent of adaptive capacity is responsible for varying degrees of vulnerability among individuals or households within the same community (Smit & Wandel, 2006; Eakin & Bojórquez-Tapia, 2008).

In the next section, I delve into the concept of adaptation, linking it directly to the vulnerability context previously established. I provide a holistic understanding of how to navigate and thrive amidst climate change challenges. By exploring how systems are exposed and sensitive to climate risks, and how adaptive capacity influences these dynamics discussed earlier, I contextualize adaptation that can mitigate these vulnerabilities and provide practical solutions to vulnerability. I start by discussing the conceptualizations and definitions of adaptation to clarify the scope and focus of my research. How adaptation is defined influences the interpretation of adaptive actions, the identification of influencing factors, and the evaluation of effectiveness. By thoroughly exploring different conceptualizations, I position my study within the existing literature, justify my analytical approach and provide a nuanced context for my research findings.

## 2.7 Conceptualizations and definitions of adaptation

The concept and practice of adaptation are not new and have expanded significantly in recent years (Kotir, 2011; Berrang-Ford et al., 2021). Adaptation in the context of climate and environmental change has been extensively researched, as evidenced by a wealth of existing literature (Bawakyillenuo et al., 2016; Owen, 2020). Understanding adaptation relies on the diverse and intersecting ways in which people know, experience, and respond to climate change (Owen, 2020). Over the past decades, adaptation has become a central and widely acknowledged component of the international climate policy and research agenda (Klein et al., 2014; Owen, 2020). In addition to the Paris Agreement, with Article 7 establishing climate adaptation as a key issue for global governance (Persson, 2019), it received its own International Organization for Standardization (ISO) standard [ISO 14090] in 2019. These developments solidify adaptation as

a distinct area of research, practice and policy (Nalau & Verrall, 2021). However, there remains a need to further understand how and where adaptation is occurring, share best practices, prioritize adaptation financing, identify gaps and map evidence across regions and sectors (Berrang-Ford et al., 2021).

At a fundamental level, adaptation appears straightforward—it involves adjusting actions, behaviours, and decisions within social, biological, and built systems in response to climatic changes (Smit & Pilifosova, 2003). Adjustments can be reactive—responding to events that have already occurred—or anticipatory—preparing for future events or conditions (Smit et al., 2000; Smit & Pilifosova, 2003). Adaptation inherently means dealing with deep uncertainty arising from various factors, including uncertainties in emissions, climate system responses, societal reactions, future global socio-economic developments and climate modelling (Hallegatte, 2009). Adaptation is inherently contingent upon the specific events or conditions it is reacting to or anticipating (Owen, 2020). While the field of climate change adaptation is relatively new, it builds on decades of research into responses to environmental change (Liverman, 2015). It was formulated as a fundamental concept in cultural ecology and hazard and risk studies in the latter part of the 20th century (Head, 2009; Bassett & Fogelman, 2013; Owen, 2020).

In practice, adaptation suffers from a lack of clarity in its definition (IPCC, 2014). In positioning adaptation within the context of climate change discourse, several authors have defined it in holistic terms (Bawakyillenuo et al., 2016). From the perspectives of Adger (2003) and Smit & Wandel (2006), adaptation refers to adjusting a system to cope with climate impacts in both short-term and long-term processes. According to Nelson et al. (2007), adaptation refers to the decision-making processes and the set of actions implemented to maintain the capacity to address current or anticipated future changes. Similarly, adaptation may be defined as the process of making adjustments to reduce the adverse impacts of climate on people's health and well-being while capitalizing on the opportunities provided by their climatic environment (Eriksen et al., 2011). The IPCC (2022a) defines adaptation as adjusting natural or human systems to actual or expected climate and its effects, to moderate harm or exploit beneficial opportunities.

These definitions highlight the basic goals of adaptation: to increase adaptive capacity—the ability to respond effectively to changing shocks and stresses to reduce or manage risks (Engle,

2011); to enhance resilience—the ability of a socio-ecological system to maintain functionality when confronted with stress and shocks (Nelson et al., 2010); and to reduce vulnerability—the susceptibility to harm when exposed to external hazards (Yamin et al., 2005). These adaptation goals are often interconnected (Smit & Wandel, 2006). A system with high adaptive capacity is generally less vulnerable to harm, thereby becoming more resilient and better equipped to cope with risks (Owen, 2020).

These definitions and goals of adaptation are important as they highlight the critical elements and the complexity of adaptation, including a system's adjustments to climate-related stressors and vulnerability reduction (Atampugre, 2018). For example, the IPCC (2022a) definition of adaptation emphasizes that societal change is essential for responding to shifts in a socio-environmental system. Here, adaptation is perceived not as an object but as a process through which social systems manage diverse changes, including climate change (Pelling, 2011; Eriksen et al., 2015). This perspective broadens the scope of adaptation beyond environmental changes to include adjustments to other forms of change, such as demographic and land-use changes.

Consequently, adaptation is framed as part of a broader development challenge (Masud-All-Kamal, 2019; Amoah & Simatele, 2021). From this standpoint, Pelling (2011) argues that adaptation efforts must address the root causes of vulnerability through incremental or transformative changes in the socio-political system (see Section 2.10). Also, Nelson et al. (2007) define adaptation as the processes of decision-making within a system, rather than merely the adjustments a system makes in response to changing conditions or climatic stimuli<sup>18</sup>. This definition highlights the importance of understanding the nature of such changes and their effects on a specific socio-ecological system to ensure that decisions do not inadvertently exacerbate the impacts of those changes or reduce the system's capacity to respond effectively (Freduah, 2016; Schipper & Mukherji, 2024). These definitions imply that adaptation involves building adaptive capacity to enhance the ability of a system—whether individuals, groups, or communities—to adjust and implement adaptive strategies (Nelson et al., 2007).

Having explored the conceptualizations and definitions of adaptation, I now examine the relationship between adaptation and the adoption of innovations. In the context of my research,

<sup>&</sup>lt;sup>18</sup> Stimuli refer to stressors, events, hazards, doses, perturbations or disturbances. They are typically associated with climate or weather conditions, as well as the ecological or human impacts of such conditions (Smit et al., 1999; Turner et al., 2003)

understanding how smallholder farmers perceive, evaluate, and ultimately adopt adaptation actions is vital for explaining the variations in adaptive capacity and outcomes. I discuss how farmers' decisions are influenced by several factors, including social, personal, economic, and institutional factors.

#### 2.8 Adaptation and adoption of innovations

In the context of adaptation to climate change by farmers, changes in practices have been traditionally described through a diffusion of innovations lens (Rogers, 2003). The numerous definitions of adaptation reveal several confluences that highlight the inherent characteristics of the concept and its connections to the diffusion of innovations theory (Rogers, 2003; Bawakyillenuo et al., 2016). According to Rogers (2003; p. 26) "an innovation is an idea, practice, or object that is perceived as new by an individual or other unit of adoption". Climate change adaptation and adoption of innovations are related fields of research. Rodima-Taylor et al., 2012, p.107) define innovations as "human adaptations to changing needs and socioeconomic conditions and are therefore embedded in social processes".

In both adaptation and adoption, the characteristics of the innovation and those of the adopter, in addition to local biophysical, socio-cultural and institutional contexts, mediate practice change and may encompass the adoption of technology transfer across locations and interventions by institutions.

Understanding current applications and adoption of adaptation relies on the multiple and intersecting ways in which people perceive, experience, and respond to climate change (Owen, 2020). Adaptation efforts exhibit regional variations and are shaped by multiple, interrelated factors, including socio-demographic and psycho-social attributes, livelihood capitals, and institutional support mechanisms (e.g. Adeagbo et al. 2023; Asante et al. 2024; Ali et al., 2025). Adopting innovations is a function of perception and available resources (Brullo et al., 2024; Matos, 2025). For example, psycho-social attributes such as perception of need are the driving force behind innovation, as they drive agents to develop solutions to identified issues such as targeted adaptation measures (Rogers, 2003; Grothmann & Patt, 2005; Zhang et al., 2023) and help policymakers to appreciate ground-level scenarios to refine climate change actions and

interventions tailored to the local context (Akhtar et al., 2018; Panja & Mukhopadhyay, 2024; Ricart et al., 2025).

Farmers' climate perception is a complex process that incorporates various psychological aspects, including knowledge, behaviours, opinions and practices related to changes in climate patterns (Whitmarsh & Capstick, 2018). Perception denotes a range of judgments, attitudes and beliefs shaped by exposure, memory, experience, expectation and definition (Taylor et al., 1988; Sam et al., 2020). Eakin et al. (2016) and He et al. (2022) posit that farmers' adaptation decisions are shaped by their perception of climate change. Such perception is a critical element for assessing adaptation strategies and the initial move towards adaptation (Gardezi & Arbuckle, 2018; Aliyar et al., 2022; Chetto et al., 2025). Matos (2025) found that initiating and advancing adaptation efforts depend not only on the presence of risks or vulnerabilities but also on key stakeholders' perception and recognition of the problem. Individuals, institutions, and organizations that perceive their climate risks to be high are more likely to take action to reduce their vulnerability (Dilling et al., 2017; Brullo et al., 2024).

In regard to the above, farmers' responses to climate change are more influenced by their beliefs and attitudes than by the real climate trends themselves. Perception of climate change and worrying about its impacts spur adaptation (Bohensky et al., 2016; Ricart et al., 2025). Evidence also shows that individuals who perceive and understand the causes and consequences of climate change are more concerned about its potential impacts and are therefore more likely to seek and implement adaptive changes (e.g. Bremer & Linnenluecke, 2017; Brullo et al., 2024). Consequently, in the context of climate risks, farmers form their climate-related risk perceptions and adaptation perceptions, which in turn influence their decisions to adopt specific adaptation measures (He et al., 2025). As a result, if farmers misjudge climate risks, they may either fail to implement necessary adaptation measures or engage in maladaptive practices, ultimately leading to increased vulnerability to climate threats (Jin et al., 2020; Hashmiu et al., 2022; Ricart et al., 2025).

While climate perception and its impacts can motivate adaptive behaviour (Hyland et al., 2016), farmers' adaptation decisions and behaviours are also influenced by multiple external factors (Smit & Skinner, 2002; Brullo et al., 2024). Also, farmers' behaviours are strongly influenced by environmental, personal and socioeconomic contexts (Findlater et al., 2018). Therefore, to better

understand their adaptation behaviours, it is essential to investigate both internal factors (e.g., psycho-social attributes, socio-demographic and farming characteristics) and external factors (e.g., institutional and biophysical conditions) (Khan et al., 2020; Talanow et al., 2021; Abbas et al., 2022; Ricart et al., 2025). These factors act as barriers or supporters of adaptation behaviour. They include access to resources and capital and societal and systemic support (Smit & Pilifosova, 2003; Grothmann & Patt, 2005; Matos, 2025).

According to Brullo et al. (2024), resources are critical for adaptation and people with more resources are more likely to adopt innovations (Runhaar et al., 2018; Matos, 2025). Resource availability significantly influences the adoption of innovative adaptation measures. For example, innovators—who readily adopt new ideas—often possess substantial resources that facilitate their access to knowledge and innovative practices. This resource advantage enables them to absorb potential failures associated with new implementations, thereby fostering a culture of continuous innovation adoption and adaptation (Zhang et al., 2023; Matos, 2025).

Households combine and use a variety of resources to develop their livelihood strategies (Scoones, 1998; Quandt, 2018; Atta-Aidoo & Antwi-Agyei, 2025). Therefore, a household's adaptive capacity is dependent on its ability to utilize local resources and develop short-term adjustments or long-term transitions in livelihood strategies to effectively address crises (Natarajan et al., 2022; Nath & Arrawatia, 2025). Sustainable livelihoods depend on households' ability to manage trade-offs when using resources to generate income or expand their resource base, even in the face of crises and constraints by interacting with other actors and institutions (Scoones, 1998; Nath & Arrawatia, 2025). A household's ability to effectively combine different resources to absorb crises and adapt to future crises by learning from past experiences and exposures determines its adaptive capacity (Sun et al., 2023; Nath & Arrawatia, 2025).

Again, social identities such as gender, age, education, and access to livelihood capitals intersect to determine who has access to adaptation opportunities and who faces constraints. Such a deeper understanding of the interconnections between socio-cultural categorisations (such as race, class and gender) applied to actors (such as smallholder farmers) that create overlapping and interdependent systems of discrimination, disadvantage or exclusionary practices is an essential aspect of adaptive capacity assessment and adaptation (Nyantakyi-Frimpong, 2020; Puig et al., 2025).

Feminist scholars and geographers emphasise a critical gendered perspective to understand how gender shapes diverse groups' vulnerabilities and adaptive capacities globally (Arora-Jonsson, 2011; Carr & Thompson, 2014). Other authors argue that the complexity of gender, often treated as a dichotomous category upon which vulnerability can be neatly mapped, has been somewhat oversimplified in climate change research. Such oversimplification neglects other complex social characteristics (Thompson-Hall et al., 2016; Chaplin et al., 2019). For example, Deressa et al. (2008) highlight the importance of age and gender in shaping farmers' adaptive capacities and, subsequently, adaptation to reduce their levels of vulnerability. Adaptive capacity is significantly influenced by marital status, with women's marital status, in contrast to that of men, playing a critical role in defining their access to adaptive strategies (Yimam & Holvoet, 2023).

Lawson et al. (2020) and Opoku Mensah et al. (2025) found that migrant women farmers have less land access than indigenes. Older farmers have greater access to land and are more likely to have land tenure security than younger farmers. While married women with sons have better land access, young, single women are more likely to migrate and less likely to implement innovative adaptation strategies. Furthermore, higher levels of education are linked to higher levels of adaptive capacities and lower levels of vulnerability (e.g. Muttarak & Lutz, 2014). Intersecting vulnerabilities linked to being a woman and unskilled limit access to income diversification opportunities. This limitation constrains their capacity to adapt to social-ecological change (Erwin et al., 2021).

Institutions are omnipresent and serve diverse purposes in adaptation that include operationalising adaptation campaigns (Stocker, 2014), mobilising climate funds (Yaro et al., 2015), communicating climate change information (Bawakyillenuo et al., 2016), establishing policy partnerships for effective adaptation (Béné et al., 2016) and delivering environmental services to vulnerable groups and communities (Tahiru, 2019). Institutions can be conceptualized as formal and informal rule-making systems, and actor networks at all levels of society that are established to steer societies towards preventing, mitigating, and adapting to climate change (Biermann et al., 2009; Patterson, 2021; Park, 2023). Thus, institutions are human-made mechanisms that shape social and individual expectations, interactions, and behaviours (Agrawal, 2008; Park, 2023).

For climate change adaptation, institutions are commonly categorised into two groups; formal, which encompass tangible governance and organisational structures, and informal, which are the uncodified 'rules of the game', cultural norms and traditions that govern the behaviour and nature of human interaction (Jones et al., 2010, p.5; Mubaya & Mafongoya, 2017, p.94). Collectively, institutions act to influence adaptation in three major ways: (i) they reduce the vulnerability of smallholder farmers in a given socio-ecological context; (ii) they create an incentive framework and shape how smallholder farmers collectively or individually respond to climate change; and (iii) they mediate the effect of external interventions on climate adaptation (Agrawal, 2008; Yomo et al., 2020). Communities' vulnerability hinges on biophysical outcomes and the place-based, socio-political and institutional framework that largely determines adaptive capacity (Adger, 2006; Mubaya & Mafongoya, 2017).

Institutions help to foster diverse approaches to adaptation and are recognised as key actors in knowledge production, risk and vulnerability mapping and community capacity building (Tahiru et al., 2019). For example, institutional services play a crucial role in shaping farmers' adaptation behaviours in a changing environment (North, 1990; Madaki et al., 2025). Institutional services, such as access to climate-related information and extension services, enhance farmers' awareness of the potential and anticipated effects of climate change. These services also inform farmers about available adaptation actions and their associated benefits (Madaki et al., 2025; Baffour-Ata et al., 2025). Again, access to credit can provide the financial capacity needed to invest in adaptive inputs and services, while participation in farmer groups can facilitate resource pooling for capital-intensive adaptations (Madaki et al., 2025).

Zilberman et al. (2012) distinguish between adaptation and adoption based on intent, with adoption primarily focused on economic outcomes (considerations of profit, risk, credit and biophysical constraints) and adaptation with a reduction in vulnerability to major shocks (such as climate change). Adaptation and adoption of innovations do not operate in isolation. Instead, they are interconnected with broader socio-ecological systems, including programmes at multiple levels (local, regional, and national), and often emphasize enhancing adaptive capacity (Huq et al., 2004; Smit & Wandel, 2006). For example, household decisions on adopting adaptation actions are considered within the general utility or profit maximization framework. Economic agents, such as agro-pastoralists, have adopted adaptation actions only when the perceived utility

or net benefit of adopting a particular adaptation significantly outweighs the cost of adoption. This adoption becomes more feasible and profitable in an enabling environment created by available institutional services (Bryan et al., 2013; Madaki et al., 2025).

In this context, the utility of economic agents is not directly observable or measurable; however, their behaviour can be observed through their decisions (Di Falco et al., 2011; Bryan et al., 2013). For example, farmers are more likely to adopt adaptation measures if they perceive these actions as beneficial and effective in addressing climate challenges. However, given their typically low income, high costs may reduce their motivation to adopt expensive strategies, leading them to opt for lower–cost behaviours (Bain et al., 2016; He et al., 2025). Furthermore, when farmers perceive adaptive actions as effective and feel empowered to implement them, their intention to adapt is further boosted (Etana et al., 2022).

Having explored the connection between adaptation and the adoption of innovations, I now examine the different approaches to adaptation decision-making: planned adaptation and autonomous adaptation. I aim to analyze how smallholder farmers make decisions about climate change risks and provide a more nuanced analysis of their decision-making processes.

#### 2.9 Approaches to adaptation decision-making

Two common approaches to adaptation decision-making are planned adaptation and autonomous adaptation (Fankhauser et al., 1999; Schipper, 2020; Maskell et al., 2025). Adaptation is classified as autonomous or planned, depending on the degree of spontaneity (freedom of response) (Adger, 2003; Smit & Wandel, 2006). Thus, the distinction between autonomous and planned adaptation is not merely about the specific practices farmers adopt but rather about the underlying drivers of those changes.

Autonomous adaptation refers to immediate, spontaneous responses to climate stimuli, often consisting of local responses (Adger, 2003; Smit & Wandel, 2006). Autonomous adaptation can be an automatic, spontaneous, localized, dynamic, natural, short-term or immediate process (Smit & Wandel, 2006; Blakeney, 2020). Autonomous adaptations occur independently as a reaction to changes in the climatic system, without intervention from public or other agencies (Smit & Pilifosova, 2003; Huq et al., 2004). It is a household-level, bottom-up approach, rather than an outside top-down approach or policy-driven response (Smit et al., 2000). Autonomous

adaptation is implemented by local communities using their locally available resources and occurs naturally (Blakeney, 2020).

Autonomous adaptation is not a conscious response to climatic stimuli (Smit et al., 2000). It is engaged by farm households and communities in response to perceived or experienced changes in climate (Huq et al., 2004; Füssel, 2007b; Tuihedur Rahman et al., 2021). IPCC (2019) highlights the importance of combining autonomous adaptation with indigenous knowledge for agricultural adaptation. This approach requires active farmer participation in research, governance structures, and the design of systems for generating and disseminating knowledge and technology, ensuring that farmers' needs and insights are adequately reflected.

Planned adaptations are deliberate, large-scale socio-economic, policy, and political decisions typically undertaken by governments and other agencies in response to the awareness that conditions are changing or have already changed (Füssel, 2007b; Tuihedur Rahman et al., 2021). These actions aim to minimize losses or benefit opportunities (Pittock & Jones, 2000; Smit & Pilifosova, 2003). According to Smit & Pilifosova (2003), planned adaptation can be either anticipatory, undertaken before impacts become apparent, or reactive.

Carter et al. (2007) argue that vulnerability is shaped by ongoing autonomous and planned adaptation processes. While planned adaptation has been criticized for inadequately addressing context-specific vulnerability and poverty linkages (Rahman & Hickey, 2019), autonomous adaptation is typically rooted in local knowledge and resources (Bawakyillenuo et al., 2016). Therefore, it is essential to enhance the alignment between planned and autonomous adaptation by giving greater prominence to context-specific and culturally relevant practices, and by recognizing that adaptation responses are shaped by multiple, intersecting stressors that affect different groups in diverse ways (Stringer et al., 2009; Schipper, 2020). This approach accounts for socio-ecological contexts, helps avoid maladaptation<sup>19</sup>—where poorly designed adaptation actions inadvertently increase vulnerability to climate change impacts—and ensures equitable access to the resources necessary for sustaining livelihood activities (Tuihedur Rahman et al., 2021; Schipper, 2020). The ensuing literature is vital for exploring smallholder farmers'

<sup>&</sup>lt;sup>19</sup> Actions that increase the risk of adverse climate-related outcomes, increased or shifted vulnerability, more inequitable outcomes, or diminished welfare, either now or in the future. In most cases, it is an unintended consequence. (IPCC, 2022a). Maladaptation is not simply being poorly adapted to climate change; rather, it is a process in which people become increasingly likely to be negatively affected by climate change (Schipper, 2020).

adaptation actions and unpacking how institutional support can enhance adaptation decisionmaking and reduce maladaptive tendencies.

Building on the exploration of planned and autonomous adaptation as key approaches to decision-making, in the next section I delve deeper into the spectrum of responses to climate change, from coping responses to adaptation responses. This understanding is important for analyzing how smallholder farmers navigate immediate climate stressors and longer-term environmental changes. I seek to provide a more comprehensive analysis of farmers' adaptive behaviours tailored to the realities of their vulnerable communities.

## 2.10 Response to climate change: From coping responses to adaptation responses

Responses to climate change can be broadly categorized into coping strategies and adaptation—both incremental and transformational. These approaches have sparked considerable debate within policy and practice circles (Fedele et al., 2019; Antwi-Agyei & Nyantakyi-Frimpong, 2021). Determining whether farmers cope or adapt is crucial for developing policies that promote short-term, temporary adjustments and long-term, sustainable adaptation in response to environmental change (Fischer, 2019). Antwi-Agyei & Nyantakyi-Frimpong (2021), asserts that coping responses precede adaptation responses in explaining social responses to environmental stress. They are short-term actions that farmers implement to address adverse climate impacts (Eriksen et al., 2005). According to IPCC (2022a), coping responses involve the use of available resources, opportunities and skills to address adverse conditions to achieve the basic functioning of people, institutions, organizations and systems in the short to medium term.

Coping responses are employed to maintain the socio-ecological system in a business-as-usual state, without altering its existing characteristics and functions (Perrings, 2006; Kates et al., 2012). They are often reactive and applied to reduce current risks by immediate measures (Sam et al., 2020). These measures are typically adopted when climate impacts are less severe, when individuals lack the financial or technical capacity to respond differently, or when there is limited recognition of the need for sustained change (Fedele et al., 2019). They may not necessarily be environmentally or economically sustainable (Kates et al., 2012). They are largely autonomous and ad-hoc, which increases the risk of maladaptation (Berman et al., 2012; Brooks et al., 2009).

Adaptation responses are advanced forms of coping responses (Antwi-Agyei & Nyantakyi-Frimpong, 2021). Adaptation responses have been characterized in various overlapping ways, one of which distinguishes between incremental and transformational adaptation responses (Kates et al., 2012). The vast majority of documented adaptation responses primarily occur at the local level, where households and individuals play a pivotal role in implementing incremental adaptation strategies (Berrang-Ford et al., 2021). Incremental adaptations are the "extensions of actions and behaviours that already reduce the losses or enhance the benefits of natural variations in climate and extreme events" (Kates et al., 2012, p. 7,156). They are often more anticipatory and go beyond routine adjustments (Tschakert et al., 2013; Feola, 2015). Such responses drive small-scale and minor adjustments to social-ecological systems (Adger & Jordan, 2009; Kates et al., 2012).

Incremental adaptations risk perpetuating unsustainable practices within a changing environmental context (Dilling et al., 2015). According to Antwi-Agyei & Nyantakyi-Frimpong (2021), such a reactive approach to adaptation often adopts a technocratic and managerial perspective, viewing potential climate threats as a series of identifiable risks that require institutional and technological solutions to maintain the status quo. Consequently, there have been calls for transformational adaptation—a process that goes beyond mere adjustments to existing practices (Antwi-Agyei & Nyantakyi-Frimpong, 2021).

As climate impacts intensify, adaptation measures may need to shift from relying solely on incremental adjustments to adopting a more transformational approach that seeks to reduce the root causes of vulnerability (Kates et al., 2012; Taylor et al., 2025). Adaptation responses aim to reduce vulnerability and promote overall sustainable development (Sam et al., 2020). Differing from incremental adaptations, Kates et al. (2012, p. 7,156) described at least three classes of adaptations that are transformational: "those that are adopted at a much larger scale or intensity, those that are truly new to a particular region or resource system, and those that transform places and shift locations".

Similarly, Pelling et al. (2015, p. 114) describe transformational adaptation as prioritizing actions that "have the reach to shift existing social systems (and their component structures, institutions and actor positions) onto alternative development pathways, even before the limits of existing adaptation choices are met". This shift implies that adaptation responses should aim to

fundamentally transform the attributes of socio-ecological systems, enabling societies to effectively address the complex and far-reaching climate change challenges (Kates et al., 2012; Berrang-Ford et al., 2021). Transformational adaptations extend beyond adjustments to existing practices. They shift systems away from undesirable or unsustainable trajectories toward fundamental systemic changes that create new states and interactions within social-ecological systems (O'Brien, 2012; Olsson et al., 2014; Gil-Clavel et al., 2025).

Transformational adaptation responses, like incremental responses, can be either responsive—occurring during or after significant climate change impacts—or anticipatory, implemented in advance of threats that pose serious risks of severe consequences. While some transformational adaptations are technological, they also include behavioural changes that influence how individuals and societies make decisions and allocate resources to address climate change. Additionally, they may involve fundamental shifts in institutional arrangements, priorities, and societal norms (Kates et al., 2012; IPCC, 2014; Owen, 2020). There is growing recognition that adaptation requires transformative, system-wide changes that tackle the root causes of vulnerability (UNEP, 2022; Taylor et al., 2025).

Tschakert et al. (2013) argue that adaptation should address the underlying conditions that generate or perpetuate risk. Thus, adaptation should go beyond merely addressing the surface symptoms of vulnerability and instead target its root causes at a society-wide level (O'Brien, 2012; Eriksen et al., 2015; Taylor et al., 2025). Transformational adaptations can be collective adaptations that are explicitly planned and implemented and autonomous adaptations that, when combined, can result in transformative outcomes, or actions initially intended to address other problems that evolve into transformative adaptations (Kates et al., 2012).

In the next section, I delve into the interconnected concepts of adaptation and adaptive capacity. Understanding adaptive capacity is not just about identifying how farmers respond to climate risks, but about uncovering the underlying factors that enable or hinder effective adaptation. By examining these dynamics, I explain the disparities in vulnerability observed among different households and communities.

#### 2.11 Adaptation and adaptive capacity

Adaptation, whether analyzed for assessment or practical implementation, is intimately associated with vulnerability and adaptive capacity (Chapagain et al., 2025a). Adaptive capacity represents the potential of a system to adapt rather than a specific adaptation per se. Adaptive capacity is a prerequisite for adaptation to take place (Adger et al., 2007; Chepkoech et al., 2020; Chapagain et al., 2025a). It predicates the success of climate adaptation, and its assessment identifies the factors hindering or promoting adaptation (Elrick-Barr et al. 2022). The extent to which vulnerability can be reduced depends on adaptive capacity. In this context, adaptive capacity is defined as the stock of various resources (or capitals) and the processes that enable these resources to be deployed in pursuit of adaptation (i.e. an enabling environment) to achieve sustainable rural livelihoods (Smit & Wandel, 2006).

Addressing adaptation within the framework of adaptive capacity is crucial, as it serves as an indicator for understanding the occurrence or potential for adaptation (van Maanen, 2024). It is, therefore, a critical element of the adaptation process serving as the vector of resources that constitute the asset base from which adaptation actions can be undertaken (Adger & Vincent, 2005). Adopting adaptation actions depends on farmers' adaptive capacity to control tangible and intangible vectors of resources that shape the effectiveness of adaptation measures (Klein et al., 2014; Tong et al., 2024). It reflects the ability to optimally utilize limited resources to anticipate or respond to perceived or existing stressors under conditions of uncertainty. It varies across systems and contexts. This variation highlights the need to contextually identify factors that support or constrain adaptation efforts (Engle, 2011).

Adaptation is the "manifestation of adaptive capacity and represents ways of reducing vulnerability" (Smit & Wandel, 2006, p. 286). Adaptive capacity provides the means to inform adaptation better since the forces which influence a system's ability to adapt are the determinants or drivers of adaptive capacity (Adger, 2003). This perspective is echoed by Engle (2011), who emphasizes that the successful implementation of adaptation is strongly dependent on the adaptive capacity of socio-ecological systems. It is, therefore, a critical property to foster adaptation (Engle, 2011). According to Smit & Wandel (2006, p. 287), "adaptations, or changes within a system to more effectively address problematic exposures and sensitivities, are a reflection of its adaptive capacity". Adaptation and adaptive capacity refer to the "strategies,

techniques and assets employed or available to modify institutional frameworks (cultural and legislative rules that define rights and responsibilities) and structural frameworks (the balance and distribution of assets and information) that constrain human action to address vulnerability at any given moment in time" (Birkmann et al., 2013, p. 201). It encompasses both the availability of requisite preconditions and the capacity to mobilize these resources for adaptation and learning (Engle, 2011; Nelson et al., 2007).

High levels of adaptive capacity offer flexibility and enhance opportunities to adjust and modify future trajectories, and as such are a prerequisite for successful adaptation (Smit & Wandel, 2006; Nath & Arrawatia, 2025). Adaptive capacity is critical for fostering adaptation; the higher the adaptive capacity of a system, the more likely it is to adapt (Engle, 2011). However, adaptive capacity is generally described as a set of latent intrinsic properties of SESs—representing both the potential to adapt and the ability to actively engage in processes of change (Pelling & High, 2005; Smit & Wandel, 2006). Thus, high levels of adaptive capacity do not clearly result in correspondingly high levels of adaptation as the relationship between them is far from direct (Mortreux et al., 2020).

Therefore, as operationalised in this thesis, greater attention needs to be paid to the evolution of several generations of adaptive capacity assessment—from objective levels of resource availability (or asset deficit models) (e.g. Brooks & Adger, 2004) to the influence of psychosocial attributes, such as perception of risk and uncertainty, in driving change (Grothmann & Patt, 2005) to the incorporation of transference of capacity (governance and institutional interventions) to encourage system-scale transformation (Agrawal, 2010; Elrick-Barr et al., 2022)—as critical interacting factors to advance understanding of the complex influences that drive the adoption of adaptation actions (Gupta et al., 2010; He et al., 2022).

Building on these conceptions, adaptive capacity and adaptation are intertwined concepts (Smit & Wandel, 2006; Fidelman et al., 2017). While adaptive capacity measures a system's capacity (e.g. resources, strengths and attributes) to transition to a more well-adjusted state (Turner et al., 2003), adaptation is conceptualised as actions and their outcomes that bring about significant adjustments within a system to moderate harm or seize beneficial opportunities (IPCC, 2022a). In this thesis, the assessment of adaptive capacity is framed within the broader context of adaptation, recognising that adaptation includes both adaptive actions and the capacity to

undertake them. This perspective is informed by the understanding that adaptive capacity shapes the scope of possible actions, which, in turn, can either constrain or enhance the capacity for future adaptation (Pelling, 2011).

It is also critical to note that adaptive capacity is not equally distributed across contexts or systems; rather it is contingent upon specific local conditions or contexts (Adger et al., 2004). For instance, although climate change impacts affect everyone, certain social groups bear a disproportionate burden. These groups experience more significant resource losses and greater disruptions to their livelihoods and identities compared to others. This variation in vulnerability, regardless of facing similar levels of physical change, is primarily shaped by social factors rather than physical factors (Thomas et al., 2019; Puig et al., 2025).

#### 2.12 Conclusion

This theory review explores the themes underpinning this research, providing a broader context and a robust foundation for understanding the multifaceted nature of climate change vulnerability and adaptation within socio-ecological systems. The chapter presents a theory review for understanding key vulnerability and adaptation approaches and their interrelated components. It outlines how the concepts of vulnerability and adaptation are situated within existing theoretical discourses, particularly in relation to the impacts of climate change on SESs. Understanding the vulnerability of these systems to climate-related risks is a crucial first step in promoting effective adaptation among individuals, groups, and communities—especially those living in marginalized contexts. This exploration of context and the multiple issues embedded in the review helps to illustrate the central theme of this thesis.

Having established a comprehensive theoretical foundation through the theory review, I translate these insights into a practical research methodology and context in the next chapter. By connecting the theoretical underpinnings with the empirical landscape, I ensure that the research approach is not only methodologically sound but also contextually relevant. I lay the groundwork for a rigorous and context-specific exploration of the complex dynamics influencing climate change adaptation.

## **Chapter Three**

# Research methodology and context

#### 3.1. Introduction

Research methodology involves the strategy, plan of action, processes behind the choice and use of particular methods and the linkage of methods applied to the research outcomes (Crotty, 2020). This chapter provides the research methodology used to answer the research questions within this research context. I divide this chapter into ten main sections. Section one discusses the philosophical foundations of the research. The second section explains my positionality in the conduct of the research. The third section focuses on the study area profile. Sections four and five justify the research approach and research design, respectively. The sixth section discusses the data analysis. Section seven details the ethical considerations of the research. Sections eight, nine and ten describe the data documentation and management, research validity and reliability and the methodological limitations of the research, respectively.

Building on the introduction, I delve into the philosophical foundations that underpin this research in the next section. I explore the epistemological and ontological perspectives that shape this study and establish the theoretical lens through which my research questions are framed, and the methodological choices are justified.

#### 3.2 Philosophical foundations of the research

This thesis acknowledges throughout the analysis that research participant responses are based on how they construct reality and their interactions with their environment. This acknowledgment is important because, as Hoffman (2012, p. 32) puts it, "the debate over climate change, like almost all environmental issues, is a debate over culture, worldviews and ideology". How people experience vulnerability and their adaptive responses will vary depending on the historical, socio-political, environmental and economic contexts within which they operate (Thompson-Hall et al., 2016). Therefore, as part of the reflexive processes of social research, this thesis acknowledges the philosophical foundations that influence the choice and application of research methods, including how questions are asked and how observations are interpreted (Bryman, 2016; Moon et al., 2016). According to Adams (2019), the different research

paradigms <sup>20</sup> and their related ontological and epistemological positions <sup>21</sup> are linked to the different approaches often adopted in vulnerability, resilience and adaptation research.

This thesis adopts a constructionist epistemological approach to link people's perspectives to their context and provide a holistic view of how discourses are embodied by different actors (Packer & Goicoechea, 2000; Burr, 2015). Constructionist inquiry involves "explicating the processes by which people come to describe, explain, or otherwise account for the world (including themselves) in which they live" (Gergen, 1985, p. 266). The constructionist epistemological position argues that social and psychological phenomena emerge through interactions between individuals and are shaped by the social contexts of their lives (Andrews, 2012). These interactions—and the phenomena they produce—are conceptualised and structured by the society and culture in which we live, the power relations in which we are embedded, and the broader economic structures of our society (Galbin, 2014).

The constructivist approach aligns with the relational ontology framing and pragmatism paradigm to understand the interactions between knowledge and experience. It assumes a relational ontology—multiple realities—a subjectivist epistemology—knower and respondent co-create understandings—and a naturalistic—in the natural world—set of methodological procedures (Denzin & Lincoln, 2005a; Lee, 2012). Like constructivism, relational ontology argues that the ideational and the material are complexly interdependent and interwoven (Hay, 2008). Similarly, in line with the pragmatism epistemological perspective<sup>22</sup>, this thesis focuses on relational ontology (Slife, 2004; Wildman, 2006). This focus is important because reality is enacted through practice, which is always multiple, relational and partial (Law & Hassard, 1999; Haraway & Goodeve, 2018).

Relational ontology posits that there are multiple realities (Lee, 2012). The relations between entities are more fundamental than the entities themselves, and no entity pre-exists the relations that constitute it (Wildman, 2006; Walsh et al., 2021). It considers how 'matter', 'discourse' and

<sup>&</sup>lt;sup>20</sup> Fundamental principles, beliefs and values that researchers bring to the research and guide them in their choice of methods and underlie the overall logic of their research (Bryman, 2016; Creswell & Poth, 2018; Crotty, 2020)

<sup>&</sup>lt;sup>21</sup> While ontology is concerned with the philosophy of reality—the nature of what exists, epistemology addresses how we come to know that reality (Krauss, 2005; Schnegg, 2021). Researchers' ontology and epistemology are related to a research paradigm and overall methodology (Adams, 2019).

<sup>&</sup>lt;sup>22</sup> It combines the reliability of the empirical counts with the validity of the lived experience of researchers or research participants (Crotty, 2020). Such paradign enables researchers to adopt a holistic perspective and grasp the social, ecological, historical and political context underpinning their research (Creswell & Creswell, 2023).

'society' co-produce one another such that any separation between them is impossible (Castree, 2001). Such co-production matters as many adaptation and resilience solutions seek to manage the properties ascribed to pre-existing systems and focus on "getting the rules right" (Cote & Nightingale, 2012, p. 480). For example, according to the proponents of relational ontology, the world can be broken down into a set of properties and parts. These properties and parts can combine to cause, for example, maladaptation which can be fixed by targeted interventions (Shah et al., 2024).

Relational ontology manages relations between and among people and natural systems (Mancilla García et al., 2020). It thus provides a framework to understand "the social" in a way that assumes its inseparability from "the natural" (Goldman et al., 2016, p.28). By committing to describing relations of "things, people and the broader world of substance" (Robbins & Marks, 2010, p. 179), relational ontology helps to avoid often single frameworks of how the world is understood either through "risk-hazards approaches or social vulnerability" (Shah et al., 2024, p. 5). The adoption of relational ontology in this thesis allows the study of the relationship between the nature of a problem (e.g. vulnerability), the context in which it exists (e.g. among smallholder farmers) and how humans respond to the situation (e.g. through adaptation and institutional interventions). Social phenomena such as vulnerability result from the interactions between humans and their economic and natural resource contexts (see Robbins & Marks, 2010; Shah et al., 2024).

This thesis examines the complex dynamics of climate change adaptation among smallholder farmers in Ghana's climate-vulnerable Guinea Savannah agro-ecological zone. Using mixed methods, including focus group discussions, interviews with institutions, household surveys and participant observations, the research explores the interplay of factors influencing farmers' adaptation decisions, the role of intersectionality in shaping adaptive capacities and the effectiveness of institutional interventions. By analysing these issues from the perspectives of the "inquirer and the knowable", or between the "knower and the respondent" (Lee, 2012, p. 407) to understand the contextual issues associated with the complex socio-ecological system of Ghana's climate-vulnerable Guinea Savannah agro-ecological zone, this research hinges on the pragmatism-constructivism epistemological and relational ontology perspectives.

Having established the philosophical foundations that guide my research, I now reflect on my positionality. In the next section, I explore how my background, experiences, and perspectives may have influenced the research process, from data collection to analysis and interpretation. I seek to ensure transparency and acknowledge the potential impact of my positionality on the study.

### 3.3 Positionality

According to Masud-All-Kamal (2019), considering researchers' positionality<sup>23</sup> helps them to reflect on their research process, their relationship with research participants and the entirety of the data collection process. By acknowledging and addressing my positionality throughout my research journey, I aimed to produce research findings that are credible and respectful of the perspectives of the research participants.

In this research, I introduced myself to research participants as a PhD researcher who is affiliated with the University of Technology Sydney in Australia. I also informed them that I am a Ghanaian, born and raised in southern Ghana and also worked in northern Ghana, including the Talensi district—the study district—for over five years. Even though I worked in the district, I had no prior relationship with the research participants. I also positioned myself as someone with lived experiences growing up in a farming community throughout my interactions with them. I was, therefore, simultaneously received as an insider and an outsider. Such dual positions enrich and complicate research differently (e.g. Osman, 2023). My multi-positionality influenced the dynamics of my interactions and the interpretation of my findings. Being an insider from Ghana and having worked in the district offered me cultural familiarity and an understanding of broader societal norms that eased rapport-building with the research participants.

However, my outsider status introduced complexities. I remained conscious of potential biases and assumptions from my distinct educational and socio-economic background. These factors influenced how community members perceived me and how I navigated the cultural, social and political dynamics of the district. I was viewed by the communities as an educated male person, who has travelled to a foreign country and come back to engage them. These factors created an initial distance between me and the communities. Additional time was therefore required to build

<sup>&</sup>lt;sup>23</sup> How researchers define and present themselves to their research participants in different contexts and, in turn, how they are perceived and treated by their research participants (Chereni, 2014).

rapport and trust. Rapport and trust building were facilitated by being transparent about the research content, aim and researchers' intentions and relationships. I also engaged in normal practices of building rapport and trust, including staying in the communities and sharing meals and drinks (e.g. Dorkenoo, 2024). As a male researcher conducting research in a patriarchal area, where gender roles are deeply embedded in societal norms (Nyantakyi-Frimpong, 2020; Osman, 2023; Opoku Mensah et al., 2025), gender dynamics shaped my access to certain groups or experiences within the district. My outsider status and academic training further layered my positionality, potentially influencing how I framed and interpreted the lived realities of the research participants.

Through reflexivity<sup>24</sup>, I critically examined how my positionality affected the research process. This examination included reflecting on my assumptions, beliefs, and interactions with participants to mitigate biases and ensure that my representation of the communities was as authentic and nuanced as possible. For example, I recruited and trained four research assistants: two men and two women, native to the study communities and fluent in both English and the local Talen and Guruni languages of the Talensi district to support me during data collection. Also, due to the district's patriarchal nature, which often discourages women and youth from speaking freely in mixed groups (Koomson-Yalley & Kyei, 2022; Opoku Mensah et al., 2024), participants in focus group discussions were grouped by gender and age: men-only, women-only, and youth-only.

With my positionality outlined, I provide context for the research setting. In the following section, I present the study area profile, offering a detailed overview of the geographical, socioeconomic, and environmental characteristics of the study area.

### 3.4 Study area profile

To set the stage for understanding the study area, I begin with a broad overview of Ghana's climate profile and agricultural systems, followed by a discussion of the country's agroecological zones. I seek to provide a necessary national context before narrowing the focus to the specific agro-ecological context of the Talensi district within the Guinea Savannah zone. I intend

<sup>&</sup>lt;sup>24</sup> A form of critical thinking that addresses identity and positionality by making researchers' assumptions explicit and developing strategies to critically examine them (Lazard & McAvoy, 2020).

to sequentially transition from national-level climate and agricultural dynamics to the local realities faced by smallholder farmers in my study area.

## 3.4.1 Overview of Ghana's climate profile and agriculture systems

Ghana is located in SSA on the Atlantic Coast of West Africa (Figure 5). It lies close to the equator at latitudes 4.5°S and 11.5°N and longitudes 3.5°W and 1.3°E. Ghana shares borders with Togo to the East, Côte d'Ivoire to the West, Burkina Faso to the North, and the Gulf of Guinea to the South (EPA, 2020). Ghana is divided into 16 administrative regions with a sub-tropical warm and humid climate (EPA, 2020; GSS, 2022). Ghana's mean annual rainfall varies from 1,000 mm to 2,200 mm. The mean annual temperature varies from 26.1°C to 28.9°C, but can reach up to 40°C in North-eastern Ghana, where the research district is located (MoFA, 2022). Ghana is warm and comparatively dry along the southeast coast, hot and humid in southwest, and hot and dry in the north (GSS, 2022). There are also regional differences, with a pronounced north—south divide—stark development disparity between a relatively developed south and a trailing north (Kambala, 2022). The north-south divide in terms of assets and vulnerability is exacerbated by climatic stress in the north, where temperatures are relatively high (GSS, 2022).

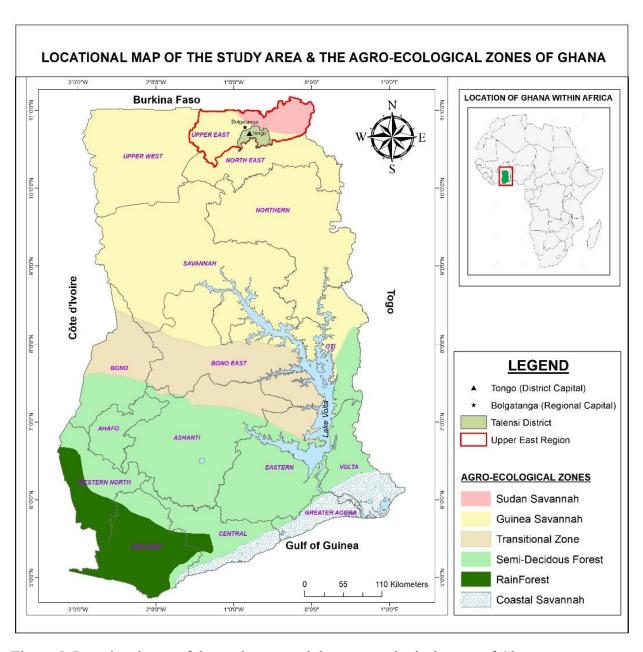


Figure 5: Locational map of the study area and the agro-ecological zones of Ghana

Source: Author's construct, 2025

Ghana has a total land area of 243,438 km², 69% of which is classified as agricultural land and 41% forest areas of which 24.4% is under cultivation. Agriculture in Ghana relies heavily on manual labour and traditional farming methods with limited mechanization. Only 3% of arable land is under irrigation (Asare-Nuamah & Botchway, 2019; MoFA, 2022). Ghana's agriculture sector is usually divided into 4 subsectors; crops (arable and tree cropping), livestock, forestry and logging, and fishing. The major subsectors are crops and livestock, with crop-livestock

farming systems facilitating livelihood activities, growth and development (GSS, 2020; Ecker, 2018). Crop production accounts for 75% of the sector's total output. The remaining 25% is collectively contributed by the livestock, forestry and fishing sub-sectors (World Bank, 2018; MoFA, 2022). Ghana's main agricultural commodities include industrial crops (cashew, cocoa, coconut, coffee, cotton, oil palm, rubber, shea); starchy, tuber and root crops (cassava, cocoyam, plantain, yam); cereals (maize, millet, rice, sorghum); legumes (Bambara bean, cowpea, groundnut, sweet potato, soy bean); fruit (banana, mango, orange, pineapple); vegetables (egg plant, okra, onion, pepper, shallot, tomato); livestock (ruminants) [cattle, goat, sheep], pig, poultry [chicken, duck, guinea fowl, ostrich, turkey], and non-conventional species [grass cutter, guinea pig, rabbit, snail]; and fisheries and aquaculture (Embassy of Israel, 2020; Bellon et al., 2020).

The agricultural sector employs approximately 45% of the country's labour force. In rural areas, it accounts for 75% of employment among unskilled workers (MoFA, 2017; World Bank, 2018). It contributes approximately 20% to Ghana's Gross Domestic Product (GDP) and three-quarters of Ghana's export earnings (Breisinger et al., 2011; MoFA, 2022). With the advent of the Green Revolution in Africa (AGRA, 2023), Ghana's agriculture sector continues to remain highly rainfed, traditional, informal and subsistence-based, and reliant on family labour with limited use of high-yielding seed and improved technology (Embassy of Israel, 2020; EPA, 2020). The sector accounted for 24% of the total national Green House Gas (GHG) emissions in 2016; 16% came from crop management practices with the remaining 8% attributed to livestock (EPA, 2020). The agricultural sector in Ghana is composed of 90% smallholder farmers who cultivate about two hectares of land and produce 80 per cent of total agricultural output (Asare-Nuamah & Botchway, 2019; GSS, 2020; MoFA, 2022).

Although agriculture contributes significantly to livelihoods in Ghana, land tenure arrangements and high poverty levels—especially in northern Ghana—limit many farmers to small-scale farming, often with landholdings of less than 1.5 hectares. This situation dramatically impacts income levels, perpetuating a cycle of poverty for many Ghanaian farmers (Lambrecht & Asare, 2016; Guodaar et al., 2021). Ghana's agriculture sector is highly vulnerable to climate change and variability and is characterised by low productivity levels (Asare-Nuamah & Botchway, 2019; World Bank, 2021). Climate change poses a significant challenge to the agricultural sector,

threatening food security and livelihoods—especially in communities in northern Ghana (Guodaar et al., 2021).

# 3.4.2 Ghana's agro-ecological zones

Ghana is divided into six agro-ecological zones (cf. Figure 5) based on their climatic conditions and natural vegetation and influenced by the soil types (EPA, 2021). The different AEZs exhibit different climatic characteristics (Asare-Nuamah & Botchway, 2019), with a gradient of increasing aridity—rainforest, semi-deciduous forest, coastal savannah, forest-savannah transition, Guinea savannah and Sudan savannah—from southern to northern Ghana (Antwi-Agyei et al., 2012). Temperature and rainfall differ in the AEZs. Historical climate data of Ghana shows increasing average temperatures and decreasing average annual rainfall across all AEZs (Asare-Nuamah & Botchway, 2019). The different characteristics—climatic conditions, natural vegetation cover and soil types—of the different AEZs influence their agricultural production and practices (Jumpah et al., 2024). These different characteristics determine crop growth periods and crops cultivated with varying effects on their productivity (GSS, 2020; MoFA, 2022).

The Guinea Savannah agro-ecological zone (the zone of study for this research) is a climate change vulnerability hotspot in Ghana due to its high exposure to climate risks, the sensitivity of its agricultural production systems, and limited adaptive capacity (EPA, 2020; Owusu et al., 2021). Warming trends and extreme climatic events—including floods, droughts, wildfires, and rainstorms—are intensifying in the zone, further increasing farmers' vulnerability to livelihood disruptions (Agyin-Birikorang et al., 2022; Jumpah et al., 2024). The single rainfall season in the Guinea savannah AEZ is followed by a period of drought that lasts until the next rainy season, which is frequently protracted (Asare-Nuamah & Botchway, 2019; Jumpah et al., 2024).

Droughts are a major contributor to declining crop yields in the zone, and they also impact livestock production by reducing forage availability and water access—often resulting in poor feed quality and high herd mortality (Twumasi & Jiang, 2021; Naazie et al., 2024). Flood events across many parts of the zone inundate farms and cause extensive damage to crops, livestock, property, and even human lives (Derbile et al., 2022). However, despite their adverse impacts on agricultural systems, floods can also enhance residual soil moisture and deposit nutrient-rich

sediments on floodplains, creating opportunities to extend farming activities beyond the traditional growing season (Balana et al., 2019).

The zone is highly susceptible to wildfires due to a combination of high temperatures, prolonged droughts, continuous grassland vegetation interspersed with scattered shrubs, and dry Harmattan winds (Husseini et al., 2020; Agyin-Birikorang et al., 2022). These environmental conditions create significant uncertainties for the future livelihoods of farming communities and, in turn, constrain their adaptive capacities (Dickinson et al., 2017; Gyimah et al., 2024). The high exposure of the Guinea Savannah AEZ, coupled with the sensitivity of its agricultural systems to climate change and associated risks, undermines communities' capacity to adapt and heightens their vulnerability (Freduah et al., 2019).

# 3.4.3 Agro-ecological context of the Talensi district

The Upper East region—the 3<sup>rd</sup> most vulnerable region in Ghana (EPA, 2020) is one of 16 regions of Ghana (cf. Figure 5). Ghana is further subdivided into 216 districts for administrative purposes. The Talensi district, as selected for the research, is one of the 15 administrative districts of the Upper East region of Ghana. Bolgatanga serves as the regional capital of the Upper East region, whereas Tongo serves as the district capital of the Talensi district (cf. Figure 5). As shown in Figure 6, the Talensi district is bordered to the north by the Bolgatanga Municipality, south by the West and East Mamprusi districts, Kassena Nankana East municipality to the west and Nabdam district to the east. It lies between latitude 10°15' and 10°60' north of the equator and longitude 0°31' and 1°05' and west of the Greenwich meridian. It has a land area of 867 km² (GSS, 2014; Talensi District Assembly [TDA], 2022).

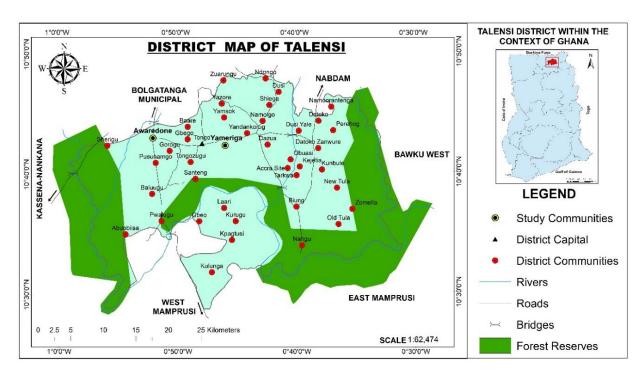


Figure 6: Map of the Talensi district, showing the locations of Awaredone and Yameriga Source: Opoku Mensah et al., 2023; Abunyewah et al., 2024.

The population of the Talensi district is 87,021, representing 7% of the Upper East region's total population of 1,301,226. Males constitute 50.4% of the population. As high as 88% of the population lives in rural areas. The population of youth—people between the ages of 15 and 35—within the district is 41%. It is depicted by broad-based population pyramid that tapers off with a small number of the elderly population (7%) (GSS, 2014; Yorose, 2019). The district has only one tar-sealed road, with feeder roads running across the district. These roads are sometimes inaccessible, especially during the rainy season. The poor nature of roads in the district increases transportation costs of goods and passengers. This situation disincentivises the production, marketing and transportation of agricultural products (TDA, 2022). The district does not have any major markets. Because of its proximity to the Bolgatanga municipality, the three main markets in the district are not well patronised as they fall on the same day as the Bolgatanga market (TDA, 2022).

In terms of topology, the district is characterized by scattered rock outcrops and upland slopes with relatively undulating lowlands with gentle slopes, which range from 1<sup>0</sup> to 5<sup>0</sup> gradient at the Tongo areas. The soil is developed mainly from granite rocks, is predominantly coarse in texture,

low in soil fertility, structurally weak with low organic matter content, and shallow (TDA, 2022). Erosion is a problem in the district. Valley areas have soils which range from salty clays to sandy loams. They have rich natural fertility but are difficult to till and prone to seasonal waterlogging and flooding. The major river in the district is the White Volta and its tributaries (GSS, 2014; TDA, 2022). Its vegetation is Guinea Savannah woodland consisting of sparse short deciduous trees and a ground flora of grass. The common economic trees are shea, Parkia biglobosa/African locust bean (dawadawa in the local language), baobab and acacia (GSS, 2014; TDA, 2022).

Figure 7 shows the temperature and rainfall trends in the Talensi district during the past 42 years. Generally, temperature has increased over a 40-year period (see Figure 7 and Table 1). Figure 7 shows an increase in annual average precipitation with consistently high inter-annual rainfall variability across months and seasons in the district (Table 2). Inter-annual rainfall variability in the dry season is increasing with an increasing trend relative to the rainy season. The Talensi district experiences a tropical climate characterized by two distinct seasons: a highly variable rainy season from May to October, and a dry season from November to April. The district receives an average annual rainfall of 950 mm. Temperatures peak at around 45°C in March and April, while the lowest temperatures, around 12°C, occur in December (GSS, 2014; TDA, 2022). The district's agricultural production system is environmentally fragile and largely dependent on rain-fed (non-irrigated) dryland farming (Opoku Mensah et al., 2023).

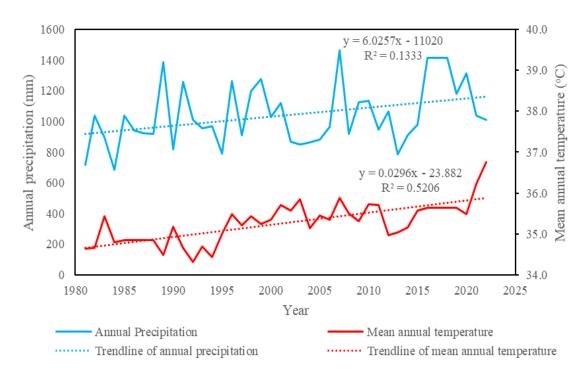


Figure 7: Precipitation and temperature change of the Talensi district for the past 42 years (1981–2022)

Source: Author's construct using meteorological data collected from the Upper East regional office of GMet (2022)

Table 1: Statistical summary of temperature in the Talensi district for the past 42 years (1981–2022)

Parameter (°C)	Min	Max	Mean	SD	CV	MK
Average annual temperature	34.3	36.8	35.27	0.50	0.01	4.94***
January	32.2	37.7	35.36	1.50	0.04	1.65*
February	35.0	40.1	37.73	1.20	0.03	2.73***
March	37.6	44.0	39.67	1.11	0.03	2.99***
April	37.0	47.4	39.58	1.57	0.04	1.01
May	33.0	38.4	36.41	1.16	0.03	1.02

June	32.1	35.0	33.48	0.70	0.02	1.18
July	30.1	33.1	31.40	0.76	0.02	3.15***
August	29.6	36.1	30.64	1.01	0.03	3.53***
September	28.5	34.0	31.55	0.82	0.03	0.95
October	32.3	36.0	34.23	0.90	0.03	1.83*
November	34.2	38.5	36.88	1.19	0.03	5.03***
December	34.0	37.8	36.34	0.97	0.03	2.50**

Note: \*, \*\*, \*\*\* indicate significant statistical levels of p < 0.1, p < 0.05, p < 0.01, respectively; CV < 0.20 = Low, 0.20 < CV < 0.30 = Moderate, CV > 0.30 = High

Source: Author's construct using meteorological data collected from the Upper East regional office of GMet (2022)

Table 2: Statistical summary of rainfall in the Talensi district for the past 42 years (1981–2022)

Parameter (mm)	Min	Max	Sum	Mean	SD	CV	MK
Average annual rainfall	57.1	122	3641.6	86.70	16.88	0.19	2.18**
Rainy season	623.9	1309.1	40420.4	962.39	188.32	0.20	1.66*
Dry season	6.4	182	3278.6	78.06	46.06	0.59	2.69***
January	0.0	1.2	1.4	0.03	0.19	6.33	-0.25
February	0.0	23.1	96.5	2.30	5.64	2.45	0.62
March	0.0	97.8	839.4	19.99	27.06	1.35	1.65*
April	2.8	176.5	2036.6	48.49	37.83	0.78	2.48**
May	32.6	199.8	4328.7	103.06	42.59	0.41	2.32**

June	36.8	275.5	5590.1	133.10	52.63	0.40	-0.20
July	74.8	446.5	8073.2	192.22	91.85	0.48	0.80
August	95.6	601.3	11247.4	267.80	109.79	0.41	0.61*
September	23.8	331.1	8542.0	203.38	74.40	0.37	-1.78*
October	0.0	236.1	2639.0	62.83	46.86	0.75	-1.88*
November	0.0	46.5	233.3	5.55	10.25	1.85	-0.81
December	0.0	44.6	71.4	1.70	7.85	4.62	-0.88

Note: \*, \*\*, \*\*\* indicate significant statistical levels of p < 0.1, p < 0.05, p < 0.01, respectively

Source: Author's construct using meteorological data collected from the Upper East regional office of GMet (2022)

Agriculture plays a significant role in the district, with 91% of households engaged (GSS, 2014; TDA, 2022). These households are primarily smallholder farmers dependent on a favourable climate for their agricultural production. Agro-pastoralism (crop farming and livestock production) is the main agricultural activity, with some silviculture and aquaculture also practised (GSS, 2014; TDA, 2022). The district's farming systems comprised integrated combinations of crops, livestock, trees and fishery (TDA, 2022; Opoku Mensah et al., 2024).

The agro-pastoral production system in the Talensi district represents one of Ghana's most vulnerable production systems to climate-related hazards, including seasonal temperature changes, rainfall variability, and extreme events. The district's unimodal rainfall pattern, combined with its reliance on smallholder agriculture, makes it one of the most climate-vulnerable districts in Ghana (EPA, 2020). Additionally, the system is weakened by persistent poverty and inadequate infrastructure development (GSS, 2014; TDA, 2022). The district's agricultural system has experienced major impacts of climate change, including drought, famine, crop loss, floods, wildfires, and pest infestations (TDA, 2022). The district's smallholder agropastoral farmers have witnessed annual rainfall variability, loss of forest cover, biodiversity disappearance, and loss of productivity from declining soil fertility (TDA, 2022).

Power relations embedded within the patriarchal social structure of northern Ghana—where this study was conducted—play a significant role in shaping climate change vulnerability, particularly among women and other marginalized groups (Sova et al., 2017; Nachibi & Morgan, 2025). In the Talensi district, traditional gender roles and hierarchies place men in dominant positions of authority, especially in household decision-making, land ownership, access to productive resources, and participation in community leadership. Women, on the other hand, often have limited control over land, income, and mobility, despite their central role in agricultural production and household resilience strategies (TDA, 2022). Moreover, intrahousehold power relations affect how resources are distributed and how adaptation decisions are made. In many cases, men retain the final say on land use decisions and the adoption of climate adaptation technologies (TDA, 2022; Opoku Mensah et al., 2025).

Accordingly, land tenure arrangements play a critical role in shaping the climate vulnerability of smallholder farmers in the Talensi District. In this predominantly patrilineal and agrarian setting, land is largely owned and allocated through customary systems, where traditional authorities and family heads exert significant control over land access and distribution. Women, particularly, face structural barriers to land ownership and long-term land security (Tangonyire & Akuriba, 2021; TDA, 2022). Most smallholder women farmers access land through male relatives—husbands, fathers, or brothers—and their use rights are often temporary, insecure, and subject to change due to events such as divorce, widowhood, or land reallocation within families. This lack of tenure security significantly constrains women's willingness and ability to invest in long-term adaptation strategies (TDA, 2022; Opoku Mensah et al., 2025). These tenure-related constraints compound their overall vulnerability to climate change, as they restrict both their access to productive resources and their adaptive capacity (Yorose, 2019; Tangonyire & Akuriba, 2021; TDA, 2022).

Industrial activities in the district are generally limited (Tangonyire & Akuriba, 2021). They include the processing of shea into the valuable 'white gold'—shea butter; dawadawa into food additives; groundnuts into oil; brewing of pito (a locally brewed wine); and the parboiling and milling of local paddy rice (GSS, 2014; TDA, 2022). The district also hosts two main extractive activities: gold mining—which remains underdeveloped, often conducted illegally and on a small scale—and quarrying (GSS, 2014; TDA, 2022). Smallholder farmers in the Talensi district are

subject to institutional interventions such as capacity building and ecological restoration to promote adaptation and maintain sustainable livelihoods (Abunyewah et al., 2024; Opoku Mensah et al., 2024).

This district was chosen because of its distinct local socio-economic and climatic characteristics, including exposure to climate change, ecological sensitivity, historical lack of development, the existence of institutions supporting improved agricultural practices and adaptation interventions, and its agro-pastoral livelihoods (Abunyewah et al., 2024; Opoku Mensah et al., 2024). Thus, the biophysical environment and strong institutional presence in the Talensi district made it a good selection for the research. Through key informant interviews as detailed in section 3.6.2.1—Key informant interviews—two agro-pastoral communities, Awaredone and Yameriga (cf. Figure 6), were selected as the study communities. Table 3 summarises the key socio-demographic and environmental characteristics of Awaredone and Yameriga

While Yameriga is located in the central part of the Talensi district, Awaredone is located in the western part. The terrain of the communities is predominantly savannah, characterised by grasslands interspersed with shrubs and scattered trees. The estimated population of Yameriga is 2,639, while that of Awaredone is 2,595. Agriculture is the mainstay of the communities' economy, with residents engaged in subsistence farming. Common crops include millet, sorghum, maize, and groundnuts. Livestock rearing, particularly goats, sheep, and poultry, supplements household incomes (TDA, 2022). The communities have seen developments in infrastructure and ecological restoration (Abunyewah et al., 2024; Kandel et al., 2022) including the construction of irrigation facilities to provide water for irrigation and livestock to support agricultural activities and reduce their dependence on rain-fed agriculture, thereby increasing resilience against climate variability. However, irrigation facilities such as dams in Yameriga and Awaredone and a solar-powered mechanised borehole in Awaredone are currently not optimally functioning, and the communities cannot repair them without support.

Table 3: Key characteristics of the study communities

Characteristics	Awaredone	Yameriga
Agro-ecological zone	Guinea Savannah AEZ	Guinea Savannah AEZ
Location	Western part of the district	Central part of the district
Vegetation and terrain	Savannah: grassland with shrubs and scattered trees	Savannah: grassland with shrubs and scattered trees
Estimated population	2,595	2,639
Main economic activity	Subsistence agriculture	Subsistence agriculture
Dominant agricultural land use systems	Food crops and livestock	Food crops and livestock
Major crops	Millet, sorghum, maize, groundnuts, guinea corn, cowpea, soybean, Bambara beans, tomato, pepper, leafy vegetables	Millet, sorghum, maize, groundnuts, guinea corn, cowpea, soybean, Bambara beans, tomato, pepper, leafy vegetables
Livestock activities	Goats, sheep, cattle, pigs	Goats, sheep, cattle, pigs
Farming seasons	One main farming season (May – October	One main farming season (May – October
Challenges	Erratic rainfall, prolonged dry seasons, malfunctioning infrastructure	Erratic rainfall, prolonged dry seasons, malfunctioning infrastructure
Type of tenure system	Patrilineal	Patrilineal

In response to environmental degradation and climate challenges, Yameriga has become a focal point for land restoration and sustainable agricultural practices. Initiatives such as Farmer Managed Natural Regeneration (FMNR) have revitalized the local ecosystem, providing residents with resources such as fuelwood, fodder, and non-timber forest products (Abunyewah et al., 2024). This initiative has led to diversified livelihoods and improved food security within the community (Opoku Mensah et al., 2024). Similarly, Awaredone is among the communities in the Talensi district that benefited from ecological restoration and renewable energy projects

aimed at enhancing sustainable development (Kandel et al., 2022). For example, the Landscape and Environmental Agility across the Nation (LEAN) project provided solar-powered boreholes to Awaredone to support landscape restoration and create income-generating opportunities. Despite these advancements, the communities continue to face challenges related to climate change, such as erratic rainfall and prolonged dry seasons.

With a clear understanding of the study area's climate, agricultural systems, and agro-ecological context, I focus the next section on my research approach and design. I aim to provide the blueprint for how I investigated the complexities of climate change adaptation, intersectionality, and institutional support among smallholder farmers. By outlining my methodological choices, I ensure the study is rigorously structured to address the research questions effectively.

I first discuss the research approach—the overall philosophical and methodological orientation of my study—before delving into the research design—the specific framework and steps I used to collect, analyze, and interpret data. I use the research approach to lay the philosophical and methodological foundation for the study, shaping how knowledge is generated and interpreted. I establish this broader framework to allow for a more coherent discussion of the research design, which operationalizes the approach into specific methods and strategies I use to collect and analyze data.

## 3.5 Research approach

Based on the philosophical foundations of this research, as discussed in section 3.2, I combine qualitative and quantitative data collection methods and varied analysis and interpretations (mixed methods) to comprehensively understand and generate systemic and synergistic insights (Osman, 2023; Baffour-Ata et al., 2025) into my research questions (see Figure 4). Qualitative and quantitative methods have different epistemological and ontological backgrounds but can be combined to deepen understanding through cross-validation of data (Bryman et al., 2019). I emphasize the practical integration of different approaches and methods to generate the most comprehensive knowledge possible to directly inform policy and practice (Creswell & Creswell, 2023; Baffour-Ata et al., 2025).

Central to the philosophical foundations of the research is the urgency to understand and overcome difficulties which arise in our uncertain world (Yvonne Feilzer, 2010). The mixed-

method approach has gained importance in many fields—including agricultural studies, rural development, and poverty studies—for analysing social phenomena from diverse perspectives, to capture diverse perspectives and a more holistic view of research questions, and to produce more nuanced insights and robust conclusions (Flick, 2017; Meydan & Akkaş, 2024). It is also helpful to unravel the complex contexts and realities that characterise the lives of rural people (Grix, 2019; Strijker et al., 2020). According to Yeleliere et al. (2023), one such uncertain global real-world issue is climate change, which requires concerted and collective action across all levels and fronts to realise practical outcomes for resilient systems. Given the complexity of climate change as a challenge for rural livelihoods, adopting multiple methods to study it offers opportunities to dissect the complex realities and contexts of rural life (Osman, 2023).

The mixed methods approach involves including and mixing qualitative and quantitative components in the same research—combining and connecting them—in such a way that they are conversing with each other (SAGE Research Methods Datasets, 2019). The mixed methods approach is a research strategy with a philosophical assumption—guiding data collection and analysis and a mixture of qualitative and quantitative approaches—and methods of enquiry collecting, analysing and mixing quantitative and qualitative data. The central philosophical premise of the mixed methods approach is that combining qualitative and quantitative approaches provides a better understanding of the research questions than either alone (Creswell & Plano Clark, 2018). Thus, this approach provides integrated results, allowing the strengths of one method to compensate for the weaknesses of the other (Creswell & Creswell, 2023). For example, it is generally acknowledged that research methods must capture the complexity of human behaviour beyond quantitative data and experimental models to effectively understand and address the complexities of physical and social processes (Strijker et al., 2020). Qualitative methods can provide nuanced insights into people's commitment, understanding and awareness concerning climate change that are often missed in broader quantitative analyses (Strijker et al., 2020).

In this study, I adopt the mixed methods approach because neither qualitative nor quantitative data collection and analysis alone was adequate to answer the research questions. As shown in the interpretation section of Figure 4, the research questions intersect various environmental, social, demographic and economic issues within households and communities' environments and

livelihoods. Empirically addressing such a multiplicity of factors requires mixed methods of data collection and analysis (Osman, 2023). In the context of this research, I used the quantitative data collection method to collect and analyse data in the form of values required for particular variables. This method is particularly important when research questions are related to "which of several variables?", "how much of given variables?", or "how many of given variables?" (Nardi, 2018; Adams, 2019, p. 81). For example, as detailed in Section 1.6 of this thesis, this research included questions such as 'which factors influence climate change adaptation by smallholder farmers? and 'what role does intersectionality play in shaping the adaptive capacity of smallholder farmers?'. On the other hand, qualitative data collection methods (see Figure 8) are important to collect data in the form of texts, words or pictures when research questions are related to who?, how?, and why? to elicit information from research participants (Denzin & Lincoln, 2005a; Bryman, 2016).

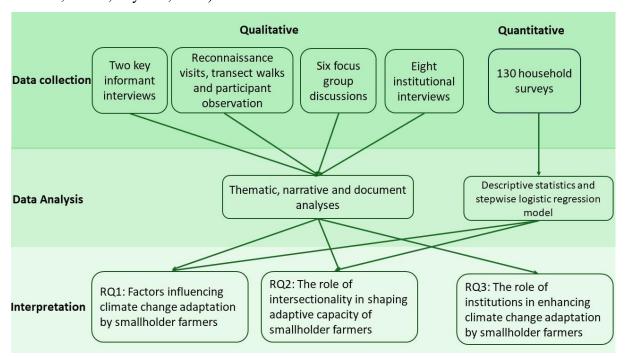


Figure 8: Schematic view of the research process

Source: Author's construct (2025)

Adopting the mixed-methods approach in this research provides the means to achieve the logic of triangulation—enhancing the validity and credibility of research findings by cross-verifying data from different data sources (data triangulation) and combining qualitative and quantitative methods to comprehensively address the research questions (methodological triangulation)

(Donkoh & Mensah, 2023; Kálmán & Malomsoki-Sántha, 2023). Although the mixed-methods approach generally produces more valid and reliable results than the use of a single method (Creswell & Plano Clark, 2018), its application is noted to require more work, a large financial commitment and the need for researchers to master each method (Creswell & Creswell, 2023; Strijker et al., 2020).

Having established the research approach of this study, I discuss the research design in the next step. I build upon the research approach by detailing the specific strategies, procedures, and techniques I used to collect and analyze data. By first understanding the broader research approach, I aim to better appreciate how the study is structured to answer the research questions effectively.

## 3.6 Research design

In terms of research design, I adopt a cross-sectional design to intrinsically combine qualitative and quantitative methods as an integrated set of methods to compare several variables concurrently (Yeleliere et al., 2023). Here, I adopt an exploratory sequential design—beginning research with an exploratory, qualitative phase and moving sequentially to a quantitative phase (Creswell & Plano Clark, 2018; Creswell & Creswell, 2023) to blend interviews, focus group discussions, observations and household surveys. In the exploratory sequential mixed-method design, the qualitative phase provides critical information to develop specific research questions in the quantitative phase (Creswell & Plano Clark, 2018). I obtained qualitative information through participatory methods, including Key Informant Interviews (KIIs), Focus Group Discussions (FGDs), institutional interviews and participant observations. These participatory methods are bottom-up approaches widely used to gather information from rural populations to garner a deeper understanding of their environmental conditions (Walter, 2019). Participatory approaches are grounded in actionable activities and direct engagement with community members (Kemmis & Wilkinson, 1998). Using participatory methods adds depth to the quantitative findings to achieve methodological goals (Creswell & Plano Clark, 2018).

I used household surveys to collect quantitative data. Surveys are valuable tools for identifying specific issues and establishing patterns of association and relationships between variables (Bryman, 2016). They allow researchers to estimate key characteristics of a study population for

more detailed analysis (Creswell & Creswell, 2023). Moreover, surveys provide accurate measurements of research variables, thereby facilitating broader generalization of findings (Marshall & Rossman, 2011). Such an exploratory sequential design helps gain deeper insight into the decision-making processes involved in farmers' adaptation decisions. Also, it may uncover hidden determinants of practice change that are difficult to capture by a survey alone (Aqib et al. 2024).

As part of the research design, I collected data in five interconnected phases between September 2022 and March 2023, as shown in Figure 9. To capture the diversity of agricultural actors at each study site, the data collection consisted of semi-structured interviews with key informants from local institutions involved in climate change and agricultural production, followed by reconnaissance visits, transect walks and participant observation, community-based focus group discussions, institutional interviews and surveys of heads of households.

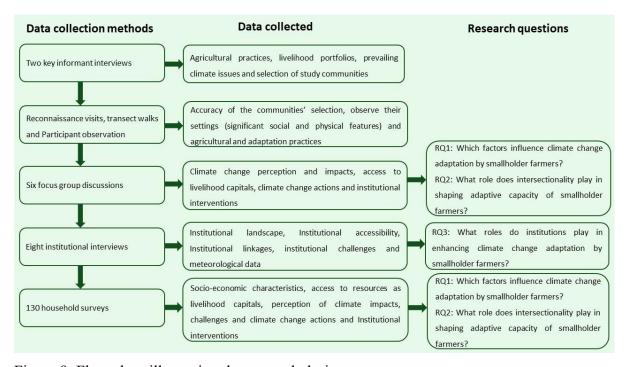


Figure 9: Flow chart illustrating the research design

Source: Author's construct (2025)

# 3.6.1 Recruitment and training of research assistants

Given the district's patriarchal nature, I recruited and trained four research assistants; two men and two women (see Table 4) who come from the study district to support me during data collection. This arrangement ensured that the women assistants interacted with women smallholder farmers while men assistants connected with their men counterparts to moderate cross-gender and cross-cultural sensitivities (Nyantakyi-Frimpong, 2020) and foster trust and participation. Selection criteria for these research assistants as listed in Table 4 included previous experience in similar studies, educational qualifications, leadership qualities, community respect, impartiality during interviews, availability and fluency in both English and the local Talen and Guruni languages of the Talensi district.

Table 4: Research Assistants

Sex	Selection criteria						
	Educational qualifications	Previous experience	Leadership qualities	Availability	Fluency in English and local languages		
1. Man	BSc. Community Development	Yes	Senior High School Teacher and Pastor	Yes	Yes		
2. Man	MSc. Development studies	Yes	Agricultural Officer	Yes	Yes		
3. Woman	BSc. Environmental Studies	Yes	Assistant Planning Officer	Yes	Yes		

4. Woman	BSc. Education	Yes	Junior High	Yes	Yes
			School		
			Teacher		

Bryman et al. (2019) emphasise the importance of training and supervising research assistants when their services are sought. Accordingly, I trained the four assistants in Tongo, the district capital, over two days to ensure consistent data collection and minimise misunderstandings and ambiguities. The training sessions were centred on sampling, administrating digitised questionnaires, appropriate probing styles and focus group activities. We also used the training sessions to discuss how to enhance communication and facilitate using locally appropriate terminology for subjective concepts such as climate (see Smith et al., 2000). We reached an agreement for the team to meet at the close of work every day to discuss the day's work and plan for the following day. Also, we agreed upon bi-weekly reflections to review the data collection process and ensure consistency. In addition to the research assistant administering questions and serving as co-moderators, note-takers and interpreters, they also provided interpretative insights into the cultural complexities and sensitivity issues, agricultural practices, people's connection with lands, social support and inter and intra-household relationships, among others.

In the next section, I first focus on the qualitative data collection aspect of my research design before moving on to the quantitative data collection. This sequence is deliberate, as the qualitative approach provides deeper contextual insights into the lived experiences, perceptions, and social dynamics that shape climate adaptation. By first exploring these rich narratives, I introduce the quantitative data collection, which allows for broader generalizability and statistical validation of key patterns. I seek to ensure a comprehensive understanding of the research findings by balancing depth with breadth.

## 3.6.2 Qualitative data collection

## 3.6.2.1 Key informant interviews

The initial data collection phase commenced with Key Informant Interviews (KIIs) with key actors in agricultural production and climate change in the Talensi district. KIIs allow researchers to seek clarification and gain deeper insight into issues from the respondent's

perspective. Their open-ended format minimizes restrictions on the content and scope of responses, facilitating richer and more nuanced data (Creswell, 2021). These interviews focused on the nuances of the district's agricultural practices, livelihood portfolios, and prevailing climate issues. On pragmatic grounds, the district's Department of Agriculture (DoA) and the TDA were chosen as primary sources of information due to their extensive experience, knowledge, and recognised involvement in climate change initiatives, agricultural production and rural development in the district. The knowledge gathered from key informant interviews also provided the basis for selecting the study communities. For example, with the involvement of the DoA and using stratified sampling, two agro-pastoral communities, Awaredone and Yameriga (cf. Figure 2), were sampled from the district's three area councils informed by the local socio-economic and climatic characteristics, natural environment, agro-pastoral production systems, and institutional presence. These communities were at discrete locations in the district and had similar sizes and populations, with several institutions operating in them (Abunyewah et al., 2024). These communities contribute significantly to the district's demographic and agricultural profile and provide a good representation of the district (TDA, 2022).

## 3.6.2.2 Reconnaissance visits, transect walks and participant observation

I followed the selection of the communities with reconnaissance visits and consent meetings with the communities' leaders, primarily chiefs, opinion leaders, elders and assembly members—community/neighbourhood level political representatives who represent the interests of their immediate communities/neighbourhoods in the local governance system (Osman, 2023). According to Bryman et al. (2019), reconnaissance visits involve a researcher's preliminary and brief visit to the research site to familiarize themselves with the study context before starting the actual research. I used the visits and meetings to introduce myself, verify the accuracy of the communities' selection, become familiar with, establish necessary contacts and acquire entry into each selected community. The DoA facilitated the community entry in each community through their respective assembly members. During the reconnaissance visits, I was introduced by the assembly members. I then discussed the research objectives and the nature of the research and obtained feedback at the community level. Also, I thoroughly discussed the interview processes and sought community consent. For example, the community leaders in Yameriga sought to know what the research would bring them. I explained the research goal in relation to

informing academic learning and policy attention for a sustainable and just future for climate-vulnerable communities and households. After all clarifications were sought and anonymity assured, the communities, through their leaders, verbally consented to participate in the research.

I also conducted community and farm transect walks with community opinion leaders. A transect walk is a participatory approach whereby the research team walks through a village or community with community leaders (Sallu et al., 2009). This technique facilitates active participation from community members, allowing them to contribute local knowledge and insights (Rojas et al., 2021). These walks were important to observe the communities' settings and agricultural and adaptation practices, and get an overview of the communities' significant social and physical features. I leveraged the reconnaissance visits and transect walks to build trust and establish rapport with the communities.

Again, I conducted participant observation as an integral part of this research throughout the entire data collection process. Participant observation is a qualitative research method involving researchers immersing themselves in a social setting to systematically record behaviours, interactions, and cultural practices (Kearns, 2016; Gray, 2018). I took an observer-as-participant role—participants were informed about research activities, and as someone with dual positionality (see Section 3.3) to the communities, I took a mid-point between my insider and outsider status to participate in the research-related activities to carry out observation (Gold, 1958; Kearns, 2016). I took this position to maintain a balance between my insider position—being emotionally and physically involved to achieve an internal perspective on the lives of the research participants and my outsider position—difficulty in accessing field settings (Gray, 2018).

I conducted participant observation to closely observe the communities' settings, climate impacts, and agricultural and adaptation practices to get an overview of their significant social and physical contexts. Informal conversations were made during the observation process, taking cognisance of the fact that participant observers can examine people in their everyday lives without interrupting them (Denscombe, 2017). This process allows researchers to move beyond participants' self-interpretations and opinions of their attitudes and actions by observing and listening to them in their natural settings (Gray, 2018). Participant observation allows researchers to gather complementary insights that may not be accessible during formal data collection, such

as interviews and focus group discussions (DeWalt & DeWalt, 2011; Masud-All-Kamal, 2019). I undertook participant observation on farmlands, communities and households. As part of the observation, I took photographs to document stories. I used a field diary to note all observations, verbal and non-verbal behaviours, discussions and stories for analysis. I wrote detailed notes after each observation.

Participant observation is essential for capturing evidence of the participants' ethnographic settings (Adams, 2019), providing valuable insights into the socio-ecological contexts relevant to this research. For example, during the data collection period between September 2022 and March 2023, the smallholder farmers engaged in farming activities, allowing for field-based observations of their farming and adaptation actions. I performed the observation processes in accordance with standard ethics protocol by seeking consent from the communities' leaders and research participants.

### 3.6.2.3 Focus group discussions

In the next phase of the research design, I co-moderated six FGDs with the research assistants. Two research assistants assisted in each community, serving as co-moderators, note-takers and interpreters. FGD is a qualitative data collection method where several participants discuss a defined topic, collaboratively constructing meaning about a phenomenon as a group, with the process facilitated by a moderator (Krueger & Casey, 2015). The research assistants and I conducted three in each community to facilitate collective dialogues, gather diverse perspectives and assemble valuable insights from the discussants' lived experiences (Opoku Mensah et al. 2023). Ritchie et al. (2013) emphasised the importance of ensuring the representativeness of the group to avoid collecting data that is unrepresentative of the population being studied. To ensure balance and representativeness of the discussants while selecting the optimal number of discussants (Adams, 2019), the discussions were open-ended, and each group consisted of 5-10 participants, including community opinion leaders like chiefs or their representatives, assembly members, local group leaders, and heads of households.

Due to the district's patriarchal nature, which often discourages women and youth from speaking freely in mixed groups (Koomson-Yalley & Kyei, 2022; Opoku Mensah et al. 2023), we grouped the participants by gender and age: men-only, women-only, and youth-only. This approach

aimed to create a more comfortable environment, allowing participants to express their views and potentially highlighting any social differences in perspectives. According to Aqib et al. (2024), including underrepresented farming groups, such as women and youth, adds more nuance to understanding farmers' adaptation behaviours and ensures a more comprehensive appreciation of communities' adaptation strategies.

The successful organization of a focus group depends on several factors, including the choice of the meeting venue, the discussants' willingness to engage in the discussion, and their language needs (Bryman, 2016). We held the discussions in the local Talen and Guruni dialects, each lasting approximately three hours, with short breaks in between sessions. In consultation with community leaders, we scheduled the discussions for late afternoons after farmers had completed their daily activities to ensure maximum participation. Also, in consultation with community leaders, we held the discussions in locations determined suitable, including chief's palace and community meeting grounds. The discussion topics included climate change perception and impacts, access to livelihood capitals, climate change actions and institutional interventions (see Appendix I for the FGD guide). With the consent of the discussants, we audio-taped the discussions. As advocated by Ritchie et al. (2013), audio recording enables researchers to fully concentrate on moderating the discussions.

#### 3.6.2.4 Institutional interviews

I conducted in-depth interviews with eight institutions that were identified during the FGDs to be involved in climate change and agricultural production in the research communities based on their availability, applicability and willingness to participate in the study. An interview is a social encounter that allows participants to share their experiences, feelings, and perspectives on a specific issue (Seale et al., 2004). It is widely regarded as a key research method in the social sciences, offering valuable insights into individual or group viewpoints (Denzin & Lincoln, 2005a). To ensure that the data represented the institutional landscape in the district, I interviewed a mix of the three institutional types—state/public (n=4), private/market (n=1), and civic/civil society (n=3). These institutions have extensive experience, knowledge, and recognised involvement in climate change initiatives, agricultural production and rural development in the district. I conducted all interviews to clarify discrepancies, minimise

interpretation bias, and validate responses (Lawless et al., 2022). Representatives from identified institutions, who were mainly field staff, were interviewed.

The interviews explored the nature and goals of the identified institutions (landscape), how they facilitate adaptation actions—as identified during the interviews—through implementation tools (accessibility), whether and how they coordinate their responses and whether they cover the most vulnerable smallholder farmers (linkages) (see Appendix II for the interview guide). Also, as part of the institutional interviews, I collected meteorological data of the Talensi district for the past 42 years (1981–2022) from the Upper East regional office of the Ghana Meteorological Agency [GMet]. I conducted the interviews in English, the official language of Ghana, and at the institutions' offices. The interviews lasted approximately an hour and were audio-taped with the consent of the participants.

I also utilised secondary data sources (Chatfield, 2020)—including institutional websites, published reports, and programme/project documents—to better understand the structure and function of the institutions to support adaptation. Such secondary data sources are useful to contextualize data and corroborate and support evidence collected during interviews, observations and other sources (Bowen, 2009; Yin, 2018).

#### 3.6.3 Quantitative data collection

#### 3.6.3.1 Household surveys

I adopted a household survey since the main unit of analysis of this research is the farm household. A farm household is defined as a farm family unit comprising a group of interrelated individuals who live together, share the same dwelling, work on the family farm, make farm-level decisions (including those related to adaptation), and pool their labour to manage their farm under the primary leadership of the household head (Solomon et al., 2007; Davies & Bennett, 2007). I used a questionnaire (see Appendix III for the questionnaire) to collect the household data. In designing the household questionnaire, I considered three important principles: keep questions relevant, simple and clear to ensure clarity of content; avoid leading questions to prevent potentially biased responses; and ensure logical ordering of questions to achieve coherence and ease of response (Neuman, 2021).

The research assistants and I pretested a preliminary questionnaire with 20 households. According to Fink (2017), pretesting is important to ensure the relevance of research questions and help respondents better understand the questions. Based on feedback from respondents, I finalised the questionnaire, which consisted of a set of open and closed-ended questions divided into four parts to elicit information on the heads of households':

- 1. Socio-economic characteristics;
- 2. Access to resources as livelihood capitals;
- 3. Perception of climate impacts, challenges and climate change actions; and
- 4. Institutional interventions.

This division was done to achieve coherence during the interviews (Adams, 2019). I designed the questionnaire to comprise open- and closed-ended questions for two main purposes. First, closed-ended questions enable researchers to collect as much data that can be easily aggregated within a short period. In response to Bryman's (2008) observation regarding the potential biases associated with using questionnaires consisting solely of pre-coded questions—which can limit participants in their responses—the inclusion of the response option 'other' in this research allowed participants to provide answers beyond the pre-coded options (Adams, 2019). Second, including open-ended questions enables researchers to delve deeper by asking follow-up questions to uncover participants' reasoning behind their answers to pre-coded questions (Lewin, 2005).

I digitized the questionnaire using the Open Data Kit (ODK) mobile app (Hartung et al., 2010) to enhance the quality and efficiency of data collection. ODK is an open-source, extensible suite of tools designed to support the development of information services (Hartung et al., 2010; Bokonda et al., 2019). ODK allows the inclusion of filter questions, ensuring participants only answer questions relevant to them, thereby reducing the time required to complete the questionnaire and respondents' fatigue. ODK allows all collected data to be verified by principal researchers before uploading to a secure server (Brunette et al., 2013; Bokonda et al., 2019). The finalised questionnaire was conducted with 130 agro-pastoral households, defined as those who considered crop farming as their primary source of income and owned at least five head of cattle and a herd of sheep or goats (Zampaligré et al. 2014). In addition to engaging in agro-pastoral

activities, selected households must also have received climate change support from institutions. The surveys were conducted in the local dialects of Talen and Guruni and were 45-60 minutes in duration.

A systematic sampling method was employed to select participating households (Mostafa and Ahmad 2018). According to the specifications of the sample frame and inclusion criteria, 130 valid questionnaires were returned for the two communities of Awaredone and Yameriga. Cochran's formula (Cochran, 1977) was used to determine the sample size needed to satisfy a 95% confidence level (z=1.96), 91% agricultural households and a 5% level of precision (α) from 14,291 total households as follows:

$$n = \frac{z^2 * p * (1-p)}{(\alpha)^2} \quad n = \frac{1.96^2 * 0.907 * (0.093)}{(0.05)^2} \quad n = 130$$

n = sample size, z = critical value of desired confidence level, p = degree of variability in the population and  $\alpha$  = desired level of precision.

The required sample size 'p' for each of the two communities was determined by Probability Proportional to Size (PPS) (see Appiah et al., 2017; Asante et al., 2021) calculated from the sample size 'n' (130) using the formula:

$$p = \left(\frac{population\ of\ community}{Total\ population\ of\ the\ 2\ sampled\ communities}\right)*n\ (130)$$

Because Awaredone and Yameriga had similar sizes and populations, 65 agro-pastoral households were selected and interviewed in each community. In each household, only household heads or agricultural decision-makers who make final agricultural decisions (Kuang et al., 2022) participated in the survey. The decision to focus on household heads or agricultural decision-makers was guided by the specific objective of understanding how adaptive capacity is shaped by those who directly influence agricultural decisions. In the context of the Talensi district, where agriculture is largely a household-level endeavour (TDA, 2022; GSS, 2014), household heads or primary decision-makers play a critical role in resource allocation and responses to climate risks (Tindan et al., 2022; Opoku Mensah et al., 2023). Therefore, focusing on this group allowed me to capture insights into decision-making dynamics central to adaptation. Additionally, the inclusion criterion related to livestock ownership was intended to ensure the

inclusion of smallholder farmers actively engaged in agro-pastoral production systems. Livestock ownership is a common indicator of socio-economic status and resource endowment in the Talensi district (TDA, 2022; Abunyewah et al., 2024), and it plays a crucial role in shaping adaptive capacity and managing climate risks (Geda et al., 2024).

## 3.7 Data analysis

I combined quantitative and qualitative data analysis techniques (cf. Figure 4) to address the research questions effectively. The data analysis was not based on preconceived ideas but on responses and issues from the research participants (Vogt et al., 2014). Before starting the data analysis, I grouped data from various sources separately. Such categorisation is important to prevent mixing data from different sources and allow researchers to reflect more effectively on the appropriate analytical techniques for each dataset (Adams, 2019). However, I combined the analysed qualitative and quantitative data in interpreting and presenting the results (cf. Figure 3) to give a clearer and more general picture of the research objectives (Strijker et al., 2020; Creswell & Creswell, 2023).

#### 3.7.1 Qualitative data analysis

I analysed the qualitative data using thematic and narrative analysis (Bryman, 2016). These analyses led to inductive analysis—detailed analysis of raw data to identify inherent patterns, themes, and categories such that findings emerge from the data (Thomas, 2006; Azungah, 2018)—and deductive analysis—applying existing frameworks or theories to interpret data and guide data analysis from general principles to specific instances (Patton, 2015; Mihas, 2023). While the inductive analyses are detailed in Chapters 4 and 5, the deductive analysis is detailed in Chapter 6.

Thematic analysis helps to identify, analyse and report themes or patterns within data sets (Braun et al., 2017). Analysis of data thematically suits various ontological and epistemological approaches, including constructivist and relational ontology paradigms that allow their proponents to examine how events, realities, meanings, and experiences are constructed within societal discourses (Braun et al., 2017). By adopting this approach, researchers can analyze the meaning of texts within their socio-cultural context and structural conditions, thereby gaining a broader understanding of the research phenomenon (Vaismoradi et al., 2013). Also, the recursive

process—researchers' ability to move back and forth throughout the phases as required—in thematic analysis provides a nuanced account of the data collected (Braun et al., 2017).

In emphasising stories articulated by discussants, I used narrative analysis in the form of quotations to emphasise stories from research participants, substantiate claims, explain the real-life context of the research participants' opinions and illustrate the interconnections between themes (Bryman, 2016). To ensure rigour and trustworthiness, I maintained participants' own words with low use of inference descriptors (Baxter & Eyles, 1997). I reached saturation when no new information or insights emerged from the data, and previous findings started to be repeated (Miles et al., 2019). Furthermore, narrative analysis is particularly effective for achieving "the depth and richness required for a sophisticated intersectional analysis" (Hopkins 2018, p. 587) as captured in Chapter 5 of this thesis. According to Christensen & Jensen (2012), people's narratives about their live stories can provide the most insight into social categories and their intersections.

I also used document review analysis to analyse secondary data from the institutions (see Davila et al., 2024) as detailed in Chapter 6.

#### 3.7.2 Quantitative data analysis

I exported the household data from the ODK server, cleaned it, and imported it into Statistical Package for Social Science (SPSS) Statistics 28 and Microsoft Excel 2019 for analysis. I recategorized several variables for a more detailed and manageable data analysis (e.g. Adams, 2019). I conducted computer-aided analytical procedures following these processes based on the needs of the research questions.

I used descriptive statistics (frequency, maximum, minimum, mean, percentages) (e.g. He et al., 2022) to summarise the data (see Chapters 4 and 5). I also used inferential statistics (Chi-square tests) (e.g. Aboye et al., 2023) to analyse the adaptive capacity of the smallholder farmers, and how the livelihood capital indicators and other socio-demographic characteristics of smallholder farmers intersect to shape their climate adaptation (Chapter 5). Again, I used the Chi-square test of independence to determine the significance of associations between the ratings of selected livelihood indicators and the socio-demographic characteristics of the respondents (Onchiri, 2013) (Chapter 5). I also employed a stepwise logistic regression model to analyse the factors

influencing farmers' adoption of climate change actions (see Chapter 4). Furthermore, as shown in section 3.4.3—Agro-ecological context of the Talensi district—I used a times series design (e.g. Asare-Nuamah & Botchway, 2019; Yeleliere et al., 2023) to establish the extent of climate change and variability by analysing meteorological data of the Talensi district for the past 42 years (1981–2022).

#### 3.8 Ethical consideration

Researchers must be resolute in their commitment to ethical issues—codes of practice and acceptable moral behaviour that researchers must consider (Stutchbury & Fox, 2009; Yeleliere et al., 2023). I complied with the Australian Code for the Responsible Conduct of Research and the National Statement on Ethical Conduct in Human Research, undertaking all research activities according to fairness, justice, respect, accountability, honesty, and transparency after receiving approval from the Human Research Ethics Committee (HREC) at the University of Technology Sydney (UTS), under approval number UTS HREC ETH22-7303 (see Appendix IV). I made conscious efforts to avoid any biases that could influence the data collection process. I carefully designed, conducted and reviewed at every stage of the research process to ensure quality and integrity.

Paying attention to communities and recognizing their norms and cultural practices is critical to conducting research responsibly, as outlined in the Australian Code for the Responsible Conduct of Research (Australian Research Council et al., 2018). The research assistants and I conducted questionnaire administration, interviews, focus group discussions and observation processes following standard ethics protocol by seeking consent from the communities' leaders and research participants for their involvement in the research. The research assistants and I gave participants an information sheet (see Appendix V) outlining a comprehensive overview of the research's purpose and their role in the data collection process and a consent form (see Appendix VI). The research assistants and I discussed the information sheet with the research participants. The research assistants and I addressed all clarifications before seeking their consent to proceed with the interviews. The research assistants and I consistently sought to minimise risk by maintaining a respectful and considerate approach. Fortunately, no participants experienced or reported distress or risk during the interviews.

During fieldwork, several ethical issues emerged, particularly in relation to consent, power dynamics, and privacy. In administering household surveys, the primary concern was ensuring that participation was genuinely voluntary, especially among women and youth, who may have felt pressured by family members or community leaders. To address this, interviews were conducted in private spaces, and participants were repeatedly reassured that they could withdraw at any time without consequence. In conducting FGDs, an ethical issue arose around power imbalances, especially in mixed-gender or mixed-generation groups. To address this, FGDs were disaggregated by gender and age groups (men-only, women-only, and youth-only) to create safe spaces for open expression. Facilitators, trained in gender-sensitive approaches, were careful to encourage quieter voices and ensure equal participation. KIIs also required ethical sensitivity, particularly in handling confidential or politically sensitive information. Some informants expressed concerns about being quoted or identified. As such, I ensured strict anonymity and clarified that no personally identifying information would be attributed in the thesis or any resulting publications. Notes and recordings were stored securely, and all data were de-identified during transcription and analysis.

### 3.9 Data documentation and management

I developed a Research Data Management Plan (RDMP) in Stash—UTS's research data management platform. In the RDMP, I provided details about the type of data to be collected, the approach to analyse data and the ethical considerations of the research. I also indicated how the data is stored and archived in UTS's Research Data Portal. I de-identified all the data to protect anonymity and ensure the confidentiality of research participants. I brought all the data collected from the fieldwork in Ghana back to Australia. I stored them securely on a computer in password-protected electronic files following UTS standard ethics protocol. I stored all physical materials, such as hard copies of data collection instruments in files in a locked cabinet on the university premises. I followed UTS's standard confidential waste management protocol for the final destruction/disposal of the data. For example, all audio records were deleted after they were transferred to UTS cloud storage and password-protected.

#### 3.10 Research validity and reliability

Research validity is the extent to which research findings can be reliable and correct, as described by research participants and the researcher (Bryman, 2016; Creswell & Poth, 2018). It also entails concluding the reliability of the research by considering the conditions under which it was conducted (Angen, 2000). Reliability refers to the stability of the findings. Thus, justifying that research findings are dependable by considering when, how, and from whom data were collected (Whittemore et al., 2001; Freduah et al., 2019). Validity and reliability are critical aspects that determine the accuracy and soundness of research findings. They encompass various dimensions, including the appropriateness of research design, sampling methods and data analysis techniques (Karnia, 2024). I optimised the validity and reliability of this research by ensuring that its findings are credible, robust, and reflective of the realities faced by smallholder farmers in the Talensi district by following these strategies.

First, the use of the mixed-methods approach helped to triangulate and cross-check information collected from various sources (Adams, 2019). This approach integrates the subjective perspectives of research participants and enhances the validity, reliability and replicability of results (Bryman, 2016). Second, the pretesting the household questionnaire helped improve construct validity—ensuring that the test measures the theoretical construct it claims to measure (Karnia, 2024). The pretesting ensured that the research instruments captured context-specific nuances and realities of the Talensi district's socio-ecological context, institutional frameworks, and smallholder farming practices and adaptation behaviours. Third, my six-month field engagement enabled me to experience and closely observe the communities' settings, climate impacts, and agricultural and adaptation practices. Such prolonged stay and engagement enable researchers to experience some issues in their research communities and ensure the validity and reliability of research (Fetterman, 2020; Osman, 2023). Lastly, I maintained comprehensive records of all research activities, including raw data, coding frameworks and decisions made during data collection and analysis.

## 3.11 Methodological limitations

The approach adopted for this research inevitably comes with certain limitations related to the overall methodological approach and the data collection process. First, a mixed-methods

approach entails specific trade-offs and issues arising from differences in values and norms. These differences can result in epistemological and ontological inconsistencies and significantly influence the communication and applicability of the research (Mahoney & Goertz, 2006; Bryman, 2016). As a result, qualitative and quantitative components can be treated as separate entities. This separation can lead to differing interpretations of the findings (Bryman, 2007; Creswell & Plano Clark, 2018). Mitigating such issues typically requires carefully selecting and applying methods and clearly defining the role of each method and their combinations within the overall methodological design (Dorkenoo, 2024). I have explained how the presentation of the results combined the analysed qualitative and quantitative data (cf. Figure 8 and section 3.7) to give a clearer and more general picture of the research objectives (Yorose, 2019). Also, I addressed these limitations through triangulation and cross-checking of information collected from various sources (Adams, 2019) and reaching saturation when no new information or insights emerged from the data, and previous findings started to be repeated (Miles et al., 2019).

Second, due to the nature of the research, the available resources, and the time frame within which the research was conducted, I limited the research to two communities. Also, working with two research communities within these constraints inevitably limited the time and attention I devoted to each. I, therefore, concentrated on the most critical issues of the research to allow me to conduct a more in-depth analysis of the two communities to generate valuable findings. Third, the data collection process is subject to various constraints and biases—such as sampling process, collaborative field research, and access—that can influence the validity of the data (Dorkenoo, 2024). For example, collaborative data collection can inevitably introduce biases and inconsistencies stemming from differences in researchers' interview approaches and inconsistencies in language translation (Dorkenoo, 2024). I mitigated this limitation by training the research assistants and agreeing with them to meet at the close of work every day to discuss the day's work and plan for the following day. Also, we agreed on bi-weekly reflections to review the data collection process and ensure consistency.

Fourth, access and relationships are central to the research process (Dorkenoo, 2024). In this research, identifying and engaging with multiple institutions was challenging. I contacted some institutions through emails and phone calls for interviews. However, the invitations were not honoured even after follow-up emails and phone calls. I excluded such institutions from the

research. This situation notwithstanding, I interviewed a mix of the three institutional types—state/public (n=4), private/market (n=1), and civic/civil society (n=3) to ensure that the data represented the institutional landscape in the district. Also, institutions may lack comprehensive or accurate records of their support programmes and institutional representatives may have vested interests, leading to selective disclosure of information. I therefore utilised secondary data sources to contextualize data and corroborate and support evidence collected during interviews, observations and other sources (Bowen, 2009; Yin, 2018). Fifth, research participants may struggle to recall details about past institutional support or climate-related events accurately, especially without written records (Adams, 2019). They may also provide responses they believe align with what researchers want to hear. I addressed this limitation by using different sources of information, including focus group discussions and household surveys (cf. Figures 4 and 5).

Finally, this thesis is structured as a hybrid model in accordance with the UTS Graduate Research Candidature Management, Thesis Preparation, and Submission Procedures (2019), with Chapters 4, 5 and 6 comprising individual papers that have been published or are under review. In such a format, some redundancy across chapters is unavoidable because each empirical chapter is designed to stand alone and provide the necessary context. Nevertheless, I carefully minimised overlaps and ensured that the narrative remains coherent throughout the thesis.

With the research methodology and context established, the next three sections focus on the empirical chapters that present the core findings of my study. By first detailing the research methodology and context, I provide a clear roadmap for understanding how the findings were generated. I systematically explore the key themes of my research in the empirical chapters—factors influencing adaptation, the role of intersectionality, and institutional support—offering in-depth analysis and evidence-based insights.

## **Chapter Four**

# Factors influencing climate change adaptation by smallholder farmers in the Talensi district of Ghana

Chapter four is an article submitted to *Agroecology and Sustainable Food Systems*. It is under revision. The paper answers research question 1: which factors influence climate change adaptation by smallholder farmers?, and its sub-research questions:

- i. How do perception, livelihood capitals and institutional intervention, individually and in combination, influence smallholder farmers' adoption of a range of common adaptation actions to reduce their vulnerability to climate change?
- ii. Is smallholder farmers' adoption of multiple adaptation actions complementary?
- iii. What rationale—based on smallholder farmers' lived experiences of unique contexts explains smallholder farmers' practice adoption?

This chapter examines the factors that shape smallholder farmers' adoption of climate change adaptation actions in the Talensi district, a recognized climate change hotspot in Ghana. Using a mixed-methods approach—including stepwise logistic regression and thematic and narrative analyses—the study explores how climate perception, livelihood capitals, and institutional interventions influence farmers' adaptation decisions.

Table 5: Statement of authorship for chapter four

Title of paper	Factors influencing climate change adaptation by smallholder				
	farmers in the Talensi district of Ghana				
Publication status	Submitted and under review				
Publication details	Opoku Mensah, S., Jacobs, B., & Cunningham, R. Factors				
	influencing climate change adaptation by smallholder farmers				
	in the Talensi district of Ghana. Agroecology and Sustainable				
	Food Systems (under revision)				
Principal author (candidate)	Seth Opoku Mensah				
	Production Note: Signature removed prior to publication.				
Contribution	85%				
	Conceptualization, methodology, formal analysis,				
	investigation, writing - original draft, writing - review &				
	editing, visualization, project administration, formal analysis,				
	data curation				
Co-authors' contribution					
First co-author	Brent Jacobs				
Contribution	10%				
	Methodology, writing - review & editing, visualization,				
	validation, supervision				
Second co-author	Rebecca Cunningham				
Contribution	5%				
	Methodology, writing - review & editing, visualization,				
	validation, supervision				

# Factors influencing climate change adaptation by smallholder farmers in the Talensi district of Ghana

#### Abstract

This study investigates factors influencing smallholder farmers' choice of climate change actions in one of Ghana's climate change hotspots—the Talensi district. A stepwise logistic regression model and thematic and narrative analyses were employed to examine the impacts of climate perception, livelihood capitals, and institutional intervention on smallholder farmers' adoption of six common climate change actions. All smallholder farmers reported adopting one or more actions to reduce their vulnerability. Planting improved crop cultivars was most commonly adopted (89% of farmers), and raising more livestock was least common (19%), with complementarities observed among the climate change actions. The adoption of some climate change actions was influenced by a large number of complex interacting variables (e.g., planting improved crop cultivars), and others were less so (e.g., raising additional livestock). Given the unique contexts of farming communities, agricultural policymakers, development practitioners, and decision-makers at different institutional levels must intensify their efforts to promote context-specific and targeted climate change actions which consider the vital role of farmers' perceptions, livelihoods and institutional factors in their adaptation decisions. Also, consideration should be given to how smallholder farmers combine climate change actions, with a focus on the complementarity of these practices and the factors influencing their adoption, while also acknowledging that the attributes of individual actions remain important to develop appropriate packages of actions to shape farmers' adaptation decisions and minimise climate risks.

#### 4.1 Introduction

Extreme weather events linked to climate change, including changes in precipitation, droughts, floods, and heat waves, have significantly damaged agricultural production (Tong et al. 2024). The impacts of these events are severe on farmers in developing countries, with smallholder farmers being the most vulnerable and least empowered to address climate impacts (Food and Agriculture Organization [FAO] and the African Union Commission [AU] 2022). As climatic changes amplify the vulnerability of farming communities, farmers must adapt their production systems to cope with climate risks and opportunistically utilise prevailing conditions (Intergovernmental Panel on Climate Change [IPCC] 2022a). The choice of adaptation strategy involves adoption decisions (Zilberman et al. 2012), which are multi-stage processes where farmers implement adaptation actions to varying degrees to maximise the benefits (Adesina and Zinnah, 1993). Therefore, smallholder farmers' adoption of adaptation strategies is central to overall adaptation success (Lamichhane et al. 2022).

Climate change adaptation and adoption of innovations are related fields of research. Rodima-Taylor et al.,2012, p.107) define innovations as human adaptations to changing needs and socio-economic conditions and are therefore embedded in social processes. In agriculture, factors affecting innovation adoption by farmers have been studied extensively (e.g. Montes de Oca Munguia et al. 2021). In both adaptation and adoption, the characteristics of the innovation and those of the adopter, in addition to local biophysical, socio-cultural and institutional contexts, mediate practice change and may encompass the adoption of technology transfer across locations and interventions by institutions. However, Zilberman et al. (2012) distinguish between adaptation and adoption based on intent, with adoption primarily focused on economic outcomes (considerations of profit, risk, credit and biophysical constraints) and adaptation with a reduction in vulnerability to major shocks (such as climate change).

For farmers, while models to describe and predict the adoption of innovations abound (Montes de Oca Munguia et al. 2021), studies of climate change adaptation have largely occurred through the lens of adaptive capacity. Adoption of adaptation actions depends on farmers' adaptive capacity to control tangible and intangible resources (Tong et al. 2024). According to IPCC (2022a), adaptive capacity is the ability of systems, institutions, humans, and other organisms to adjust to potential damage and capitalise on opportunities to respond to consequences. Adaptive

capacity predicates the success of climate adaptation, and its assessment identifies the factors hindering or promoting adaptation (Elrick-Barr et al. 2022). Adaptive capacity assessment has evolved through several generations to advance understanding of the complex influences that drive the uptake of adaptation actions (Gupta et al. 2010). Its early conceptualisations focused on objective levels of resource availability (or asset deficit models) (e.g. Brooks and Adger, 2004) followed by recognition of the influence of psycho-social attributes, such as perception of risk and uncertainty, in driving change (Grothmann and Patt, 2005). Later conceptualisations incorporate the need for transference of capacity to encourage system-scale transformation (Elrick-Barr et al. 2022). This evolution has emphasised governance and institutional interventions (Agrawal 2010) as critical interacting factors in developing and sustaining the capacity to adapt.

Previous studies have explored the factors influencing farmers' adoption of climate change adaptation strategies in SSA (Adeagbo et al. 2023). Although these studies provide rich insights into the factors influencing the adoption of adaptation strategies, significant research gaps remain (Asante et al. 2024). Most existing research concentrates on specific factors influencing farmers' adoption decision-making, resulting in a lack of comprehensive research that examines the multifaceted factors influencing their adoption of climate change actions (Tong et al. 2024). For example, a literature review on agricultural technology adoption revealed that while the factors influencing adoption are varied, most identified determinants seldom include latent perception factors related to adoption but are important for adaptation (He et al. 2022; Gudina and Alemu 2024). While climate perception is a central feature of farmers' adaptation decisions, the adaptation literature in the developing world often focuses on the significance of resources available to farmers to develop strategies within a specific institutional context to achieve sustainable livelihood outcomes (He et al. 2022). With the increasing severity of climate change and with more countries and regions prioritising adaptation, the role of institutions in climate change adaptation warrants greater attention (IPCC 2022b).

Previous studies have often focused on individual adaptation actions, often assuming that farmers adopt only one action at a time on their farms (Asante et al. 2024). However, farmers are more likely to adopt a combination of adaptation actions to overcome production challenges, suggesting complementarity among actions often ignored in adaptation studies (Adeagbo et al.

2023). Accordingly, Gudina and Alemu (2024) called for further empirical investigation to understand the factors influencing smallholder farmers' adoption of multiple adaptation actions and their complementarity. Furthermore, studies of practice adoption often fail to consider the lived experiences of smallholder farmers and how their unique contexts and experiences shape their adaptation behaviours (e.g. Llewellyn and Brown 2020). These oversights are not unique to any specific region, as evidenced by the situation in Ghana (Asante et al. 2024) and other regions (e.g. Aqib et al. 2024). Against this background, there are research and knowledge gaps in understanding how perception, livelihood capitals and institutional interventions, individually and in combination, influence smallholder farmers' choice of adaptation actions to reduce their vulnerability to climate change in Ghana. While recognising the difficulty of capturing the full complexity of adoption decisions and limited consideration of technological and structural drivers (Rodríguez-Barillas et al. 2024; Ricart et al. 2025), this paper aims to investigate the relative influence of perception, livelihood capitals and institutional interventions on smallholder farmers' adoption of a range of common adaptation actions to reduce their vulnerability to climate change.

#### 4.2 Methods and materials

#### 4.2.1 Survey design and data collection

This study analyses the factors influencing smallholder farmers' adoption of climate change actions in semi-arid Ghana. The study adopted a pragmatic, mixed-methods approach to unravel the complex contexts and realities that characterise the lives of rural people (Strijker et al. 2020). According to Strijker et al. (2020), the mixed-method approach has gained importance in many fields—including agricultural studies, rural development, and poverty studies—for analysing social phenomena from diverse perspectives. Qualitative information was obtained through Key Informant Interviews (KIIs) and Focus Group Discussions (FGDs), while household surveys were used to collect quantitative data. Such mixed-method approaches help gain deeper insight into the decision-making processes involved in farmers' adaptation strategies. Also, they may uncover hidden determinants of practice change that are difficult to capture by a survey alone (Aqib et al. 2024).

## 4.2.2 Study area description

Fieldwork was conducted in the Talensi district in Ghana's northern savannah Agro-ecological Zone (AEZ) (Figure 10) between September 2022 and March 2023. Within this period, the smallholder farmers were engaged in farming activities, allowing for field-based observations of adaptation strategies. This district was selected due to its unique local socio-economic and climatic characteristics, such as climate-induced exposures, ecological sensitivity, historical lack of development, presence of institutions championing adaptation interventions and improved agricultural practices, and its agro-pastoral based livelihoods (Opoku Mensah et al. 2023). The Talensi district experiences a tropical climate characterized by two distinct seasons: a highly variable rainy season from May to October, and a dry season from November to April. The district receives an average annual rainfall of 950 mm. Temperatures peak at around 45°C in March and April, while the lowest temperatures, around 12°C, occur in December (GSS, 2014; TDA, 2022). The district's agricultural production system is environmentally fragile and largely dependent on rain-fed (non-irrigated) dryland farming (Opoku Mensah et al., 2023).

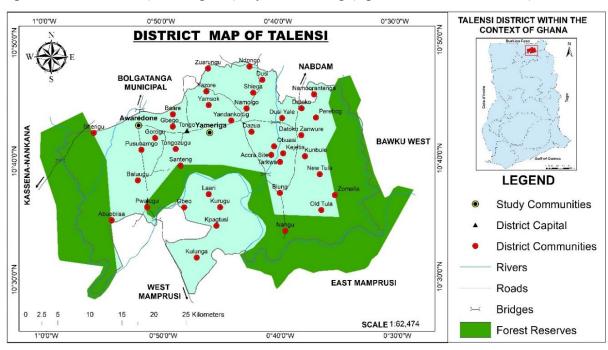


Figure 10: Map of the Talensi district, showing the locations of Awaredone and Yameriga.

Source: Opoku Mensah et al. (2023); Abunyewah et al. (2024).

Talensi district has experienced major impacts of climate change, including drought, famine, crop loss, floods, wildfires, and pest infestations (TDA 2022). Agriculture plays a significant role in the district, with 91% of households engaged. These households are primarily smallholders dependent on a favourable climate for their agricultural production (TDA 2022). Agropastoralism (crop farming and livestock production) is the main agricultural activity, with some silviculture and aquaculture also practised (TDA 2022). The district's smallholder agro-pastoral farmers have witnessed annual rainfall variability, loss of forest cover, biodiversity disappearance, and loss of productivity from declining soil fertility (TDA 2022). The agropastoral production system in the Talensi district represents one of Ghana's most vulnerable production systems because of its susceptibility to climate-related hazards such as rainfall variability, seasonal temperature changes, and extreme events, coupled with persistent poverty and limited infrastructure development (TDA 2022). Talensi district's smallholder farmers are subject to institutional interventions to promote adaptation and maintain sustainable livelihoods, including capacity building and ecological restoration (Opoku Mensah et al. 2023; 2024). The biophysical environment and strong institutional presence in the Talensi district (Abunyewah et al. 2024) contributed to the site selection for the case study.

#### 4.2.3 Data collection

Data collection consisted of semi-structured interviews with key informants from local institutions involved in climate change and agricultural production, followed by community-based focus group discussions and surveys of heads of households. Figure 11 shows the schematic view of the research process.

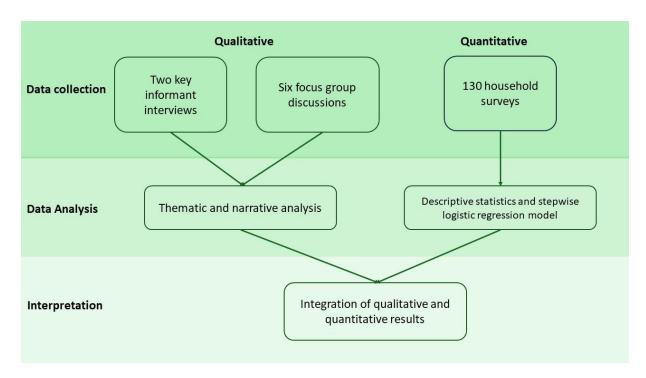


Figure 11: Schematic view of the research process

Four research assistants, native to the study communities, were recruited to support the principal researcher during data collection. For the two Key Informant Interviews (KIIs), the Department of Agriculture (DoA) and the TDA were interviewed by the principal researcher due to their extensive experience, knowledge, and recognised involvement in climate change initiatives, agricultural production and rural development in the district. The interviews focused on the nuances of the district's agricultural practices, livelihood portfolios, and prevailing climate issues. The knowledge gathered from these KIIs provided the basis for selecting the study communities. Two agro-pastoral communities, Awaredone and Yameriga (cf. Figure 10), were selected from the district's three area councils informed by the local socio-economic and climatic characteristics, natural environment, agro-pastoral production systems, and institutional presence. These communities were at discrete locations in the district and had similar sizes and populations, with several institutions operating in them—state/public, private/market, and civic/civil society (Abunyewah et al. 2024).

Following the KIIs, six FGDs were conducted, with three in each community, to facilitate collective dialogues, gather diverse perspectives and assemble valuable insights from the discussants' lived experiences (Opoku Mensah et al. 2023). The discussions were open-ended, and each group consisted of 5-10 participants, including community opinion leaders like chiefs

or their representatives, assembly members, local group leaders, and heads of households. Due to the district's patriarchal nature, which often discourages women and youth from speaking freely in mixed groups (Opoku Mensah et al. 2023), participants were grouped by gender and age: men-only, women-only, and youth-only. This approach aimed to create a more comfortable environment, allowing participants to express their views and potentially highlighting any social differences in perspectives. According to Aqib et al. (2024), including underrepresented farming groups, such as women and youth, adds more nuance to understanding farmers' adaptation behaviours and ensures a more comprehensive appreciation of communities' adaptation strategies.

The principal researcher co-moderated the FGDs. Two research assistants assisted in each community, serving as co-moderators, note-takers and interpreters. Discussions were held in the local Talen and Guruni dialects, each lasting approximately three hours. They were scheduled for late afternoons after farmers had completed their daily activities to ensure maximum participation. The discussion topics, which included climate change perception and impacts, access to livelihood capitals, climate change actions and institutional interventions, were audiotaped with the consent of the participants.

After the FGDs, a preliminary questionnaire was pretested with 20 households in September 2022. Based on feedback from respondents, the questionnaire was finalised, which consisted of a set of open and closed-ended questions divided into four parts to elicit information on the heads of households': 1. socio-economic characteristics; 2. access to resources as livelihood capitals; 3. perception of climate impacts, challenges and climate change actions; and 4. institutional interventions. The survey instrument was digitised using the Open Data Kit (ODK) mobile app to enhance the quality and efficiency of data collection. ODK allowed all collected data to be verified by the principal researcher and uploaded to a secure server daily (Abunyewah et al. 2024). The finalised questionnaire was conducted with 130 agro-pastoral households, defined as those who considered crop farming as their primary source of income and owned at least five head of cattle and a herd of sheep or goats (Zampaligré et al. 2014). In addition to engaging in agro-pastoral activities, selected households must also have received climate change support from institutions. The surveys were conducted in the local dialects of Talen and Guruni and were 45-60 minutes in duration.

A systematic sampling method was employed to select participating households (Mostafa and Ahmad 2018). According to the specifications of the sample frame and inclusion criteria, 65 agro-pastoral households were selected and interviewed in each of the two communities. Thus, 130 valid questionnaires were returned for the two communities of Awaredone and Yameriga. Cochran's formula (Cochran, 1977) was used to determine the sample size needed to satisfy a 95% confidence level (z=1.96), 91% agricultural households and a 5% level of precision (α) from 14,291 total households as follows:

$$n = \frac{z^2 * p * (1-p)}{(\alpha)^2} \quad n = \frac{1.96^2 * 0.907 * (0.093)}{(0.05)^2} \quad n = 130$$

n = sample size, z = critical value of desired confidence level, p = degree of variability in the population and  $\alpha$  = desired level of precision.

Only the heads of households or household agricultural decision-makers participated in the survey in each household.

#### 4.3 Data Analysis

## 4.3.1 Quantitative data analysis

The household data was exported from the ODK server, cleaned and imported into Statistical Package for Social Science (SPSS) Statistics 28 and Microsoft Excel 2019 for analysis. Descriptive statistics (frequencies and percentages) were calculated, and a stepwise logistic regression model was employed to analyse the factors influencing farmers' adoption of climate change actions. The model's explanatory variable is dichotomous, i.e. adoption/non-adoption of a particular adaptation strategy (yes = 1, no = 0) (see Yimam and Holvoet 2023 for validation). A fundamental challenge with the stepwise regression model is that some real explanatory variables with causal effects may not be statistically significant, while nuisance variables may be coincidentally significant (Smith 2018). To overcome these issues, plausible explanatory variables that influenced the adoption of climate change actions were identified among smallholder farmers during the FGDs and key informant interviews. This approach satisfies Smith's (2018) insistence on using context-specific information and opinion in selecting the initial list of predictors in a stepwise regression model. Stepwise regression of the survey responses was then used to prune the identified plausible explanatory variables into a more

parsimonious set of the most useful predictors associated with adopting adaptation strategies. Additionally, a multivariate probit model was used to test for complementarity in adoption among the selected strategies (Gudina and Alemu 2024).

#### 4.3.2 Variable settings

The stepwise regression model has three components, which were applied additively in an order that followed the logic of farmers' adoption of climate change actions: 1. perception of risk, 2. deployment of livelihood assets, and 3. access to institutional support mechanisms. Because climate perception is a primary influence of adaptive behaviour in farmers (Grothmann and Patt 2005), their perception of meteorological parameters of precipitation, temperatures and extreme events were selected, as shown in Table 6. Key indicators representative of endowments of smallholder farmers' livelihood capitals were also identified as likely influencing adopting climate change actions (Ellis 2000). Including the livelihood capitals allowed exploration of the influence of resource availability on adaptation. The study adopted the five capitals framework human, social, natural, physical and financial—as the key components shaping a farmer's adaptive capacity (Ellis 2000). Specifically, given that adaptive capacity is contingent upon specific local conditions or contexts (Adger et al. 2004), 24 locally relevant indicators of the five capitals were included based on their current capacity to support or constrain climate adaptation as identified during the discussions (see Table 6). Also, because climate change adaptation does not occur in an 'institutional vacuum' (Agrawal 2008, p. 19), key institutional interventions influencing smallholders' adaptation behaviour were included, as identified during the discussions (Table 6). The description of the variables is shown in supplementary material 1, and the key institutional interventions are detailed in supplementary material 2.

Table 6: Identified indicators during the focus group discussions

Types	Variables
Intervention	Training and capacity building
	Technology transfer
	Input supply

	Marketing and value chain integration
Human capital	Farming experience
	Household size
	Age
	Level of education
	Gender
Social capital	Community group
	Farmer networks
	Social networks
	Access institutional support
	Access to information
Natural capital	Manage tree/forest
	Decision over farmlands
	Farmland area
	Land tenure system
	Climate variability
Physical capital	Improved agricultural practices
	Farm machinery and tools
	Communication systems
	Infrastructure
Financial capital	Secondary occupation

Value of livestock

Access to credit

Agricultural subsidy

Remittances

Climate Perception Precipitation

Temperature

Extreme events

The analysis and subsequent discussions concentrated on the sets of factors most closely associated with adopting specific adaptation strategies and focused on only the coefficients significant at P<0.01 to avoid the inclusion of coincidental correlations.

## 4.3.3 Econometric model setting

Following He et al. (2022), a stepwise regression model was used to explore the factors influencing the smallholder farmers' adoption of climate change actions. The specific functional form is:

$$prob(event) = e^z/(1 + e^z)$$

Where:  $Zi = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \dots + \beta_p x_{pi}$ , and p = number of independent variables.

The probability of an event not occurring is:

prob(noevent) = 1 - prob(event)

Transform the equation:

$$\begin{split} \frac{prob(event)}{prob(noevent)} &= e^{b_0 + b_1 x_1 + b_2 x_2 + \dots + b_p x_p} \\ ln \left[ \frac{prob(event)}{prob(noevent)} \right] &= \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \dots + \beta_p x_{pi} \end{split}$$

When there is a unit change in argument i, there is a change in the probability of the event Exp  $(\beta)$ 's occurrence.

## 4.3.4 Multicollinearity diagnosis

Multicollinearity occurs when an approximately linear relationship exists between two or more independent variables (Chan et al. 2022). A multicollinearity test using Variance Inflation Factor (VIF) and Tolerance was performed to determine if the independent variables were highly correlated. Hair et al. (2019) suggest that a VIF exceeding 4.0 and a Tolerance of less than 0.25 indicate a multicollinearity problem and are unacceptable. After analysing multicollinearity, the VIF values ranged from 1.28 to 2.58, and Tolerance levels varied between 0.39 and 0.78. These results indicate no violation of the multicollinearity assumption among the independent variables in the regression analysis.

#### 4.3.5 Qualitative data analysis

Qualitative data from six FGDs were analysed using thematic and narrative analysis (Bryman 2012). Audio recordings from the FGDs were transcribed verbatim into text, translated into English and read several times to identify and thoroughly understand the raw data (Møller et al. 2018). The texts from the FGDs were assembled and compared against the recorded audio files to understand the varying opinions within the text and to ensure the accuracy of the data (Møller et al. 2018). NVivo 14 was used to code the transcripts to identify recurrent and interconnected themes from the discussions. The thematic areas derived from the analysis (Bryman 2012) were climate change and its impacts on the district, institutional support, adoption of climate change actions and their influencing variables, including the attributes of the practice. Narrative analysis allows for the use of quotations to emphasise stories from participants, substantiate claims and illustrate the interconnections between themes (Bryman 2012). To ensure rigour and trustworthiness, participants' own words were maintained with low use of inference descriptors (Baxter and Eyles, 1997). Saturation was reached when no new information or insights emerged from the data, and previous findings started to be repeated (Miles et al. 2019).

#### 4.4 Ethics approval

The research received approval from the Human Research Ethics Committee (HREC) at the University of Technology Sydney (UTS), under approval number UTS HREC ETH22-7303.

Before administering KIIs, FGDs or questionnaires, all participants provided informed consent for their involvement.

## 4.5 Results

## 4.5.1 Smallholder farmers' climate change actions

This section focused on the climate change actions of smallholder farmers to minimise the impacts of extreme weather events and climate change. All farmers (n=130) reported adopting one or more climate change actions (Figure 12), with planting improved crop cultivars being the most common (89% of smallholder farmers) and raising more livestock being the least common (19% of smallholder farmers).

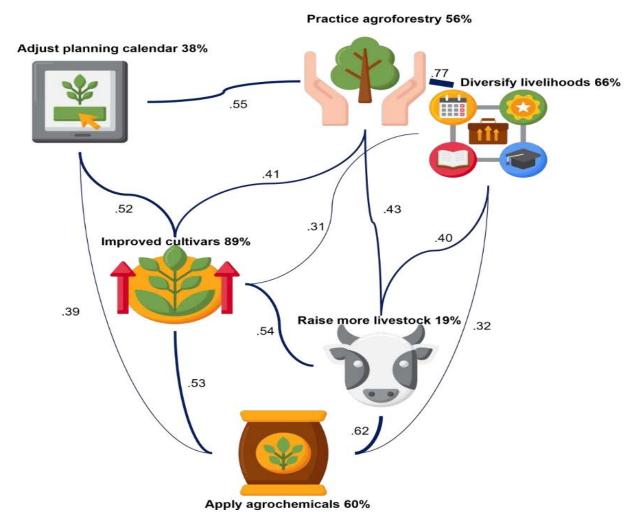


Figure 12: Infographic showing the percentage of smallholder farmers' adoption of climate change actions (icons and their %) and the complementarity (decimal correlation coefficients,

thickness of connecting lines and proximity of icons) of the six actions associated with climate change adaptation. All correlations shown were significant at P<0.01.

The results of the multivariate probit model showed that 12 of the 15 pairwise correlation coefficients were positive and significant at P=0.01 (Figure 12), indicating complementarity of adoption by the smallholder farmers among the climate change actions. The likelihood ratio test was also significant at P=0.01, indicating mutual interdependence among the multiple climate change actions. Adoption of agroforestry and livelihoods diversification were closely correlated practices (R=0.77), as were raising more livestock and applying agrochemicals (R=0.62). Planting improved cultivars was correlated (R>0.50) with agrochemical application, adjustment of the planting calendar and raising additional livestock, suggesting these actions formed a complementary 'technology package' to optimise the potential benefits of high-yield varieties.

#### 4.5.2 Factors associated with smallholder farmers' climate change actions

For the climate change actions shown in Figure 7, a stepwise regression model was used to analyse the impacts of climate perception, livelihood capitals, and institutional intervention on smallholder farmers' adoption of each action in response to climate change. The detailed estimation results for all variables influencing smallholder farmers to adopt climate change actions are shown in supplementary material 3. The pseudo R<sup>2</sup> (Table 7) increased with the addition of each variable, although the extent of the increase varied markedly among the strategies. Perception alone was weakly associated with adoption for four of the six actions, with planting improved cultivars, diversification of livelihoods, application of agrochemicals and practising agroforestry showing pseudo R<sup>2</sup> values less than 0.046. However, perception was closely associated with adjustment of the planting calendar and raising additional livestock with acceptable pseudo R<sup>2</sup> values of 0.61 and 0.75, respectively.

The addition of livelihood capitals (Model 2) and institutional interventions (Model 3) improved the model's association with the adoption of all actions, with pseudo R<sup>2</sup> values ranging from 0.289 to 0.810 and 0.324 to 0.817, respectively. The improvement in pseudo R<sup>2</sup> was greatest for strategies with the poorest fit under Model 1.

Table 7: Pseudo R<sup>2</sup> of stepwise regression models for adaptation strategies

Climate change action	Regression model			
	Model 1	Model 2	Model 3	
	Perception	Perception + capitals	Perception + capitals + interventions	
Plant improved crop cultivars	0.043	0.360	0.594	
Diversify livelihoods	0.043	0.377	0.419	
Apply agrochemicals	0.027	0.331	0.359	
Practice agroforestry	0.046	0.289	0.324	
Adjust planting calendar	0.610	0.754	0.765	
Raise more livestock	0.748	0.810	0.817	

# 4.5.3 Association of climate perception with the adoption of climate change actions

Three variables were included in the climate perception model: precipitation, temperature and extreme events (Table 8). While the model coefficients of all climate perception variables were significant at P<0.05, the adoption of adjustments to the planting calendar and raising additional livestock were most strongly associated with perceived changes in precipitation (P<0.01). The odds ratios of the coefficients indicated that smallholder farmers who perceived changes in precipitation were at least 1.5 times more likely to adopt these actions.

Table 8: Estimation results (model coefficients,  $\beta$ , and odds ratios) for the influence of Model 1 (climate perception) on the adoption of selected adaptation strategies

Perception	Statistic	Adjust planting	Raise more livestock
variable		calendar	

Precipitation	β	0.435***	0.455***
	Odds Ratio	1.545	1.576
Temperature	β	0.012***	0.004***
	Odds Ratio	1.012	0.996
Extreme events	β	0.037***	-0.011**
	Odds Ratio	1.038	0.989
	Pseudo R <sup>2</sup>	0.610	0.748

Note: \*, \*\*, \*\*\* indicate significant statistical levels of P < 0.1, P < 0.05, P < 0.01, respectively.

## 4.5.4 Association of livelihood capitals with the adoption of climate change actions

When variables associated with each of the livelihood capitals were added to climate perception in Model 2, the fit of the model improved. The pseudo R<sup>2</sup> values of Model 2 rose to above 0.30 for three climate change actions that were not closely associated with climate perception alone. As shown in Table 6, pseudo R<sup>2</sup> for the fit between livelihood capitals + perception and growing improved crop cultivars rose from 0.043 to 0.360, with diversification of livelihoods from 0.043 to 0.377 and with application of agrochemicals from 0.027 to 0.359. The addition of livelihood capitals also improved the model's fit for the adoption of planting calendar adjustment (from 0.610 to 0.754) and for increased livestock production (from 0.748 to 0.810) over Model 1 alone. Some climate change actions were influenced by a large number of complex interacting variables (e.g., planting improved crop cultivars), and others were less so (e.g., raising additional livestock). However, while the adoption of improved crop cultivars was significantly (at P<0.01) associated with eight livelihood variables, a few variables were relatively more influential on the model based on the value of the model coefficients (Table 9). More specifically, of the range of factors associated with improved cultivar adoption, access to information ( $\beta = -0.149****$ , O.R. = 0.862) and the value of livestock ( $\beta$  = 0.110\*\*\*, O.R. = 1.116) had the greatest influence. Similarly, climate variability ( $\beta = 0.224***$ , O.R. = 1.251) and secondary occupation ( $\beta =$ 0.194\*\*\*, O.R. = 1.214) were associated with the application of agrochemicals by farmers.

Climate variability was significantly associated with adoption across all climate change actions except raising additional livestock, although the values of the model coefficients were often low.

Table 9: Model coefficients ( $\beta$ ) significant at P<0.01 for associations between livelihood capital variables and adaptation strategies in Model 2.

	Climate change action					
Capital	Plant	Diversify	Apply	Adjust	Raise more	
1	improved crop	livelihoods	agrochemicals	planting	livestock	
	cultivars			calendar		
Human	Level of	Level of				
	education	education				
	(0.016)	(0.003)				
				Farming		
				experience		
				(0.054)		
Social	Social			Social		
	networks			networks		
	(0.003)			(0.024)		
	Access to					
	information					
	(-0.149)					
Natural	Land tenure					
	(-0.02)					
	Climate	Climate	Climate	Climate		
	variability	Variability	Variability	variability		

	(-0.107)	(0.009)	(0.224)	(0.060)	
	( ' ' ' ' ' ' ' ' ' ' ' ' ' ' ' ' ' ' '	(* * * * * )	(- )	(	
Physical	Infrastructure				
	(-0.052)				
Financial		Secondary	Secondary		
		occupation	occupation		
		(0.081)	(0.194)		
	Value of	Value of			Value of
	livestock	livestock			livestock
	(0.110)	(0.079)			(0.001)
	Remittances				
	(0.026)				
Total	8	4	2	3	1

## 4.5.5 Association of institutional interventions with the adoption of climate change actions

As with Model 2, when institutional interventions were added to climate perception and livelihood capitals in Model 3, the model's fit improved. The pseudo  $R^2$  values of the model rose to above 0.30 for all the climate change actions (Table 7). Variables related to institutional interventions were associated significantly (at P<0.01) with the adoption of three actions (planting improved cultivars, diversification of livelihoods and practicing agroforestry) (see supplementary material 3). Among the interventions, technology transfer ( $\beta$  = 0.141\*\*\*, O.R. = 1.151), training and capacity building ( $\beta$  = 0.239\*\*\*, O.R. = 1.270) and marketing and value chain integration ( $\beta$  = 0.262\*\*\*, O.R. = 1.300) were associated with planting improved crop cultivars, practicing agroforestry, and diversification of livelihoods respectively.

## 4.5.6 Qualitative analysis of variables associated with strategy adoption

The following section reports the analyses of qualitative information gathered from focus group discussions with smallholder farmers about climate change and its impacts on the district and how, in practice, the adoption of climate change actions was influenced by variables identified as significant in the stepwise regression models. Where there was divergence between the views expressed by men, women and youth in the study locations, these are included in the narrative analysis under their respective thematic areas.

# 4.5.6.1 Climate impacts

Across all the focus groups, farmers agreed that they were experiencing climate change and its impacts on the district. They identified drought, storms, heat waves, and flooding as the district's most typical extreme climate events. They also reported experiencing late onset, early cessation, and intense and short rainy seasons. The farmers suggested these extreme events have been more frequent over the past ten years and caused significant impacts on their agricultural production. The focus group participants indicated that the most commonly experienced climate impacts were crop failure, yield losses, decreased livestock productivity, unavailability of pasture and water scarcity. The following quote is typical of the views expressed by farmers across all FGDs:

The impacts of climate change on our agricultural activities are profound and varied. The unpredictability brought by climate change has completely disrupted our farming calendar. The future of our agriculture faces significant threats from climate change.

Awaredone men FGD

#### 4.5.6.2 Plant improved crop cultivars

Influence of livelihood capitals on the adoption of improved crop cultivars

Of the eight variables significantly associated with planting improved crop cultivars, modelling in Table 8 indicated three as most influential: access to information and climate variability (negatively correlated) and value of livestock (positively correlated). For access to information, farmers reported that despite the promise of improved crop cultivars, accessing reliable information on utilising them in local farming systems was challenging. Farmers indicated they

heard about new varieties through radio broadcasts and occasional institutional workshops. However, detailed guidance on cultivation practices, soil requirements, and pest management was often missing or too generic. This lack of precise information led some farmers to use inappropriate agronomic practices for improved cultivars and limited their performance under local conditions. Farmers described the lack of appropriate agronomic advice as a missed opportunity to enhance their productivity, as summarised by a young farmer in Awaredone:

As eager as I am to adopt improved agricultural practices, conflicting advice and information have marred my experience. With so many institutions promoting different ideas, it has become complicated to discern which options suit our local environment.

## Awaredone youth FGD

Regarding climate variability, smallholder farmers reported that erratic rainfall patterns and prolonged droughts severely impacted their ability to plant improved crop cultivars. The changing climate made planning and investing in these new cultivars increasingly difficult and increased the risk of heavy losses. A farmer in Awaredone explained:

With the increasing unpredictability of our climate, each planting season feels like a gamble. The improved crop cultivars... have not been able to withstand the sudden extreme weather events we now face.

#### Awaredone men FGD

Raising livestock alongside crops was considered an integral part of agricultural practices in the district. Farmers suggested livestock in the Talensi district were critical as a stepping stone towards a diversified and sustainable agricultural livelihood that enabled them to navigate the challenges of modern farming with greater confidence. As the quote below shows, farmers reported that livestock sales, particularly under poor seasonal conditions, provided them with the necessary capital to invest in innovative agricultural technologies. Additionally, they recognised that manure from livestock provided organic fertiliser and enhanced the sustainability of their farms.

By managing and selling part of my herd, I have invested in small-scale beekeeping and vegetable gardening, which provides products and income year-round, unlike the seasonal limitations of traditional crops.

## Yamergia youth FGD

Other livelihood variables associated with adopting improved crop cultivars included level of education, social networks, land tenure, infrastructure and remittances (Table 9; refer to supplementary material 4 for quotes). Farmers reported that completion of a higher level of education empowered them with the skills to critically assess new agricultural innovations and seamlessly integrate them into their farming operations, substantially improving productivity and profitability. Farmers indicated that social connections with fellow farmers were crucial in the district, where tradition often dictates the flow of knowledge and resources. They frequently accessed gatherings where older, more experienced farmers shared their wisdom. Learning from their successes and failures gave the farmers confidence to try innovative farming practices, such as planting new crop varieties.

Uncertainty surrounding land tenure affected all smallholder farmers, but security for men appeared marginally better than for women and youth, who were often relegated to relatively less productive areas. The fear of losing land through unexpected land ownership claims or disputes made investments in improved crop cultivars too risky for many farmers, which stifled innovation and kept the farmers tied to traditional crops that were less productive. Farmers expressed concern that their communities lacked infrastructure, such as functional irrigation systems to store and distribute water effectively, to take full advantage of improved crop cultivars. Furthermore, they questioned their communities' capacity to support sustainable agricultural advancements under current infrastructure constraints. Remittances appeared to play a critical role in enhancing the agricultural practices of smallholder farmers. Farmers suggested remittances provided the financial means required to adopt improved crop varieties successfully.

*Influence of institutional interventions on adoption of improved crop cultivars* 

The modelling of the four institutional intervention variables indicated that only technology transfer was influential in adopting improved crop cultivars. Farmers felt it was critical to ensure

they had the necessary skills and resources for successful adoption. A man in Awaredone revealed:

Benefitting from the supply of small-scale farming machinery was a turning point for me. Access to this machinery significantly reduces the labour intensity, time required for farming and investment in improved cultivars. They enable me to cultivate larger [areas of] farmland more efficiently.

Awaredone men FGD

## 4.5.6.3 Diversify livelihoods

Influence of livelihood capitals on the adoption of livelihood diversification

Table 9 shows that four variables (level of education, climate variability, secondary occupation and value of livestock) were significantly associated with diversifying livelihoods. However, the values of the model coefficients were often small (refer to supplementary material 4 for quotes). Farmers revealed that completion of a higher level of education enabled them to secure employment with stable incomes, part of which they dedicated to diversifying their livelihoods away from solely relying on agriculture. They reported that such practices catalysed change and enabled them to transform their households' economic landscape. The farmers revealed that climate variability has made it clear that relying solely on agriculture was no longer viable. This reality pushed them to diversify into agro-processing, such as shea butter, groundnut and Parkia biglobosa/African locust bean (Dawadawa in the local language), which provided a stable income even in poor agricultural seasons.

Farmers also expressed that having a secondary occupation alongside agriculture highlighted the importance of 'not putting all of one's eggs in one basket' because it increased their incomes and reduced the risks associated with crop failures. The value of livestock was also significantly associated with the adoption of livelihood diversification. Farmers indicated that raising livestock was a cornerstone of their livelihood for generations and had significantly empowered them to diversify beyond traditional crop farming. The farmers believed that income from selling livestock, particularly before crops were ready for harvest, provided them a crucial financial buffer.

Influence of institutional interventions on the adoption of livelihood diversification

Marketing and value chain integration was associated with the adoption of livelihood diversification. Farmers reported that when institutions—state/public, private/market, and civic/civil society—support them with marketing and value chain integration interventions (see supplementary material 2), it enhanced their marketing skills and gave them the confidence to innovate and expand into new areas. They suggested that their understanding of market dynamics and integration into agricultural value chains shifted their approach to farming. A farmer commented:

The support I received from an agricultural development programme in improving access to markets and integrating us into value chains was decisive. With the training and connections I received, I ventured into processing my produce, starting with small-scale groundnut oil extraction.

Yameriga women FGD

4.5.6.4 Apply agrochemicals

Influence of livelihood capitals on the adoption of agrochemical application

Livelihood capital indicators significantly associated with agrochemical applications were climate variability and secondary occupation, and the model coefficients for these variables were relatively large (Table 9). For climate variability, the farmers reported that managing risks associated with adverse climatic conditions, such as increased temperatures, irregular rainfall patterns, and extreme climate events on their crop health and productivity, influenced them to apply agrochemicals. During the discussions, a farmer reported:

Unpredictable rainfall and increasing temperatures stress our crops and encourage the spread of pests, weeds and diseases. I have turned to agrochemicals as a crucial part of my farming strategy to combat these issues and secure my harvests.

Yameriga women FGD

Furthermore, secondary occupations provided farmers with the financial means to purchase agrochemicals. They revealed that the time constraints imposed by their engagement in

secondary occupations led them to rely more on agrochemicals to ensure crop productivity with limited labour input. A farmer commented:

With an additional job as a mechanic, I find myself pressed for time. This situation pushes me to use agrochemicals to ensure my crops stay healthy and productive. It is quicker and requires less labour to manage pests, diseases, and soil fertility.

Awaredone youth FGD

# 4.5.6.5 Practicing agroforestry

Influence of institutional interventions on the adoption of agroforestry practices

Training and capacity building were associated with the adoption of agroforestry practices. This intervention reportedly gave farmers the essential knowledge and skills to integrate trees with crops and livestock, directly benefiting their farmlands and livelihoods. These benefits ultimately encouraged the widespread adoption of agroforestry. During the discussions, a smallholder farmer stated:

A capacity-building workshop on sustainable agriculture I attended was my turning point. Learning about natural regeneration techniques and their benefits motivated me to integrate tree planting into my farming operations.

Yameriga youth FGD

# 4.5.6.6 Planting calendar adjustment

Influence of climate perception on the adoption of planting calendar adjustment

Modelling indicated the perception of changes in precipitation as the most influential variable associated with the adjustment of the planting calendar (cf. Table 8). Farmers suggested this was a practice change borne out of observation and necessity. They adjusted the planting calendar to the sporadic and unpredictable rainfall to ensure the productivity of their farms and safeguard their livelihoods. The discussions in Yameriga revealed:

The constant changes in rainfall have made me rethink my entire farming schedule. With rainfall becoming more unreliable, I have adjusted by splitting my planting into two

phases. This approach allows me to mitigate the risk of total crop failure due to either early droughts or late floods.

## Yameriga women FGD

Although not significant in the modelling, farmers reported their perception of changes in temperature and extreme events also influenced planting calendar and agricultural activities in general (refer to supplementary material 4 for quotes). The farmers indicated that rising temperatures have drastically affected their traditional farming calendar. They noted that excessive heat stressed young seedlings if planted at the usual time, leading to poor germination rates. Furthermore, they reported that increasing frequency and intensity of extreme weather phenomena—ranging from prolonged droughts to flooding—posed substantial challenges to their traditional farming routines. They were, therefore, increasingly challenged to adjust their planting calendar to secure their production and livelihoods.

## Influence of livelihood capitals on the adoption of planting calendar adjustment

Farming experience, social networks and climate variability were significantly associated with planting calendar adjustment (Table 9). However, the values of the model coefficients were often small (refer to supplementary material 4 for quotes). For farming experience, some smallholders reported that they had accumulated knowledge over the years regarding local weather patterns, soil conditions, and crop behaviour that enabled them to make informed decisions about the optimal times for planting to avoid adverse weather events and ensure crop success. Moreover, they revealed that experienced farmers often served as informal community advisors and shared their insights and successful strategies with less experienced neighbours. Farmers suggested that social networks were vital for disseminating information and shared experiences. They stated that these networks facilitated the exchange of knowledge about optimal planting times and strategies to adapt to changing weather patterns and climate variability. Farmers revealed that the trust built within these networks ensured that advice and experiences shared were taken seriously and considered valuable. Farmers reiterated that climate variability has made farming more challenging than it used to be. They revealed that changing rainfall patterns and unexpected dry spells in recent years forced them to rethink the traditional planting times they had followed for generations.

#### 4.5.6.7 Raise additional livestock

Influence of climate perception on the adoption of additional livestock raising

Perception of changes in precipitation was the most influential variable associated with raising more livestock (Table 8). Farmers reported additional livestock buffered against crop failure due to erratic rainfall. Also, when precipitation was favourable, it supported both crop and livestock health and productivity. Farmers explained that when there was adequate rainfall, they offered crops and crop residues as feed for livestock, while livestock provided manure to improve soil fertility. Some farmers who own draught animals said they used them to prepare farmlands and transport goods. A farmer noted:

The seasons when we receive ample rainfall are a blessing for our crops and the natural growth of fodder for livestock. With lush and green fields, I easily graze my livestock extensively, which leads to better health, weight gain and better selling prices.

Yameriga women FGD

Perception of temperature changes was also associated with raising more livestock, although the value of the model coefficient was small (refer to supplementary material 4 for quotes). Rising temperatures affected the viability and productivity of crop farming, and livestock offered a more complementary and sustainable agricultural practice and livelihood strategy. Farmers stated that livestock were more tolerant of higher temperatures, which made them a more reliable source of income, food and livelihood security. They reported that livestock production was a form of savings or insurance they liquidated in times of need, providing a more flexible asset, as livestock could be sold or traded to meet immediate financial needs and buffer against climate uncertainties.

Influence of livelihood capitals on the adoption of additional livestock raising

The value of livestock was significantly associated with raising more livestock (Table 9). However, the value of the model coefficient was small (refer to supplementary material 4 for quotes). During the discussions, farmers indicated that livestock was a critical source of income, food, livelihood security, and a symbol of wealth and socio-cultural status in the Talensi district. They explained that this multifaceted value of livestock enhanced its attractiveness as an

investment and drove them to invest in livestock as a sustainable and beneficial agricultural practice.

# 4.5.6.8 Other factors influencing the adoption of climate change actions

In addition to how, in practice, the adoption of climate change actions was influenced by variables identified as significant in the stepwise regression models, the supplementary analysis showed that the attributes of the climate change actions also influenced their adoption. The results indicated that farmers would mostly check for the benefits of climate change actions before adopting them (relative advantage). The results also revealed that the farmers often rejected climate change actions that undermined their agency by insisting on practices contrary to what they were comfortable with (compatibility). Such actions were mostly described as difficult for them to understand, implement, and sustain effectively. Farmers favoured climate change actions with proven benefits, visible results (observability) and ease of implementation (complexity). For example, as part of adopting improved crop cultivars, which is the most common action among smallholder farmers (cf. Figure 7), all FGDs reported that even though they are faced with climate change and variability, adopting improved cultivars had visible benefits, such as noticeable increases in productivity and improved resistance to pest and diseases. Furthermore, they indicated that they could test these cultivars on a small scale without significant risk, encouraging them to experiment and enhancing adoption rates (trialability). They added that they observed these advantages in early adopters' farms, significantly boosting adoption among most farmers. The quote below captured a typical view expressed by farmers across all FGDs of how the benefits and ease of integration of improved cultivars influenced their widespread adoption:

Seeing my neighbour's success with the improved cultivars made me want to try them, too. The difference in their crops was clear and impressive. I am enjoying the same now.

Awaredone men FGD

Similarly, smallholder farmers across all the focus groups adopted agroforestry because it was a comparatively accessible and inexpensive way to increase crop yields and livestock production and improve incomes. They added that their agroforestry practices incorporated the natural regeneration of tree species, which was compatible with their traditional farming practices and

easily integrated into existing farming systems. The quote below captured a typical view expressed in FGDs:

With Farmer Managed Natural Regeneration [FMNR] [natural regeneration practice], I have seen first-hand how my farmland has recovered... It fits right into our existing farming practices and does not require us to change how we farm much. I tried it out easily and saw the benefits without much risk.

Yameriga youth FGD

#### 4.6 Discussion

The farming communities of Talensi district, in common with smallholder farmers worldwide, are vulnerable to climate stressors because they are exposed to environmental threats and uncertainties and rely on climate-sensitive rain-fed agricultural systems (FAO and AU 2022). The farmers in this study agreed they were experiencing climate change and identified drought, storms, heat waves, and flooding as the district's most typical extreme climate events. The impacts of these events included crop failure, yield losses, decreased livestock productivity, unavailability of pasture and water scarcity. Exposure to these impacts reduced agricultural production and threatened livelihoods, driving farmers in the Talensi district to seek innovative practices to reduce their vulnerability (Gudina and Alemu 2024; Hanly and McDowell 2025). The study identified the popularity of a range of climate change actions as changes in farming practices, the existence of complementary adoption of multiple actions and the rationales explaining practice adoption. All farmers adopted one or more climate change actions, which included (from most to least common, Figure ) planting improved crop cultivars, livelihood diversification, application of agrochemicals, practising agroforestry, planting calendar adjustments, and raising additional livestock.

In keeping with previous studies (e.g. Gudina and Alemu, 2024), the farmers' climate change actions were not mutually exclusive; they generally adopted multiple actions, providing evidence of complementarity among practices (Figure 12). The farmers' choices of climate change actions are consistent with those identified under Climate-Smart Agriculture (CSA)—an overarching approach to marrying adaptation and mitigation strategies with food production (FAO 2017). According to Rodríguez-Barillas et al. (2024), CSA practices, including agroforestry, new

varieties and agrochemicals, are integrated within an agricultural system across multiple scales. The climate change actions identified by the farmers in this study addressed at least two pillars of CSA, i.e., adaptation and increasing productivity. For example, adopting improved crop cultivars is associated with drought resistance, improved yields, and pest and disease resistance (Cishahayo et al. 2023). Senyolo et al. (2018) also found that while adopting improved crop cultivars is not expected to have a direct mitigating effect, their adoption allows for harvesting even in adverse conditions and supports farmers in dealing with dry spells and adapting to rain shortfall.

The farmers' choices of climate change actions consistent with those identified under CSA can produce complementary outcomes by carefully integrating multiple practices that reinforce one another (Barrett et al. 2020). The qualitative data analysis identified farmers' reasons for complementarity in practice adoption. For example, adopting improved crop cultivars was most often accompanied by the application of agrochemicals and adjusting planting calendars to optimise the potential benefits of these high-yield varieties. It was also often accompanied by raising more livestock to diversify agricultural and livelihood practices to manage risks and promote diversified and sustainable farming systems. The farmers reported that adopting improved cultivars means precision with their farming techniques. This precision is important because improved cultivars generally require specific management practices, such as targeted agrochemical applications, to maximise yield potentials and protect against pests and diseases. They also adjusted their planting calendar to align planting times with expected weather patterns, mitigating risks from unpredictable climate variations to enhance growth conditions and productivity (Asante et al. 2024). Additionally, these farmers often raised more livestock to diversify their agricultural practices, which helped them manage risks and enhance soil fertility through natural manures, thereby supporting their crop cultivation (Geda et al. 2024). With insights into the adaptation practices of smallholder farmers, understanding local adaptation contexts can ultimately inform farmer-led adaptation policies to empower smallholder farmers to adapt more effectively through the promotion of 'packages' of complementary technologies (Alvarez Carrillo et al. 2022, p. 378).

Importantly, these decisions to adopt multiple and varied adaptation options reflect not only technical responses to climate risks but also the active exercise of the smallholder farmers'

agency. Here, agency is the capacity of individuals or groups to exercise control and take actions that influence their lives and circumstances (Sen, 1985; 2000; Quarshie et al., 2023) and provide meaningful input into governance processes (Clapp et al., 2022). Lindegaard & Sen (2022, p. 1) call for the need to recognise local actors' agency in "adaptation-related policy, practice, and decision-making, underlining the importance of attention to participation, representation, and influence". The importance of local actors' agency in shaping agricultural and food production systems is emphasised by experts in development and food systems sustainability (Toledo-Hernández et al., 2021). Rather than following a rigid or externally imposed set of instructions, farmers demonstrated the capacity to assess their changing conditions, weigh their options, and strategically select, combine, and adjust practices to suit their unique realities. Their decisions were not arbitrary; they were grounded in lived experience, observations of local climate patterns, and an evolving understanding of what works in their specific agro-ecological and socio-economic context.

The choice of diverse and complementary adaptation strategies among smallholder farmers reflects their everyday adaptation practices, which is a function of their agency and intentionality—both of which are considered central to promoting sustainable climate change adaptation (Lindegaard & Sen, 2022). Moreover, the use of multiple and varied adaptation options underscores that these farmers possess the agency to make informed choices and implement context-specific strategies over time (Quarshie et al., 2023). For instance, the decision to combine improved crop cultivars with precise agrochemical application and adjusted planting calendars illustrates a level of intentionality and experimentation that goes beyond simple compliance with recommended practices. These are adaptive strategies shaped by farmers' priorities—whether ensuring food security, managing risk, or sustaining soil health. In many cases, this process also involved informal learning through trial and error, knowledge-sharing within community networks, and reflections on past outcomes. Such forms of local knowledge and innovation are rarely captured in formal adaptation frameworks, yet they are central to how farmers assert control over their farming systems.

By choosing and customising climate actions, smallholder farmers asserted agency over how they respond to climate pressures. Even under constraints like limited resources, unpredictable weather, or fragmented institutional support, farmers found room to manoeuvre—to reallocate

labour, experiment with new crops, shift the timing of their activities, or diversify into livestock. These are expressions of agency that reveal farmers as active decision-makers rather than passive victims of climate change. Recognising and supporting this agency is essential. When adaptation strategies build on farmers' logic, experience, and aspirations, they are more likely to be adopted, sustained, and refined over time. This also suggests that policy and programmatic interventions should not merely deliver solutions but rather create space for farmers to shape and negotiate those solutions on their terms. In this way, climate adaptation becomes not just a response to risk but a process through which farmers assert their right to define what adaptation looks like in their own lives. Recognising the agency of local actors in climate adaptation practices helps prevent maladaptation and enables them to express their intentionality, self-determination and political will in shaping their everyday adaptation choices (Rahman & Hickey, 2019; Lindegaard & Sen, 2022).

Informed by the 'real-world' mobilisation of adaptive capacity through the application of a stepwise regression model, the study found that some climate change actions were influenced by a large number of complex interacting variables (e.g., planting improved crop cultivars), and others were less so (e.g., raising additional livestock). A few variables were relatively more influential on the model based on the value of the model coefficients. These variables were informed by the smallholder farmers' climate perception (Grothmann and Patt, 2005), livelihood capitals (Ellis 2000), and institutional interventions (Agrawal 2010) that significantly influence farmers' adoption of climate change actions. Farmers perceive and evaluate particular risks or opportunities (climate change appraisal/adaptation intention) and then evaluate their capability to deal with them (adaptation appraisal) (Grothmann and Patt 2005). While these processes are important steps in adaptation, farmers frequently fail to implement their intentions as changes in behaviour. Access to institutional support may be an important factor contributing to the realisation of their intentions because farmers' assessments of their adaptive capacities are normally partly realistic; institutional support can directly determine their adaptation (Grothmann and Patt 2005; Puig et al. 2025).

Relative to farmers' perceptual and socio-cognitive processes, adapting to climate change encompasses their decision-making behaviours, and their perception is important in influencing their adaptation strategies (Grothmann and Patt, 2005). In this study, the smallholder farmers'

adoption of adjustments to the planting calendar and raising additional livestock were most strongly associated with their climate perceptions of meteorological parameters, including temperatures, extreme climate events and particularly precipitation. The integrated crop-livestock farming systems in the Talensi district are highly climate-dependent and mainly rainfed. Any changes in rainfall patterns, amounts and timing significantly impacted their agricultural activities. Therefore, it was evident that any perceived changes in these meteorological variables drove their adaptation intentions and behaviours. Other studies have emphasised how farmers' perception of increasing temperatures and extreme climate events threaten their farming systems and livelihoods and shape their choice of and willingness to implement climate change actions, such as raising more livestock (He et al. 2022). Understanding the climate perceptions of farmers, especially those particularly vulnerable to climate change, and how these perceptions relate to their adaptation intentions and behaviours is crucial in having a deeper consideration of the emotional and cognitive factors that may shape farmers' decision-making processes when developing policies and strategies to obviate climate impacts on agricultural production and productivity.

Adaptation can vary significantly from farmer to farmer, depending on their capabilities and needs (Cishahayo et al. 2023). When farmers are exposed to various weather and climatic stressors, their vulnerability depends on their capacity to adapt to them (Tong et al. 2024). Therefore, livelihood capitals are important factors that shape farmers' adaptation decisions, and the findings of this study align with those observations. Specifically, the study found that climate variability (natural capital) was significantly associated with the adoption of all actions except raising additional livestock. Its prominence indicates that climate change, by altering weather patterns, directly encourages farmers to diversify their production systems by adopting practices more suited to the variability in precipitation and temperature stresses (Gudina and Alemu 2024). Other factors that influenced the adoption were access to information, the value of livestock, and secondary occupation. The farmers reported that despite the promise of improved crop cultivars, accessing reliable information on utilising them in their local farming systems was often missing, too generic, challenging or conflicting, which they described as a missed opportunity to enhance their productivity. Adeagbo et al. (2023) confirmed that access to timely, accessible and comprehensible climate-related information makes smallholder farmers responsible and proactive in farm-level investment decision-making.

The smallholder farmers expressed that having a secondary occupation alongside agriculture was a testament to the power of livelihood diversification. They revealed that having multiple sources of income provided them with greater access to personal wealth, which they utilised to enhance their farming operations and adopt climate change actions (Nyantakyi-Frimpong 2017; Ndiwa et al. 2024), such as purchasing agrochemicals. Such farmers have autonomy in decision-making and show substantially greater persistence in adaptation (Corral et al. 2020). This study, in contrast to Mulwa et al. (2017), found that the value of livestock influenced farmers' decision to adopt climate change actions such as plant improved crop cultivars, diversify livelihoods, and raise more livestock. The farmers suggested livestock holding has a critical role as a stepping stone towards a diversified and sustainable agricultural livelihood that enabled them to navigate the challenges of modern farming with greater confidence.

Other variables that influenced adoption but whose model coefficient values were relatively small for all climate change actions included educational status, farming experience, social networks, land tenure, infrastructure and remittances (see Table 5). For example, the study observed that farmers' experience supported their accumulation of knowledge regarding local weather patterns, soil conditions, and crop behaviour, which enabled them to make informed adaptation decisions. Such farmers were adept at recognising subtle signs of changing climate conditions, necessitating adaptation intentions and behaviours. Geda et al. (2024) emphasised the importance of farmers' experience in their climate change actions. Recent research has demonstrated the importance of infrastructure, such as irrigation systems, storage facilities and access roads, in supporting smallholder farmers in adopting adaptation actions (Rathnayaka et al. 2023).

However, the farmers in this study expressed concern that their communities lacked the infrastructure, specifically for irrigation, to take full advantage of improved crop cultivars and questioned their communities' capacity to support sustainable agricultural advancements under current infrastructure constraints. Land tenure security has been linked to smallholder farmers' adoption of improved practices (Asante et al. 2024). However, the uncertainty surrounding land tenure and fear of losing land through unexpected claims or disputes, as this study found, made farmers' investment in improved crop cultivars too risky for many of them. The findings of this study suggest the need to implement context-specific and targeted interventions that address the

environmental impacts of climate change and variability and consider the indicators of the livelihood capitals which influence the adaptive intentions and behaviours of farmers.

Adaptation strategies are embedded in heterogeneous social and institutional conditions that have ramifications for their use (Agrawal 2010). In this study, specific institutional interventions that the smallholder farmers received impacted their choice and use of climate change actions. These findings confirm the central role of institutions in undertaking purposeful actions to address the actual or potential climate impacts, mitigate risks and promote climate adaptation strategies (Agrawal 2010). For example, similar to recent studies (e.g. Gudina and Alemu 2024), the analysis showed that training and capacity building by institutions provided Talensi district's farmers with essential knowledge and skills to utilise climate-smart technologies such as FMNR (Opoku Mensah et al. 2024). Development agencies in Africa have extensively promoted FMNR to improve agro-ecological sustainability and diversify farm livelihoods through the natural regeneration and integration of trees with crops and livestock (Francis et al. 2015).

Similarly, institutions promoting technology transfer played a pivotal role in climate change actions in the Talensi district by facilitating access to advanced agricultural technologies and practices (Tangonyire and Akuriba 2021). They transferred new technologies, such as improved crop cultivars and other small-scale farming machinery and their spare parts. The transfer of such technologies enables farmers to adapt to climate impacts and increase productivity sustainably (Tong et al. 2024). In congruence with Darge et al. (2023), the analysis revealed that when institutions promoted marketing and value chain integration, it enhanced farmers' understanding of market dynamics and integration into agricultural value chains and gave them the confidence to innovate and expand into new areas such as agro-processing.

These findings align with He et al. (2022), who reported the direct effect of institutional interventions in supporting farmers' adaptation intentions and behaviour. Many adaptation strategies are typically complex, costly, and unaffordable for smallholder farmers without strong institutional support. Therefore, institutions must provide the necessary infrastructure, policies, and regulations to support sustainable climate change actions. Moreover, these interventions must ensure that climate concerns are integrated into decision-making processes, highlighting the shared responsibility for sustainable agricultural development (Aqib et al. 2024).

In addition to how, in practice, the adoption of climate change actions was influenced variously by perception, livelihood capitals and institutional interventions, several distinctive characteristics of smallholder agriculture affect agricultural adoption in developing countries and have relevance for climate change adaptation actions (Llewellyn and Brown 2020; Matos 2025). For example, the attributes of practices—relative advantage, complexity, compatibility, trialability and observability—can influence the extent of adoption (Rogers 2003). In this study, the compatibility of climate change actions with existing farming practices played a crucial role in their adoption. Actions that seamlessly integrated into farmers' daily lives and routines without demanding significant changes to traditional methods (e.g., FMNR as part of adopting agroforestry) were accepted and sustained FMNR (Opoku Mensah et al. 2024; Yiridomoh et al. 2025). Typically, farmers promote FMNR through pruning, mulching and protection. Since planting trees is not required, FMNR is comparatively cheap and accessible, with a higher tree survival rate because species regenerate naturally and are locally adapted (Rinaudo et al. 2021). Such alignment with local norms and practices reduces resistance, as farmers are more comfortable with and confident in actions that reflect their established ways of farming and living (Fu and Huang 2024; Suuk et al. 2025).

#### 4.7 Conclusion, policy and practical implications

This study utilised primary data from 130 smallholder farmers and six focus groups in one of Ghana's climate change hotspots—the Talensi district, to analyse the factors influencing their adoption of climate change actions to obviate the impacts of climate change and variability on their agricultural production and productivity. The study adopted a combination of quantitative stepwise regression modelling and qualitative thematic and narrative analysis of discussions with farmers to identify the statistical associations between model variables and the adoption of climate change actions and explain the smallholder farmers' behaviours. The study found that the smallholder farmers in the Talensi district were highly vulnerable to environmental threats and uncertainties, including drought, storms, heat waves, and flooding. Accordingly, all farmers adopted one or more climate change actions in response to seasonal and climatic variations. The farmers' choices of climate change actions were not mutually exclusive, but they generally adopted multiple actions. The results of the multivariate probit model showed that 12 of the 15 pairwise correlation coefficients were positive and significant at P=0.01, indicating

complementarity of adoption. These cross-correlations among climate change actions have significant policy implications. Specifically, a policy change affecting one action might have spillover effects on the adoption of other actions (Gudina and Alemu 2024). Understanding these interactions is key to developing appropriate packages of climate change actions tailored to specific areas to intensify adoption and minimise climate risks to agricultural productivity.

The use of the stepwise regression model reflected, albeit in a simplified form, the 'real-world' mobilisation of adaptive capacity. It revealed that smallholder farmers' climate perception, livelihood capitals, and institutional interventions significantly influenced their adoption of climate change actions. Importantly, the analysis also highlighted how farmers combine multiple practices in complementary ways to manage risk and enhance productivity. While the study did not analyse the technical attributes of each action in depth, in keeping with the contemporary understanding of farmers' adoption of agricultural innovations (Llewelyn and Brown 2020; Matos 2025), it acknowledged that such attributes of the climate change actions remain influential in shaping adoption decisions. These findings are relevant for informing policies that support the integration of complementary adaptation strategies while addressing the cognitive, emotional, livelihood, institutional, and practical factors that influence the adoption of climate change actions in the Talensi district.

Agricultural policymakers, development practitioners, and decision-makers at different institutional levels must intensify their efforts to promote context-specific and targeted climate change actions through policy interventions that effectively transform agricultural systems to enhance sustainable agricultural productivity. It is critical to ensure that efforts to promote the adoption of climate change actions enhance farmers' awareness and understanding of climate risks and opportunities. These efforts should include providing smallholder farmers with timely, accessible and comprehensible climate-related information while appreciating their available livelihood capitals and institutional support—to reduce their vulnerability—as well as the potential benefits of adopting various climate change actions in a holistic and integrated approach. The insights in this study provide a starting point and a solid foundation for further research to inform rural development policies that identify and promote climate change actions to enhance the sustainability of smallholder farming in semi-arid regions.

#### **Chapter Five**

# The role of intersectionality in shaping adaptive capacity of smallholder farmers in the Talensi district of Ghana

Chapter five is published as an article in *Climate and Development*. The paper answers research question 2: What role does intersectionality play in shaping adaptive capacity of smallholder farmers?, and its sub-research questions:

- i. How do indicators of smallholder farmers' stocks of capital and other socio-demographic characteristics intersect to either support or constrain their climate adaptation efforts?
- ii. What smallholder farmers' narratives about their lived experience provide insight into social categories and their intersections?

This chapter examines how these intersecting factors shape farmers' adaptive capacities, influencing their ability to respond to climate variability, extreme weather events, and long-term climatic shifts. Using a mixed-methods approach—including survey data from 130 smallholder farmers, focus group discussions, and narrative analysis—this study explores how livelihood capitals either enable or constrain adaptation based on socio-demographic characteristics such as gender, age, and education.

Table 10: Statement of authorship for chapter five

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First co-author	Brent Jacobs						
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### Climate and Development



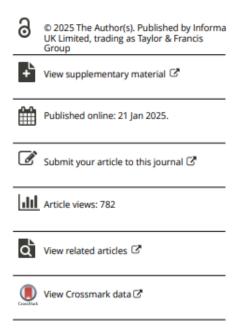
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### The role of intersectionality in shaping adaptive capacity of smallholder farmers in the Talensi district of Ghana

#### Seth Opoku Mensah, Brent Jacobs & Rebecca Cunningham

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#### RESEARCH ARTICLE



#### The role of intersectionality in shaping adaptive capacity of smallholder farmers in the Talensi district of Ghana

Seth Opoku Mensah 60°, Brent Jacobs 60° and Rebecca Cunningham 60° a,b

<sup>a</sup>Institute for Sustainable Futures, University of Technology Sydney, Sydney, Australia; <sup>b</sup>The Climate Risk Group, Newcastle, Australia

In the Talensi district of Ghana, smallholder farmers adapt to climate change—including variability, extreme weather events, and long-term temperature shifts—in varied and unequal ways. This study delves into the intersectional nature of this inequality. Specifically, it explores how the sociodemographics of these smallholder farmers intersect with their livelihood capitals, shaping their capacity for climate adaptation. Drawing from a systematic random sample of 130 smallholder farmers and six focus group discussions and employing descriptive and inferential statistics and narrative analysis, the research unpacks how livelihood capital indicators intersect with these farmers' sociodemographics, either supporting or constraining their climate adaptation efforts. The findings underscore how socio-demographic identities and livelihood resources result in unequal adaptive capacities and opportunities within heterogeneous communities. This research enriches the intersectionality literature, advocating for an intersectional approach to vulnerability studies. Such an approach can yield a deeper insight into vulnerability, allowing researchers to identify and understand vulnerable groups more precisely. An intersectionality approach is essential to avoid overshadowing complex local realities, which could inadvertently neglect the needs of many individuals and exacerbate existing vulnerabilities.

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#### 1. Introduction

Agricultural systems across the globe are invariably confronted with climate change impacts (Abdollahzadeh et al., 2023). Extreme weather affects every aspect of agriculture and the local communities dependent on it for their livelihoods (United Nations Framework Convention on Climate Change [UNFCCC, 2023]). Climate change undermines agriculture because of its susceptibility to climate-related hazards such as rainfall variability, seasonal temperature changes, and extreme events. While climate threats are global, Africa remains the most affected region (Epule et al., 2023; Intergovernmental Panel on Climate Change [IPCC], 2022). In particular, Sub-Saharan African (SSA) countries face heightened vulnerability due to their reliance on rain-fed agriculture systems, smallholder farmers for local food production and the slow implementation of adaptation actions (Campbell et al., 2023). The vulnerability of the agriculture sector in SSA is severe and will likely increase, given its high exposure and sensitivity and limited adaptive capacity, coupled with persistent poverty and limited infrastructure development (UNFCCC, 2023). In recent years, SSA has been hit by extreme weather and climate events, including more unpredictable rainfall patterns, extended dry periods, and shorter crop-growing seasons (Food and Agriculture Organization [FAO], 2022).

Scholars emphasise that the negative impacts of climate change on agricultural production can be mitigated through

appropriate adaptation strategies. While significant research has been conducted on adaptation pathways in other parts of the world (e.g. Burnham & Ma, 2018; Kim & Shin, 2024), most existing research across Africa has primarily overlooked the pathways to building the adaptive capacity of rural communities (Epule et al., 2023). The success of adaptation options depends on the capacity to plan, design and implement them. Therefore, understanding adaptive capacity is critical to effectively respond to climate change (Elrick-Barr et al., 2022). Given that the practical structures of agricultural production in rural communities are built upon farming systems, enhancing their adaptive capacity to climate change is crucial in safeguarding farm household livelihoods and providing the necessary information to design effective adaptation interventions and policies (Abdollahzadeh et al., 2023). However, adaptation actions must be contextually relevant because capacity may be locally constrained or enabled by various socio-demographic characteristics and heterogeneous biophysical, socio-economic and cultural elements (Smit & Wandel, 2006). While examples of wide-scale capacity assessments abound (Abdollahzadeh et al., 2023), local scale assessments of adaptation in agricultural systems are less common but necessary to inform practice-relevant studies (Abdul-Razak & Kruse, 2017). Consequently, adaptive capacity analysis of agricultural systems becomes imperative in initiating effective adaptation strategies (Abdollahzadeh et al., 2023).

CONTACT Seth Opoku Mensah 🔯 seth.opokumensah@student.uts.edu.au 🕝 Institute for Sustainable Futures, University of Technology Sydney, Sydney, Australia Supplemental data for this article can be accessed online at https://doi.org/10.1080/17565529.2025.2453569.

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Adaptive capacity (AC) is the ability of humans, systems, institutions, and other organisms to adjust to potential damages, take advantage of opportunities, or respond to consequences (IPCC, 2022). AC is an integral, positive component of vulnerability (Elrick-Barr et al., 2022). It reduces a system's vulnerability and draws on the foundational asset base from which investments and actions in adaptation can emerge (Adger & Vincent, 2005). High levels of AC are a precondition that enables successful adaptation and community resilience to climate impacts (Smit & Wandel, 2006). For farmers in this study, AC was defined as the stock of various resources (or capitals) and the processes that allow those resources to be deployed in pursuit of adaptation (i.e. an enabling environment) to achieve sustainable rural livelihoods (Smit & Wandel, 2006). If adaptation is indeed local and contextual (Adger et al., 2004), then a deeper understanding of the interconnections between socio-cultural categorisations (such as race, class and gender) applied to actors (such as smallholder farmers) that create overlapping and interdependent systems of discrimination or disadvantage is an essential aspect of adaptive capacity assessment (Nyantakyi-Frimpong, 2020). Vulnerability manifests heterogeneously across regions, communities, sectors, and gender groups (Thompson-Hall et al., 2016), thereby suggesting that any intervention that does not consider such heterogeneity in adapting to climate-induced shocks and stresses may not fully address the intricate intersectionalities present within communities (Raza, 2017). Individuals in a community face varying levels of vulnerability owing to their distinct positions within socio-economic systems (Raza, 2017). Gender-disaggregated analysis may unveil how livelihood choices by men farmers can alter their vulnerability to climate change compared to women farmers. Yet, an even richer perspective of vulnerability can emerge when considering other identity markers, such as the intersection of gender and age (Thompson-Hall et al., 2016; Yimam & Holvoet, 2023). Delving deeper through data disaggregation within groups can facilitate an intersectional approach to climate change research, preventing overshadowing complex local realities that could potentially misguide policy formations (Arora-Jonsson, 2011; Yimam & Holvoet, 2023).

In Ghana, most studies of agriculture's vulnerability to climate change focus on farm-level, technical adaptation strategies (e.g. Opoku Mensah et al., 2023), with limited research conducted on the adaptive capacity of smallholder farmers (e.g. Abdul-Razak & Kruse, 2017). While existing research has significantly advanced our comprehension of the impacts of climate change and adaptation, few studies have focused on specific aspects of adaptation and intersectional analysis in Ghana. For example, while Lawson et al. (2020) focused on understanding intersectional perceptions and adaptation strategies of women farmers, Alare et al. (2022) examined how inter-gender dynamics influenced access to social networks. Vulnerability analysis based on gender, class, religion, and other factors is inadequate as it risks homogenising entire groups, and ensuing interventions may miss the actual needs of countless individuals (Nyantakyi-Frimpong, 2020). Thus, existing studies in Ghana have largely overlooked intersectional analysis examining the nuanced vulnerabilities to climate extremes, the varying impacts on diverse yet equally exposed groups, and how such dynamics shape adaptive capacities among diverse yet equally exposed groups (Nyantakyi-Frimpong, 2020). Echoing earlier studies in Ghana (e.g. Abdul-Razak & Kruse, 2017), this research operationalised adaptive capacity based on the five capitals -human, social, natural, physical and financial— of the Sustainable Livelihood Framework (SLF). These capitals influence farmers' actions to mitigate climate change impacts within an existing enabling environment of policy and institutional frameworks (Scoones,

The SLF was adopted here to define the components contributing to smallholder farmers' adaptive capacity, as Ellis (2000) and Scoones (1998) outlined. The SLF evaluates livelihoods by considering people's access to various capitals, how they combine and use them to build capacity and create livelihoods, and how they can expand their capitals by interacting with other actors and institutions (Scoones, 1998). Such studies have been termed first-order capacity assessments (Elrick-Barr et al., 2022). This study seeks to enhance firstorder AC assessment by analysing how indicators of smallholder farmers' stocks of capital and other socio-demographic characteristics in the Talensi district in Ghana's northern savannah Agro-ecological Zone (AEZ) (a district identified as highly exposed to climate change, Opoku Mensah et al., 2023) intersect to shape their climate adaptation. Nyantakyi-Frimpong (2020) qualitatively demonstrated how farmers' social characteristics intersected to deepen their vulnerability and highlighted the need for more intersectional analysis to better understand vulnerability to climate extremes in Ghana. To advance this research, this study adopted a mixed-method approach to align with the growing calls for empirically grounded intersectional research to understand the diversity of actors pursuing adaptation, how intersecting identities shape their adaptation in a highly diverse context, what policies could promote more equitable adaptation within and across heterogeneous communities (Agrawal & Gibson, 1999; Erwin et al., 2021). Such intersectional research fosters a more nuanced and critical analysis of climate change and inequality dynamics (Arora-Jonsson, 2011; Hopkins, 2018).

#### 2. Intersectionality and vulnerability

The term intersectionality first emerged from Black feminist activism in the USA during the 1970s and 1980s (Singleton et al., 2021). Intersectionality was introduced as an analytical concept by Crenshaw (1989; 1991) to address the complex latent power dynamics that shape the lives of women of colour, particularly Black women (Haynes et al., 2020). Black feminism, which contends that Black women's and girls' experiences shed light on a particular understanding of their position in connection to racism, sexism, class oppression, and other systems of domination, is the foundation of intersectionality (Haynes et al., 2020). Black women were excluded and misrepresented by both white feminist middle-class movements and black emancipatory movements, which claimed to speak for all women, regardless of race or class (Castán Broto & Neves Alves, 2018). Within academia, scholars such as Crenshaw (1991) have argued that neither feminist nor antiracism discourses adequately addressed experiences shaped by



overlapping patterns of sexism and racism. Collins (2000, p. 18) further developed the idea, referring to it as 'a matrix of domination', which describes how intersecting identities interact to create differential access to experiences and resources. Intersectionality has been and is being developed to expand the analysis of gender power relations (Davis, 2014) to address the experiences of those subjected to various forms of subordination and indicate the interaction of multiple identities and experiences of exclusion and subordination (McCall, 2005).

In this study, intersectionality refers to how social identities, including race, class, gender, ability, geography, and age, interact to create complex experiences and unique meanings within and between social groups (Hankivsky & Cormier, 2011). This interaction shapes adaptation processes and outcomes, enabling a more accurate assessment that addresses inequalities and promotes equitable policies and programmes to address such inequalities (Erwin et al., 2021). According to Ahlborg and Nightingale (2018), intersectionality clarifies how social, economic, and political factors limit certain positionalities' access to adaptation resources and participation in institutions, making them multiplicatively vulnerable to social-ecological change. Ravera et al. (2016) called for the need to integrate an intersectional lens in research to document and analyse how various agricultural actors perceive, experience, and adapt to social-ecological changes, given the growing concerns about how such changes, including climate change, affect agricultural productivity and production, particularly in the Global South. This integration is necessary because social justice research concerns differences within and between groups. Understanding such differences is pertinent to discussions about climate change's causes, impacts and politics (Singleton et al., 2021) and sheds light on the numerous challenges individuals, households, and groups must overcome within different adaptation contexts (Erwin et al., 2021).

Intersectionality influences individuals' experiences with climate change vulnerability (Yimam & Holvoet, 2023). According to Thompson-Hall et al. (2016), intersectionality delves deeply into the multi-faceted identities of farmers, illuminating how these attributes coalesce to influence the vulnerability of diverse individuals. Exploration of intersectionality can facilitate the development of more nuanced understandings of the dynamic interplay between power structures and institutions and how they shape adaptive capacity. Feminist geographers and scholars have emphasised a critical gendered perspective to discern how gender shapes diverse groups' vulnerabilities and adaptive capacities globally (Arora-Jonsson, 2011; Carr & Thompson, 2014). Other authors argue that the complexity of gender, often treated as a dichotomous category upon which vulnerability can be neatly mapped, has been somewhat oversimplified in climate change studies, thereby neglecting other complex social characteristics (Chaplin et al., 2019; Thompson-Hall et al., 2016). While vulnerability analysis possesses notable strengths, it does not directly address the risks associated with intersecting social identities. Employing intersectionality as an analytical lens can mitigate this limitation (Nyantakyi-Frimpong, 2020). For instance, Thompson-Hall et al. (2016) demonstrated how intersectionality can enhance understanding of environmental change by highlighting the combined influence of different social characteristics that are otherwise treated as concrete. For example, Deressa et al. (2008) highlighted the importance of household heads' age and gender in shaping their adaptive capacities and, subsequently, their level of vulnerability. Adaptive capacity was significantly influenced by marital status, with women's marital status, in contrast to that of men, playing a crucial role in defining their access to adaptive strategies (Yimam & Holvoet, 2023). Also, Lawson et al. (2020) found that migrant women farmers had less land access than indigenes. Older farmers had greater access to land and were more likely to have tenure security than younger farmers. While married women with sons had better land access, young, single women were more likely to migrate and less likely to implement innovative adaptation strategies. Furthermore, higher levels of education have been linked to lower levels of vulnerability (e.g. Muttarak & Lutz, 2014) and intersecting vulnerabilities associated with being a woman and unskilled limit access to income diversification opportunities, limiting their capacity to adapt to social-ecological change (Erwin et al., 2021). Therefore, to attain a more nuanced understanding of vulnerability to climate extremes and vulnerable groups, it is vital to consider how multiple social characteristics such as gender, age, disability, religion, and class in combination instead of in isolation (Thompson-Hall et al., 2016) shape adaptive capacities and, subsequently, farmers' level of vulnerability (Ravera et al., 2016).

#### 3. Material and methods

#### 3.1. Survey design and data collection

This study adopted a pragmatic, mixed-method approach (i.e. combined qualitative and quantitative data collection) to the research to unravel the complex contexts and realities that characterise the lives of rural people (Morgan, 2014; Strijker et al., 2020). According to Strijker et al. (2020), the mixedmethod approach has gained importance in many fieldsincluding agricultural studies, rural development, and poverty studies-for analysing social phenomena from diverse perspectives. This study seeks to analyse how indicators of the livelihood capitals intersect with the socio-demographics of smallholder farmers to shape their adaptive capacity through interconnections among social dimensions such as gender, identity, power, governance, and institutions in various ecological, economic, and climate contexts, culminating in webs of distinct vulnerabilities (Hopkins, 2018). Qualitative information was obtained through Key Informant Interviews (KIIs) and Focus Group Discussions (FGDs), while household surveys were used to access quantitative data.

To ensure a shared understanding of key concepts, the researchers fostered an open and participatory environment by ensuring that diverse views were acknowledged and synthesized, ultimately aligning key concepts within the context of the study (e.g.Brown et al., 2010). For example, the researchers began by explaining adaptive capacity in simple, relatable terms, emphasizing its role in shaping smallholder farmers' capacity for climate adaptation. The terms constraining and supporting were central to these discussions, and while there

was some initial variation in how participants interpreted them, a shared understanding was gradually established. Through interactive dialogue, participants were encouraged to share their perspectives on what factors enable or hinder their ability to adapt.

#### 3.1.1. Study area description

Fieldwork was conducted in the Talensi district in Ghana's northern savannah AEZ (see Figure 1). This district was selected due to its unique local socio-economic and climatic characteristics, such as climate-induced exposures, ecological sensitivity, historical lack of development, presence of institutions championing adaptation interventions and improved agricultural practices, and its agro-pastoral based livelihoods (Opoku Mensah et al., 2023). The district has a tropical climate with two distinct seasons: an erratic rainy season that starts in May and ends in October and a dry season between November and April. The Talensi district has a mean annual rainfall of 950 mm. It has a maximum temperature of 45°C in March and April and a minimum of 12°C in December (Ghana Statistical Service [GSS, 2014]). The district has an environmentally fragile dryland (non-irrigated) agricultural production system (Opoku Mensah et al., 2023).

Talensi district has experienced major impacts of climate change, including drought, famine, crop loss, floods, wildfires, and pest infestations (Talensi District Assembly [TDA, 2022]). Agriculture plays a significant role in the district, with 91% of households engaged (GSS, 2014). These households are primarily smallholders dependent on a favourable climate for their agricultural production. Agro-pastoralism (crop farming and livestock production) is the main agricultural activity, with some silviculture and aquaculture also practised (GSS, 2014; TDA, 2022). District farming systems comprised integrated combinations of crops, livestock, trees and fishery (FAO, 2013). The district's smallholder agro-pastoral farmers have witnessed annual rainfall variability, loss of forest cover, biodiversity disappearance, and loss of productivity from declining soil fertility (TDA, 2022). The agro-pastoral production system in the Talensi district represents one of Ghana's most vulnerable production systems (GSS, 2014; TDA, 2022). Smallholder farmers in the Talensi district are subject to institutional interventions such as capacity building and ecological restoration to promote adaptation and maintain sustainable livelihoods (Opoku Mensah et al., 2024). The biophysical environment and strong institutional presence in the Talensi district made it a good selection for the case study.

#### 3.1.2. Data collection

The study applied intersectionality as an approach to offer a more thorough explanation for the convergence of dominating forces to illuminate specific details often overlooked in typical analyses (Haynes et al., 2020). Adopting intersectionality as an approach reveals a more complex analysis highlighting the 'social hierarchy [that] creates the experiences that produce the categories that intersect' (MacKinnon, 2013, p. 1024). The study adopted an intercategorical approach (also called the categorical approach) to research design (McCall, 2005). This approach requires that existing analytical categories are provisionally adopted and strategically used to document relationships of inequality among social groups and changing configurations of inequality along multiple and conflicting dimensions (McCall, 2005). According to Agrawal and Gibson (1999), the use of categories to discuss how social groups lack access to these resources and institutions is critical to identifying how inequalities within heterogeneous communities lead to unequal access to resources and institutions and, consequently, unequal adaptation outcomes. The categorical approach was chosen because of the observed relationships of inequality among already-constituted social groups in the Talensi district (Opoku Mensah et al., 2024), imperfect and dynamic as they are, and took these relationships as the centre of analysis (McCall, 2005). For example, the patriarchal nature of the Talensi district has resulted in power dynamics between women, youth, and men (Opoku Mensah et al., 2024). Explaining those relationships is the primary goal of the categorical approach, necessitating the provisional use of categories (McCall, 2005).

The provisional use of categories is based on the pragmatic approach that intersectional complexities between inequalities do not require new intervention instruments and, thus, makes it possible to use and extend existing resources to deal with intersectional problems (Jiménez Rodrigo, 2022; Verloo, 2006). Pragmatism is always contextual and helps understand things in relational terms and not in isolation. Pragmatism treats the social world as a series of contexts that shape the value and meaning of people, words, institutions and ideas engaged in complex relationships (Dickstein, 1998). In the context of this study, intersectionality and pragmatism exhibit similarities and deepen our understanding of how alreadyconstituted social groups shape adaptive capacities through their experiences (Collins, 2011). According to Collins (2011), combining intersectionality and a pragmatic approach to experience realigns contemporary intersectional configurations with a social movement approach to gender, sexuality, race, and class that promotes more robust analyses of inequality, experience, individuality and community. Experiences, both personal and collective, become the subject of transactions rather than being ignored. The categorical approach was applied throughout the development of data collection instruments to elicit intersectional responses and data collection and analysis processes. The data collection instruments were developed by considering provisional categories such as gender, age, educational background, marital status, religion, farmland area, residential status, and economic status informed by the literature on adaptation and intersectional studies in Ghana (e.g. Alare et al., 2022; Lawson et al., 2020; Nyantakyi-Frimpong, 2020).

Data collection was conducted between September 2022 and March 2023. To capture the diversity of agricultural actors at each study site, the data collection consisted of semi-structured interviews with key informants from local institutions involved in climate change and agricultural production, followed by community-based focus group discussions and household surveys. Specifically, the initial data collection phase commenced with key informant interviews with key actors in agricultural production and climate change in the Talensi district. These interviews focused on the nuances of the district's agricultural practices, livelihood portfolios, and

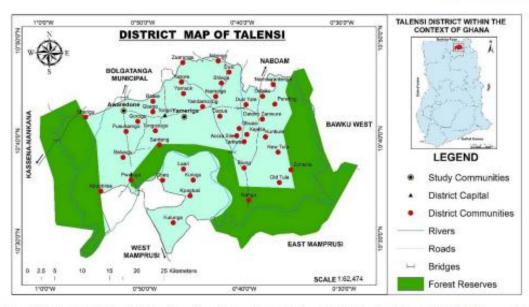


Figure 1. Map of the Talensi district, showing the locations of Awaredone and Yameriga. Source: Adapted from Opoku Mensah et al., 2023; Abunyewah et al., 2024.

prevailing climate issues. Following a pragmatic methodology, the district's Department of Agriculture (DoA) and the TDA were chosen as primary sources of information due to their extensive experience, knowledge, and recognised involvement in climate change initiatives, agricultural production and rural development in the district.

The knowledge gathered from key informant interviews also provided the basis for selecting the study communities. For example, with the involvement of the DoA and using stratified sampling, two agro-pastoral communities, Awaredone and Yameriga (cf. Figure 1), were sampled from the district's three area councils informed by the local socio-economic and climatic characteristics, natural environment, agro-pastoral production systems, and institutional presence. These communities were at discrete locations in the district and had similar sizes and populations, with several institutions operating in them (Abunyewah et al., 2024). Four research assistants, native to the study communities and fluent in both English and the local Talen and Guruni languages of the Talensi district, were recruited and trained to support the principal researcher during data collection. Given the district's patriarchal nature, two men and two women research assistants were recruited. This arrangement ensured that women assistants interacted with women smallholder farmers while men assistants connected with their men counterparts to moderate cross-gender and cross-cultural sensitivities (Nyantakyi-Frimpong, 2020) and foster trust and participation.

Six FGDs were conducted, with three in each community. Each group had 5-10 participants, including community opinion leaders like chiefs or their representatives, assembly members, local group leaders, and heads of farmer households. Due to the district's patriarchal nature, which often discourages women and youth from speaking freely in mixed groups, participants were grouped by gender and age: men-only, womenonly, and youth-only. This approach created a comfortable environment, allowing everyone to express their views and potentially highlighting any social differences in perspectives. The principal researcher co-moderated the FGDs, which took place sequentially. Two research assistants assisted in each community, serving as co-moderators, note-takers and interpreters. Discussions were held in the local Talen and Guruni dialects, each lasting approximately three hours. The discussions were audio-taped with the consent of the discussants. FGDs were scheduled for late afternoons after farmers had completed their daily activities to ensure maximum participation. These focus groups also discussed climate change impacts, extreme weather events, community adaptive capacities and institutional support. The FGDs offered valuable insights from the discussants' lived experiences regarding the investigated topics (Abdul-Razak & Kruse, 2017). For example, given that adaptive capacity is contingent upon specific local conditions or contexts (Adger et al., 2004), 24 locally relevant indicators for each of the five capitals were identified during the discussions based on their current capacity to support or constrain climate adaptation. The description and relevance of the different forms of capitals to assessing adaptive capacity are conceptualised in supplementary material 1.

In the household surveys, smallholder farmers utilised a Likert scale of 0-5 to evaluate the 24 locally relevant indicators of the five capitals identified during the focus groups based on their current capacity to support or constrain climate adaptation. A preliminary questionnaire was pretested on 20 households in September 2022. Based on feedback from respondents, the questionnaire was finalised and consisted of a set of openand closed-ended questions. The smallholder farmers explained why each indicator rating was high or low and identified priorities to enhance these ratings. A score of 5 suggested that the indicator effectively supported the smallholders in their climate adaptation. A score of 0 indicated that the indicator effectively constrained the smallholders in their climate adaptation (based on Jacobs et al., 2011). The survey instrument was digitised using the Open Data Kit (ODK) mobile app to enhance the quality and efficiency of data collection. ODK allowed all collected data to be verified by the principal researcher and uploaded to a secure server daily (Abunyewah et al., 2024). The finalised questionnaire was administered to agro-pastoral households, defined as those who considered crop farming as their primary source of income and owned at least five heads of cattle and a herd of sheep or goats (Zampaligré et al., 2014). In addition to being engaged in agro-pastoral activities, selected households must also have received institutional support. A systematic sampling method was employed to select participating households (Mostafa & Ahmad, 2018). According to the specifications of the sample frame and inclusion criteria, 65 agro-pastoral households were selected and interviewed in each of the two communities.

Cochran's formula (Cochran, 1997) was used to determine the sample size needed to satisfy a 95% confidence level (z = 1.96), 91% agricultural households and a 5% level of precision (a) from 14,291 total households as follows:

$$n = \frac{z^2 * p * (1 - p)}{(\alpha)^2} ; n = \frac{1.96^2 * 0.907 * (0.093)}{(0.05)^2} n = 130$$

n = sample size, z = critical value of desired confidence level,  $p = \sum_{i=1}^{n} p_i = \sum_{i=1}^{n} p_i$ degree of variability in the population and  $\alpha$  = desired level of precision.

In total, 130 valid questionnaires were returned for the two communities. In each household, only household heads or agricultural decision-makers who make final agricultural decisions (Kuang et al., 2022) participated in the survey. The interviews were conducted in the local dialects of Talen and Guruni and were 45-60 min long. The decision to focus on household heads or agricultural decision-makers was guided by the specific objective of understanding how adaptive capacity is shaped by those who directly influence agricultural decisions. In the context of the Talensi district, where agriculture is largely a householdlevel endeavour (GSS, 2014; TDA, 2022), household heads or primary decision-makers play a critical role in resource allocation and responses to climate risks (see Abunyewah et al., 2024; Opoku Mensah et al., 2023). Therefore, focusing on this group allowed us to capture insights into decision-making dynamics central to adaptation. Additionally, the inclusion criterion related to livestock ownership was intended to ensure the inclusion of smallholder farmers actively engaged in agro-pastoral production systems. Livestock ownership is a common indicator of socioeconomic status and resource endowment in the Talensi district (Abunyewah et al., 2024; TDA, 2022), and it plays a crucial role in shaping adaptive capacity and managing climate risks (Geda et al., 2024). Since agricultural activities and adaptive capacities within the communities are not limited to only these respondents, the descriptive power of the results may not be able to extend to the communities as a whole. An intersectional analysis of a broader set of household members/community members might reveal additional layers of inequalities in decision-making power that would significantly impact the adaptive capacities of the groups and community-level resilience to climate change.

#### 3.2. Data analysis

The household data was exported from the ODK server, cleaned and imported into Statistical Package for Social Science (SPSS) Statistics 28 and Microsoft Excel 2019 for analysis. Descriptive statistics (frequency, maximum, minimum, mean, percentages) and inferential statistics (Chi-square tests) (Aboye et al., 2023) were used to summarise the data, analyse the adaptive capacity of the smallholder farmers, and how the livelihood capital indicators and other socio-demographic characteristics of smallholder farmers intersect to shape their climate adaptation. A Chi-square test of independence was used to determine the significance of associations between the ratings of selected livelihood indicators and the socio-demographic characteristics of the respondents (Onchiri, 2013). Qualitative data from the six FGDs were analysed using narrative analysis (Bryman, 2012). Audio recordings were transcribed verbatim into text, translated into English and read several times to thoroughly understand the raw data (Møller et al., 2018). The texts from the FGDs were coded with NVivo 14 and compared against the recorded audio files to understand the text's varying opinions and ensure the data's accuracy (Boafo & Lyons, 2023). In emphasising stories articulated by discussants, narrative analysis used quotations to substantiate claims (Bryman, 2012). To ensure rigour and trustworthiness, participants' own words were maintained with low use of inference descriptors (Baxter & Eyles, 1997). According to Christensen and Jensen (2012), people's narratives about their live stories can provide the most insight into social categories and their intersections. Furthermore, in-depth narrative analysis is particularly effective for achieving 'the depth and richness required for a sophisticated intersectional analysis' (Hopkins, 2018, p. 587). Because the study adopted the categorical approach, data were systematically compared within multigroups to focus on the complexity of relationships among multiple social groups within and across analytical categories (McCall, 2005).

Methodologically, implementing intersectional analysis remains a great challenge (Nyantakyi-Frimpong, 2020). The comparative and multigroup characteristics of the categorical approach create a form of complexity by adding any analytical category to the analysis because it requires an investigation of the multiple groups that constitute the category (McCall, 2005; Verloo, 2006). In this respect, it faces trade-offs between scale and coherence or difference and sameness in determining the appropriate level of detail (McCall, 2005). Using an approach described by McCall (2005), the study managed this complexity by what at first appears to be a reductionist processreducing the analysis to at most five between-group relationships at a time-but what, in the end, was a synthetic and holistic process that brought the various pieces of the analysis together.

#### 3.3. Ethics approval

The research received approval from the Human Research Ethics Committee (HREC) at the University of Technology Sydney (UTS), under approval number UTS HREC ETH22-7303. Before administering questionnaires, interviews and FGDs, all participants provided informed consent for their involvement.

Table 1. Socio-demographic characteristics of respondents.

Socio-demographics	Categories	Frequency (n = 130)	Percentage (%)
Gender	Women	68	52
	Men	62	48
Age	<15 years	0	0
	15-35 years	37	29
	36-59 years	69	53
	≥60 years	24	18
Educational	No Formal Education	59	45
background	Primary	25	19
	Junior High School (JHS)	23	18
	Senior High School (SHS)	12	9
	Tertiary	11	9
Marital status	Married	82	63
	Widowed	37	28
	Single	10	8
	Divorced	1	1
Religion	Christianity	61	47
-	Traditional	54	41
	Islam	1	11
	No religion	14	1
Residential status	Indigenes	117	90
	Migrants	13	10
Farmland area	≤ 2 hectares	85	65
	> 2 hectares	45	35
Economic status	Low economic status	91	70
	High economic status	39	30

#### 4. Results

#### 4.1. Socio-demographic characteristics of the smallholder farmers

Table 1 depicts the socio-demographic characteristics of the 130 sampled smallholder farmers. The sample was slightly skewed towards women, who comprised 52% of the total. About 81% of farmers were 15-59 years of age, with an average age of 45. The majority of smallholder farmers (55%) in the sample had completed some level of formal schooling, which included early childhood and junior high school (GSS, 2022), although many (45%) reported having no formal education. Most respondents were married (63%), with a further 28% widowed. Typical of smallholder farmers' land holdings in Ghana (Ministry of Food and Agriculture [MoFA], 2019), land holdings of sampled smallholder farmers averaged 1.7 hectares, with farmland sizes for 65% of respondents of less than two hectares. The minimum area of farmland holding was 0.4 hectares, accounting for 6% of the smallholder farmers. A few holdings (1% of respondents) were substantially larger (up to 5.3ha). Up to 71% of the farms were family-owned.

Using the official Bank of Ghana inter-bank exchange rate of US\$1 to GH¢10.99 as of the end of June 2023 and benchmarking against a standard of living of US\$1.90 per day, as many as 70% of the smallholder farmers lived on GH¢626 or less per month and fell into the category of extreme poverty. World Bank (2019) defined extreme poverty as living on less than US\$1.90 per person per day, indicating a low economic status. Almost half of the participants (47%) reported following Christianity, 41% followed traditional beliefs, and a smaller proportion followed Islamic beliefs.

#### 4.2. Livelihood capitals support for adaptation

The average ratings for all capitals were less than 3 (Figure 2), suggesting that, in general, available resources provided limited support for adaptation. However, there was considerable variation in the mean and a broad range of ratings for each capital. Ratings for natural and physical capital never exceeded 3 and were less than 1 at

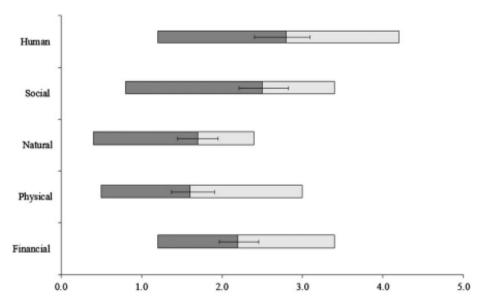


Figure 2. Pooled analysis of the individual indicators ratings of each of the five capitals. Values (x-axis) described the degree of support for climate adaptation (0 = constraining to 5 = supporting). The total length of the bar (light and dark-shaded regions) shows the range of values for each capital, the junction of the light and dark-shaded regions shows the mean value, and the error bars show the standard deviation of the mean value.

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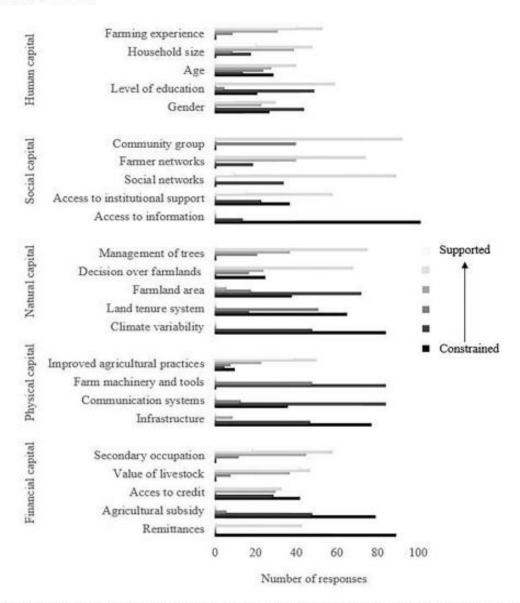


Figure 3. Ratings of the indicators of each of the five capitals by the smallholder farmers. Values (x-axis) are the number of responses associated with each indicator.

the lower end of the range. In contrast, human capital averaged 2.8 with ratings ranging from 1.2 (constraining) to 4.2 (supporting), suggesting either variation in the support offered to adaptation by component indicators or variation in the rating of individual indicators by some farmers or farmer subgroups within the sample.

#### 4.3. Analysis of the indicators of each of the five capitals

Figure 3 shows the distribution of ratings farmers assigned to component indicators of each of the five capitals. The distribution of ratings of individual indicators varied considerably. Within each capital, the rating distribution for some indicators appeared skewed towards higher ratings (support for adaptation), e.g. farming experience in human capital, improved agricultural practices in physical capital, and secondary occupation in financial capital. Other indicators were skewed towards lower ratings (adaptation constraint), including access to information in social capital and climate variability in natural capital. Between these two extremes, a third group of indicators appeared to show two distinct peaks in ratings, suggesting that the support for adaptation provided by these indicators was perceived differently by sub-groups of farmers within the sample. The indicators perceived differently by sub-groups of farmers within the sample were termed to have a 'bimodal pattern'. The indicators with such bimodal patterns included gender (human capital), access to institutional support (social capital) and remittances (financial capital), all of which were rated as both supporting and



Table 2. List of most constraining and supporting indicators of climate adaptation from highest average rating to lowest and their respective capitals.

Constraining most far	rmers	Supporting most farmers Constraining and supporting		farmers	
Indicator Farm machinery and tools	Capital Physical	Indicator Farming experience	Capital Human	Indicator Social networks*	Capital Social
Land tenure system Farmland area	Natural Natural	Value of livestock Improved agricultural practices	Financial Physical	Farmer networks* Household size	Social Human
Communication systems	Physical	Secondary occupation	Financial	Decision over farmland	Natural
Infrastructure Agricultural subsidy	Physical Financial	Management of trees Community group*	Natural Social	Access to institutional support Age	Social Human
Climate variability	Natural			Level of education	Human
Access to information	Social			Gender	Human
				Access to credit	Financial
				Remittances	Financial

Note: \* At the community level in rural Africa, network structures play a vital role in collective actions and foster community's adaptive capacity (Adger, 2003). These networks often emerge from kinship ties and acquaintances, termed social networks, or from horizontally organised farmer groups, known as farmer networks. Beyond network structures, community groups play a significant role. Membership in these groups strengthens local social ties, improves the economic situation, and empowers individuals. Furthermore, they offer access to resources outside of agriculture. These groups often serve as platforms for joint activities, savings, and solidarity (Opoku Mensah et al., 2023).

constraining adaptation by smallholder farmers. To bring out the nuances and improve discussions on intersectionality, how the different sub-groups of farmers within the sample perceived the indicators is detailed in section 4.4.

Accordingly, most indicators were placed into one of three categories: those that constrained the majority of smallholder farmers, those that supported the majority of them, and those that constrained some smallholder farmers while supporting others. These indicators were distributed across the various capitals, as summarised in Table 2.

#### 4.3.1. Indicators that constrained most smallholder farmers

The group of indicators that constrained most farmers included all capitals except human capital (Table 2). Within these constraining indicators, access to information (social capital) was identified by all smallholder farmers as a constraint to climate adaptation (Figure 3). Similarly, as detailed in Table 2 and Figure 3, three indicators of natural capital were among those rated as constraining most farmers: climate variability (all farmers rated it 1 or lower), farmland areas (96% rated it 2 or lower) and land tenure (all farmers rated it 2 or lower). For physical capital, communication systems and infrastructure constrained adaptation (Table 2) of 91% and 94% of the smallholder farmers (Figure 3), respectively. For financial capital, agricultural subsidy (Table 2) was rated as constraining 100% of farmers (Figure 3).

### 4.3.2. Indicators that supported most smallholder

Of the indicators that supported most smallholder farmers in climate adaptation as shown in Table 2, farming experience (human capital) had the average highest rating of 4.0, with 94% of the smallholder farmers rating it 3 or above (Figure 3). Among financial capital indicators, both secondary occupation and value of livestock supported adaptation (Table 2), with 92% and 95% (Figure 3), respectively, of the smallholder farmers rating them 3 or above. Table 2 shows the other indicators that generally supported most farmers, including tree management (natural capital), community groups (social capital), and improved agricultural practices (physical capital), albeit with greater variation in ratings (see Figure 3).

#### 4.3.3. Indicators that constrained some smallholder farmers while supporting others

Indicators from all except physical capital were included in this category (Table 2), with social and human capital providing three indicators each. While physical capital did not contribute an indicator, a small group of farmers (<10%) did rate infrastructure as moderately supporting (Figure 3) in contrast to the majority rating of 1 or lower (strongly constraining). Clear bimodal patterns in ratings were shown for remittances and access to credit (financial capital), access to institutional support and farmer networks (social capital), and gender and levels of education (human capital) (Figure 3). For example, about 32% of farmers rated the support to adaptation offered by remittances as 4 (strongly supporting); however, the remaining 68% rated this indicator as 0 (that is, it provided no support to adaptation). Similarly, access to institutional support was rated as 4 or above (strongly supporting) by 55% of farmers and 1 or below (strongly constraining) by 45% of farmers. For gender, 53% of farmers considered it heavily constrained adaptation, while 30% considered it strongly supported adaptation. For other indicators (Table 2), the bimodal pattern was less striking but still evident (Figure 3). For example, decisions over farmlands supported 69% of the smallholder farmers, was neutral for 12%, and constrained the remaining 19%.

#### 4.4. Intersection of indicators and socio-demographics

This section used a Chi-square test of independence to analyse the associations between the participants' socio-demographic characteristics (Table 1) and the ratings they assigned to indicators of adaptive capacity, focusing on those showing a bimodal pattern (Table 2). All indicators with bimodal patterns showed significant associations (P-values ranged from 0.001-0.03) with one or more socio-demographic characteristics (Table 3). The detailed Chi-square test results are presented as supplementary material 2.

Gender, either alone or in combination with other characteristics, influenced the pattern of adaptive capacity ratings for nine of 11 indicators that showed bimodal patterns (Table 3). For these indicators, the women smallholder farmers invariably rated their adaptive capacity as constrained, whereas the men smallholder farmers predominantly comprised the group supported by the indicator. However, for most

indicators, capacity ratings were influenced by gender combined with other characteristics (such as age, residential status, and economic status). For example, while gender generally constrained the adaptive capacity of the women smallholder farmers, those with low economic status were more affected than women with high economic status or men smallholder farmers irrespective of economic status. The quote below was typical of the views of women smallholder farmers with low economic status across all the focus groups: "Our economic status severely constrains us. While wealthier farmers can access credit and buy quality seeds and fertilisers, we cannot. We find improving our yields and securing our livelihoods against climate risks difficult". Of the 26 smallholder farmers who rated gender as 0 (highly constrained), 69% were women, and 31% were men. Conversely, of the 10 smallholder farmers who rated gender as 5 (highly supported), 60% were men and 40% were women. Within the constrained group, 50% had low economic status, compared to 19% with high economic status. Within the supported group, 80% (40% women and 40% men) had high economic status.

Age constrained more older than younger smallholder farmers. Of the 28 smallholder farmers who rated age 0 (constrained), 47% (29% women and 18% men) were 60 years and older. The remaining 53% of the constrained group was dominated by women 36-59 years (32%). Of the 39% who rated age as 4 (supporting), most (92%) were in the two younger categories, with men (54%) proportionally higher than women (38%). Only 8% (3% women and 5% men) of this group were 60 years and older. During the discussions, a young man in Awaredone noted: "As a younger farmer, I have better access to information and training on sustainable farming practices through our networks and social media. This adaptability gives me an edge over older farmers who do not use these resources as often and stick to traditional methods".

In addition to gender, the support to capacity from social and farmer networks was also influenced by residential and economic status, respectively (Table 3). Farmer networks supported more indigenes than migrants. Of the 18 smallholder farmers who rated farmer networks as 1 (constraining), 80% (49% women and 31% men) were migrants. A young woman migrant in Yameriga revealed: "As a young woman and a migrant, it is like facing a double whammy and catching a double edged sharp knife; you will definifrely get cut. The local farmer networks are tight-knit and tend to exclude migrants like me. Without access to these networks where locals share

Table 3. Selected indicators and their associated intersecting factors.

Indicator	Intersecting factor(s)	χ2	P-value
Gender	gender	12.9	0.012
Gender	gender, economic ststus	49.2	0.001
Age	gender, age	50.7	0.001
Farmer networks	gender, residential status	9.80	0.013
Social networks	gender, economic status	14.9	0.021
Decision over farmlands	gender, age	35.2	0.002
Access to institutional support	group membership	18.1	0.034
Access to credit	gender, group membership	25.3	0.003
Remittances	household size	2.51	0.022
Land tenure	gender	69.8	0.001
Improved agricultural practices	economic status	14.0	0.015
Secondary occupation	gender	19.7	0.001
Secondary occupation	level of education	17.8	0.008

resources and knowledge, I miss valuable resources and knowledge that could help me adapt to the changing climate". Conversely, of the 73 smallholder farmers who rated it as 4 (supporting), 92% (39% women and 53% men) were indigenes. For social networks, smallholder farmers with low economic status rated the support to adaptive capacity highly. Of the 33 smallholder farmers who rated social networks as 1 (constraining), 85% (42% women and 43% men) had high economic status, compared to 15% (9% women and 6% men) with low economic status. Conversely, out of the nine smallholder farmers who rated social capital as 5 (supporting), 89% (11% women and 78% men) had low economic status as against 11% (all women) with high economic status. A man farmer in Awaredone noted during the discussion: "Despite having the means, I am expected to support many people in my social networks, hindering my ability to focus on my own farm's needs. I often find myself prioritising others' needs over investing in improvements that could enhance my climate adaptation".

Decision-making over farmlands supported more aged, men smallholder farmers. Among the 67 smallholder farmers who rated this indicator as 4 (supporting), 58% (22% women and 36% men) were 60 years or above. Of the 24 smallholder farmers who were constrained, 87% were within the productive age of 15-59 years and predominantly women (41% of women 15-35 years, 25% of women 36-59 years, 13% of men 15-35 years and 8% of men 36-59 years). For example, an older smallholder farmer in Yameriga noted: "Being an elder in our patriarchal community means that my decisions about land are rarely questioned. I have the authority to make key decisions about our farmlands, ensuring that the land is managed according to my experience and judgment".

Access to credit supported more women smallholder farmers with community group membership. Of the 32 smallholder farmers who rated it as 4 (supporting), 56% were women smallholder farmers who belonged to a group. Of the 41 smallholder farmers who rated access to credit as 0 (constraining), none were women smallholders with group membership. A woman farmer in Awaredone mentioned:" ... through our collective savings and loan scheme, I can access credit more easily, which helps me buy better seeds and tools for my farm". On the other hand, access to credit constrained men smallholder farmers without community group membership. During the discussion in Yameriga, a man commented: "It is frustrating that institutions focus on forming savings groups with women, making it easier for them to access credit. As men, we are left with limited options, and we struggle to get the same level of support to invest in better seeds and technology to adapt to our changing climate".

Gender was not always the greatest influence on indicator ratings. For example, more smallholder farmers with community group membership rated access to institutional support highly, while it was rated as constraining by those who did not. While 75% (47% women and 28% men) of the 36 smallholder farmers who rated it as 0 (constraining) did not belong to groups, 90% (50% women and 40% men) of those who rated it 5 (supporting) did belong to community groups. The following quote was typical of farmers' views who belonged to groups across all FDGs: "Our community group acts as a bridge



between us and various institutions. Because support is often channelled through groups, belonging to one ensures we do not miss out on important resources and training programmes that help improve our farming practices".

Remittances supported more smallholder farmers in households with large household sizes and indigenes. For instance, while 57% of the 88 smallholder farmers who rated remittances as 0 belonged to household sizes of 1-5, 88% of the 42 smallholder farmers who rated it as 4 belonged to larger household sizes (43% for 11-15 household sizes and 45% for 16-20 household sizes).

Although the associations between ratings of adaptive capacity and socio-demographic characteristics were clearest for indicators with bimodal patterns, other indicators were also associated with socio-demographics. For example, land tenure, which farmers rated as predominantly constraining adaptive capacity, was generally rated lower by women smallholder farmers than men smallholder farmers. Of the 64 smallholder farmers who rated land tenure as 0 (constraining) (n =64) or 1 (n = 16), 81% and 82%, respectively, were women. Likewise, for improved agricultural practices and secondary occupation (indicators rated as predominantly supporting farmers), support was highest among farmers with high economic status and men, respectively. Of the 39 smallholder farmers who rated improved agricultural practices as 5 (supporting), 74% had high economic status compared to 26% with low economic status. Of the 18 smallholder farmers who rated secondary occupation as 5 (supporting), 45% had completed tertiary education, with the remainder spread across other education completion levels. For example, a farmer with high economic status in Yameriga said: "... I invest in the latest agricultural technologies and practices, such as high-quality seeds and fertilisers ... that significantly boost my productivity".

All farmers rated climate variability and access to information as constraining and showed no significant associations with the socio-demographic characteristics. For example, farmers across all FGDs typically expressed: "The unpredictable weather patterns make it hard to plan our farming activities. One season, it is drought; the next, it is flood. Our lack of access to timely weather forecasts and climate information leaves us unprepared for such extreme weather events and severely limits our ability to adapt and make informed decisions about our farming activities".

#### 5. Discussion

Understanding the range of factors underpinning a community's capacity for adaptation is essential to assessing vulnerability to climate change (Adger & Vincent, 2005). Although capacity assessment can be applied at a range of scales (Abdollahzadeh et al., 2023), the incorporation of processes that engage communities in the identification of locally relevant indicators, as in this study, helps ensure that assessments are appropriate to the scale and context at which adaptation occurs (Abdollahzadeh et al., 2023; Abdul-Razak & Kruse, 2017). While existing research has significantly advanced our comprehension of the impacts of climate change and adaptation in Ghana, few studies have focused on specific aspects

of adaptation and intersectional analysis (e.g. Alare et al., 2022; Lawson et al., 2020). In advancing the need for more intersectional analysis to better understand vulnerability to climate extremes in Ghana (Nyantakyi-Frimpong, 2020), this study adopted a mixed-method approach to explore how the socio-demographics of smallholder farmers in the Talensi district of Ghana intersected with their livelihood capitals to shape their capacity for climate adaptation.

The study draws on a systematic random sample of 130 smallholder farmers and six focus group discussions. The socio-demographic characteristics of the farmers show that the sample was slightly skewed towards women, who comprised 52% of the total. The patriarchal nature of the Talensi district and the higher representation of women as heads of household or primary decision-makers in the survey results are explained by several contextual factors. Firstly, the patriarchal system does not preclude women from becoming heads of households in specific circumstances. For instance, divorced women or women whose husbands have migrated for work often assume the role of primary decision-makers in their households. It is common for men in the Talensi district to seek economic opportunities elsewhere, especially in the dry season between November and April (GSS, 2014; TDA, 2022), which coincided with the data collection period between September 2022 and March 2023. Also, some women take on leadership roles within their households due to their economic contributions, especially in cases where they are actively engaged in farming or other income-generating activities (Koomson-Yalley & Kyei, 2022). Additionally, the focus on institutional support for women smallholder farmers (Musah-Surugu et al., 2019; Tahiru et al., 2019) explains the slightly higher representation of women as heads of households or primary decision-makers. In many rural areas in Ghana, including the Talensi district, institutions - particularly civic/civil society institutions and development agencies - target women for agricultural and livelihood support interventions. Such women are often encouraged to take on leadership roles in decision-making within their households and communities (Tahiru et al., 2019). The study, therefore, likely captured these nuances, thereby reflecting a slightly higher representation of women despite the overarching patriarchal structure of the district. This finding highlights the importance of considering local dynamics and gender roles when interpreting household-level data.

The study allowed smallholder farmers in two discrete communities in the Talensi district in Ghana's northern savannah AEZ (a district identified as highly exposed to climate change, Opoku Mensah et al., 2023) to rate locally-derived indicators of each of the five livelihood capitals (human, social, natural, physical and financial), as to the level of support provided to adaptation. While overall, the capitals appeared to provide limited support to adaptation, the considerable variation in the range of ratings assigned to individual indicators of each capital suggested that a deeper analysis is required to understand vulnerability and intersectionality.

Analysis of the frequency distribution of ratings allowed individual indicators to be categorised into one of three groups. Two groups consisted of indicators skewed towards higher ratings (support for adaptation) and those skewed

towards lower ratings (adaptation constraint). A third group of indicators appeared to show two distinct peaks, i.e. a bimodal pattern. This pattern suggests that the support for adaptation provided by these indicators was perceived differently by sub-groups of farmers within the sample, as summarised in Table 4. The categorisation of indicators in this way also has implications for how institutional responses to climate change are formulated. Where most farmers identified an indicator as constraining adaptation, a broad-scale response by institutions would appear desirable to build adaptive capacity. That some indicators supported the majority of farmers, suggests that efforts by institutions or local conditions have enhanced adaptive capacity. The third group of indicators with a bimodal pattern presents the most problematic situation for building capacity because they require an institutional understanding of local conditions through engagement with disadvantaged social groups to formulate context-specific responses, which are seldom realised through centralised interventions (Nyantakyi-Frimpong, 2020). Thompson-Hall et al. (2016) posit that such nuanced interpretation of localised realities within specific agricultural contexts offers insights into how these settings fit and intersect within the larger agricultural landscape.

The analysis of adaptive capacity showed that gender constrained women smallholder farmers more than their men counterparts. However, gender was not the only important factor, as shown in Table 4. For example, where gender intersected with low economic status, age, and residential status, it heightened the constraint on adaptation experienced by women. Specifically, similar to Lawson et al. (2020), this study found that decisions over farmland constrained more women between 15-35 years and supported men 60 years or above. Due to the patriarchal nature of the Talensi district, women farmers, particularly younger women, were unable to

Table 4. Summary of sub-groups within indicators with bimodal patterns.

Indicators with bimodal patterns								
Constraining sub-								
Indicator	Capital	groups	Supporting sub-groups					
Gender	Human	Women with low economic status	Women with high economic status and or men irrespective of economic status					
Age	Human	Women 36 years and older	Men <15 years – 35 years					
Social networks	Social	Farmers with high economic status	Men with low economic status					
Farmer networks	Social	Women migrants	Men indigenes					
Decision over farmland	Natural	Women 15-35 years	Men 60 years or above					
Access to credit	Financial	Men without community group membership	Women with community group membership					
Access to institutional support	Social	Women without community group membership	Farmers with community group membership					
Remittances	Financial	Farmers in households with household sizes of 1–5 and women migrants	Farmers in households with household sizes of 11 and above and men indigenes					
Level of education	Human	Farmers with no formal education and women with low economic status	Farmers with tertiary education and men with high economic status					

own land because they had to obtain it in ways that raised their insecurity, including borrowing from relatives, depending on men relatives and leasehold agreements, which impacted their capacity to implement innovative adaptation practices. According to Akugre et al. (2021), women's limited control and land ownership in patriarchal communities continue to impede their effective adaptation, given that access to land in such communities is particularly crucial for sustainable adaptation. While gender has been the subject of many studies on intersectionality and climate change vulnerability, other socio-demographic characteristics, such as age, have received less attention in the Global South (Erwin et al., 2021; Ravera et al., 2016). Notwithstanding the importance of gender studies, the findings of this study reveal that human-environment researchers, particularly practitioners and policymakers in adaptation, also need to account for community dynamics related to ageing in designing adaptation interventions. Previous studies (e.g. Erwin et al., 2021; Yimam & Holvoet, 2023) have also emphasised how gender intersects with different identities to shape adaptive capabilities. Therefore, when designing adaptation interventions for smallholder farmers, it is vital to consider additional factors like age, socio-economic status, and education level. Although such nuanced analysis is problematical for resource-constrained governments of SSA, incorporating these elements can lead to better adaptation outcomes (Thompson-Hall et al., 2016).

Similar to Assan et al. (2018) and Opoku Mensah et al. (2023), access to credit supported women who belonged to community groups, while constraining men who did not belong to community groups. In the study communities, institutions, particularly civic/civil society institutions, supported farmers-particularly women farmers-to cultivate a savings culture and provided access to low-interest microcredit for starting new businesses and productive investments in agriculture. This finding supports the idea that women's circumstances are diverse (Nyantakyi-Frimpong, 2020) and that there is 'a need to separate being poor from being women or the generalisation ... . that all women are poor and that the poor are always more vulnerable' (Arora-Jonsson, 2011, p. 746). According to Chaplin et al. (2019), such separation can support the development of inclusive climate policies.

Recent research has demonstrated the impact of residential status on access to resources (Erwin et al., 2021), and the findings of this study align with those observations. Specifically, we found that residential status intersected with farmer networks and remittances to constrain migrants, suggesting that migrants may have been marginalised from these networks and could not draw on financial resources from remittances. Generally, women migrants were constrained by farmer networks. The FGDs revealed that local farmer networks were tight-knit and tended to exclude migrants. This situation limited their involvement in farmer networks where locals share resources and knowledge, putting them at a disadvantage when it comes to adapting to climate change. This finding is consistent with that of Lawson et al. (2020), who found that women farmers who are indigenes have comparatively better access to resources, such as farmer networks, as in this study. Farmer networks have been promoted, particularly by institutions, as the best way to quickly disseminate information and provide farmers with cost-effective extension services delivery; but, because they are frequently not well developed and strengthened, their full potential has not yet been realised (Alare et al., 2022) and they tend to be discriminatory against women migrants. Similarly, a recent study by Kuchimanchi et al. (2019) found that migration experiences shape unequal access to livelihood capitals and affect people's vulnerability and adaptive capacity. In light of the likelihood of increased climate-induced human migration in the future (Azumah & Ahmed, 2023), such findings assume greater importance. Erwin et al. (2021) emphasised the importance of understanding the complexities of labour migration and that they should be incorporated into the design of adaptation interventions to promote adaptation for all while prioritising the needs of the most vulnerable.

Fatuase and Ajibefun (2014) found that formal education to tertiary levels influenced adaptation options. This study found that farmers' level of education in the Talensi district supported farmers with tertiary education and men with high economic status while constraining farmers with no formal education and women with low economic status. Smallholder farmers with higher levels of education reported that having a secondary occupation that supported their capacity. Information from focus group discussions indicated that these smallholders owned land and earned salaries from jobs outside of agriculture. Notably, individuals from both genders in this skilled subset reported employment in various fields, including teaching, nursing, civil/public services, crafts, entrepreneurship, and banking. Other studies have shown a relationship between higher educational attainment and reduced vulnerability to climate change (Yimam & Holvoet, 2023). Echoing findings from Erwin et al. (2021), the analysis indicated that the intersectionality between educational status and gender often led to divergent income diversification opportunities for men and women. Unskilled women, in particular, found fewer opportunities to diversify their income, which impeded their individual and households' capacity to adapt. In light of these findings, education institutions should work with unskilled smallholder farmers, particularly women, to enhance adaptation outcomes at both the household and individual levels. Unlike Alare et al. (2022), who found that level of education and marital status were the primary indicators that influence smallholder farmers' access to social networks for climate change adaptation, this study found farmers' economic status as the key indicator. Men with low economic status revealed they had more grassroots connections and influence within local networks, particularly male-dominated ones. These connections provided them with informal support, including knowledge sharing and access to communal resources that were not readily available to farmers with high economic status who were perceived as more distant or less in need of support. From the foregoing discussion, the intersection of the farmers' socio-demographic characteristics and adaptive capacity is apparent and consistent with the understanding that vulnerability is socially heterogeneous (Erwin et al., 2021; Yimam & Holvoet, 2023) and may be experienced differently by sub-groups in a community according to sociodemographic characteristics. Such understanding is vital for

supporting and planning climate-sensitive interventions grounded in principles of social justice. Without a vulnerability analysis that unmasks differences or moves beyond binary gender categorisations, subsequent interventions might overlook the needs of numerous individuals and potentially exacerbate existing vulnerabilities (Nyantakyi-Frimpong,

Although the associations between ratings of adaptive capacity and socio-demographic characteristics were clearest for indicators with bimodal patterns (i.e. supporting for some while constraining for others), other indicators were also associated with socio-demographics. For example, in keeping with Lawson et al. (2020), land tenure, which farmers rated as predominantly constraining adaptive capacity, was generally influenced by age and marital status. Particularly, younger (36-59 years) and married and widowed women farmers rated land tenure lower than men farmers between 15-59 years and men who are married. This finding was likely due to the patriarchal nature of the Talensi district, where it is against socio-cultural norms and customs for a widow to head a household. In contrast, when a man succeeds a deceased household head, he assumes the role of head and gains more ownership and control over land (Alare et al., 2022). Likewise, for improved agricultural practices and secondary occupation (indicators rated as predominantly supporting farmers), support was highest among farmers with high economic status and men, respectively. Despite the differences, there are common factors to investigate when identifying possible intersectional impacts of policy interventions. This study's common factors included climate variability and access to information, which constrained all smallholder farmers. Notably, an intersectional approach must also identify common factors prevalent across all locations and among all smallholder farmers. Such analysis is essential to unpack unique intersectional dynamics (Axelrod et al., 2022).

#### 6. Conclusion

In advancing research on the need for more intersectional analysis to better understand vulnerability to climate extremes in Ghana, this study adopted a mixed-method approach. This approach aligns with the growing calls for empirically grounded intersectional research to understand the diversity of actors pursuing adaptation, how intersecting identities shape their adaptation in a highly diverse context, what policies could promote more equitable adaptation within and across heterogeneous communities and, thereby, foster a more nuanced and critical analysis of climate change and inequality dynamics. The study draws from a systematic random sample of 130 smallholder farmers and six focus group discussions with smallholder farmers in two discrete communities in the Talensi district in Ghana's northern savannah AEZ (a district identified as highly exposed to climate change, Opoku Mensah et al., 2023) who rated locally-derived indicators of each of the five livelihood capitals, as to the level of support provided to adaptation. Employing descriptive and inferential statistics and narrative analysis, the research unpacks how livelihood capital indicators intersect with these farmers' socio-demographics, either supporting or

constraining their climate adaptation efforts. Such an intersectionality approach allowed us to view vulnerability not just as the characteristic of some socio-demographic groups but as an outcome of interdependent and various societal stratification processes leading to multiple dimensions of vulnerability and revealing a more nuanced understanding of vulnerabilities and unpacked vulnerable groups.

While overall, the capitals appeared to provide limited support for adaptation, the considerable variation in the range of ratings assigned to individual indicators of each capital suggested that a deeper analysis is required to understand vulnerability and intersectionality. Analysis of the frequency distribution of ratings allowed individual indicators to be categorised into one of three groups. Two groups consisted of indicators skewed towards higher ratings (support for adaptation) and those skewed towards lower ratings (adaptation constraint). Between these two extremes, a third group of indicators appeared to show two distinct peaks, often at opposite ends of the rating scale, i.e. a bimodal pattern, suggesting that the support for adaptation provided by these indicators was perceived differently by sub-groups of farmers within the sample. Such nuanced interpretations of localised realities within specific agricultural contexts can offer insights into how these settings fit and intersect within the larger agricultural landscape.

The findings of this study hold significant implications for human-environment researchers in theorising climate vulnerability and inequality and formulating effective adaptation policies. These findings could assist adaptation practitioners and policymakers design interventions that facilitate effective adaptation among smallholder farmers with diverse backgrounds. From a policy perspective, integrating an intersectional analysis can be complicated and time-consuming (Hankivsky & Cormier, 2011). Nonetheless, avoiding simplistic analyses that overlook intersectional analysis with various dimensions is crucial. Failing to do so can result in suboptimal policies and further marginalise specific groups of smallholder farmers through a failure to acknowledge their differential interests and varied access to adaptive strategies (Chaplin et al., 2019; Raza, 2017). While the disparities between men and women can deeply shape their vulnerability, we suggest that other socio-demographic factors might hold equal or greater significance. By adopting an intersectional approach, policymakers can broaden their understanding of the differential needs of households and individuals to better target resources and support diverse adaptive strategies. Recognising that vulnerability is socially heterogeneous, policies must be tailored to reflect different farmer groups' diverse needs and capacities. This approach will ensure that interventions are targeted, equitable, and inclusive to obviate farmers' vulnerability, particularly those marginalised by their sociodemographic characteristics, and to foster sustainable agricultural communities.

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No potential conflict of interest was reported by the author(s).

#### Notes of contributors

Seth Opoku Mensah is a PhD researcher at the Institute for Sustainable Futures, University of Technology Sydney, Australia. Seth is a community-focused transdisciplinary development planner with a research interest in human-environment interactions, focusing on adaptive governance, climate change adaptation, livelihood dynamics, and nature protection and restoration.

Brent Jacobs is an Adjunct Associate Professor at the Institute for Sustainable Futures, University of Technology Sydney. Brent's background is in agricultural science, with broad experience in agricultural systems and ecophysiology of crops and pastures. His current research interests include transformation, vulnerability and the adaptive capacity of communities to support climate change adaptation.

Rebecca Cunningham is a trans-disciplinary social scientist with broad research interests and expertise in climate change adaptation, natural resource governance, network science, public uptake of policy, science communication and trust. Rebecca has contributed to a range of projects. Examples include undertaking vulnerability assessments and climate change adaptation plans, assessing the uptake of agricultural technologies to reduce water scarcity risk, exploring heuristics for decision-making in Australian agriculture, exploring the forced innovations undertaken by sectors and businesses due to a changing climate, understanding the climate information needs of small and mediumsized enterprises sector (including agriculture) and measuring knowledge transfer and efficacy using social network analysis.

#### ORCID

Seth Opoku Mensah 😉 http://orcid.org/0000-0003-4899-4254 Brent Jacobs (1) http://orcid.org/0000-0003-3147-341X Rebecca Cunningham (0) http://orcid.org/0000-0001-8066-9019

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#### **Chapter Six**

# The role of institutions in enhancing climate change adaptation by smallholder farmers in the Talensi district of Ghana

Chapter six is an article submitted to *Environmental Development*. It is under revision. The paper answers research question 3: What roles do institutions play in enhancing climate change adaptation by smallholder farmers?, and its sub-research questions:

- i. What are the various institution-led adaptation actions and their outcomes for smallholder farmers?
- ii. What challenges limit the implementation of institutional adaptation actions?

This chapter examines institutional-led adaptation efforts, focusing on three key dimensions: scale, scope, and sustainability.

Table 11: Statement of authorship for chapter six

Title of paper	The role of institutions in enhancing climate change
	adaptation by smallholder farmers in the Talensi district of
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	editing, visualization, project administration, formal analysis,
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Co-authors' contribution	
First co-author	Brent Jacobs
Contribution	10%
	Methodology, writing - review & editing, visualization,
	validation, supervision
Second co-author	Rebecca Cunningham
Contribution	5%
	Methodology, writing - review & editing, visualization,
	validation, supervision

### The role of institutions in enhancing climate change adaptation by smallholder farmers in the Talensi district of Ghana

#### **Abstract**

The Talensi district is home to many institutions offering diverse adaptation interventions, especially for smallholder farmers. However, there is a lack of empirical research on various institutional-led adaptation actions, their outcomes, and the challenges limiting their implementation. This case study of institutional interventions in the Talensi district focuses on three dimensions of institutions' operations—scale, scope and sustainability. Using qualitative primary data collected from eight institutions, the study showed that while the institutions implemented interventions—training and capacity building, technology transfer, input supply and marketing and value chain integration—to support smallholder farmers in adopting specific adaptation actions, they also focused on broader livelihood issues to support the communities to respond to developmental and environmental challenges. The institutions were also confronted with several sustainability challenges—including donor priority, market orientation, resources, policy support, planning, transparency and group formation—that negatively impacted their ability to reduce vulnerability and build the adaptive capacity of farmers. As farmers depend on different institutions to pursue their adaptation objectives, we suggest that adaptation in smallholder production systems should consider cross-linkages and synergies to support adaptation actions and avoid maladaptive outcomes. The findings highlight the interfaces between institutional interventions and farmer adaptation behaviours.

#### 6.1 Introduction

With the intensifying impacts of climate change, adaptation efforts are increasing globally, especially for the most vulnerable countries (Intergovernmental Panel on Climate Change [IPCC], 2022a; World Meteorological Organization [WMO], 2024). Smallholder farmers in lowincome countries systematically face compounding unfavourable situations that prevent them from pursuing agriculture as a viable and sustainable livelihood (WMO, 2024a) and, therefore, have been identified as a priority for support to adapt (Food and Agriculture Organization [FAO], 2024). Climate change adaptation, defined as adjusting to actual or expected climate and its effects to moderate harm or exploit beneficial opportunities (IPCC, 2022b), does not occur in an 'institutional vacuum' (Agrawal, 2008, p. 19). It is most effective when supported by wellaligned institutions across scales, sectors, policy domains, and timeframes (IPCC, 2022a) because they can contribute to conditions that guide households and collectives to adopt specific adaptation practices (Azhoni et al., 2024; United Nations Framework Convention on Climate Change [UNFCCC], 2020). Studies of climate change adaptation have largely occurred through the lens of adaptive capacity. Adoption of adaptation actions depends on farmers' adaptive capacity to control tangible and intangible resources (Tong et al., 2024). According to IPCC (2022b), adaptive capacity, the ability of systems, institutions, humans, and other organisms to adapt, predicates the success of adaptation, and its assessment identifies the factors hindering or promoting adaptation (Elrick-Barr et al., 2022).

Although institutions have been recognised to play important roles in enabling smallholder farmers' adaptation, corresponding research in this area is largely under-explored (He et al., 2022; Azhoni et al., 2024), especially in developing countries such as Ghana (the location of this study) (Yomo et al., 2020; Tahiru et al., 2019). IPCC (2022a) recommended intensifying smallholder farm-level research to understand how institutions shape farmers responses to climate change impacts and support their adaptation behaviours (IPCC, 2022a; Petzold et al., 2023), particularly in climate-sensitive areas (He et al., 2022). Such a focus has significant implications for developing climate change actions to address farmers' vulnerability (He et al., 2022). Institutions are humanly created mechanisms that shape social and individual expectations, interactions and behaviour (Agrawal, 2008; Park, 2023). Institutions are omnipresent and serve diverse purposes in adaptation that include operationalising adaptation campaigns (Stocker,

2014), mobilising climate funds (Yaro et al., 2015), communicating climate change information (Bawakyillenuo et al., 2016), establishing policy partnerships for effective adaptation (Béné et al., 2016) and delivering environmental services to vulnerable groups and communities (Tahiru, 2019). Institutions help to foster diverse approaches to adaptation and are recognised as key actors in knowledge production, risk and vulnerability mapping and community capacity building (Tahiru et al., 2019).

For climate change adaptation, institutions are commonly categorised into two groups; formal, which encompass tangible governance and organisational structures, and informal, which are the uncodified 'rules of the game', cultural norms and traditions that govern the behaviour and nature of human interaction (Jones et al., 2010, p.5; Mubaya & Mafongoya, 2017, p.94). While both formal and informal institutions can complement household and community adaptation efforts (Mubaya & Mafongoya, 2017), this study focuses on formal institutions supporting climate change adaptation by smallholder farmers because Ghana, the setting for the research, is regarded as having a well-established rural governance infrastructure, mainly dominated by formal institutions that promote practices to reduce farmers' vulnerability and maintain sustainable livelihoods (Yomo et al., 2020). Also, actions by informal institutions are likely to be constrained in resource-limited settings. There is a limit in the degree to which shared social and human capital in informal settings can substitute for the physical and financial capital (as well as human and social capital) that formal institutions (such as through development aid projects) often deliver (e.g. Marosevic & Jurkovic, 2013; Cunningham & Dibooglu, 2020). This focus does not discount the relevance of informal institutions. Indeed, informal institutions—including extended family support networks, local norms of reciprocity, and traditional authorities (Haggis et al., 1986; Cunningham & Dibooglu, 2020)—remain deeply embedded in rural life and are highly relevant in shaping adaptive behaviours in many African agrarian contexts (Mubaya & Mafongoya, 2017; Browne et al., 2024). However, the decision to focus on formal institutions was driven by the specific objectives of this chapter and the broader research aims of the thesis, which sought to critically examine how state and non-state institutional arrangements influence the design, delivery, and equity of planned adaptation support mechanisms. While not the central focus here, social capital—community groups, farmer networks and social networks as part of informal institutions are discussed in Chapters 4 and 5.

Agrawal (2008) further categorises formal institutions into three types based on their actions. These include state/public covering bureaucratic administrative units and elected local governments, private/market that pursue commercial interests, including service organisations and private businesses, and civic/civil society that refer to non-governmental organisations and other hybrid entities such as membership and co-operative organisations. Collectively, these types of institutions act to influence adaptation in three major ways: (i) they reduce the vulnerability of smallholder farmers in a given socio-ecological context; (ii) they create an incentive framework and shape how smallholder farmers collectively or individually respond to climate change; and (iii) they mediate the effect of external interventions on climate adaptation (Agrawal, 2008; Yomo et al., 2020). Communities' vulnerability hinges on biophysical outcomes and the place-based, socio-political and institutional framework that largely determines adaptive capacity (Adger, 2006; Mubaya & Mafongoya, 2017). In assessing the structure and function of institutions to support adaptation, three elements are critical (Agrawal, 2008; Mubaya & Mafongoya, 2017): the institutional landscape, institutional accessibility, and institutional linkages.

The institutional landscape is formed from the nature and goals of the range of institutions operating to support adaptation. Typically, adaptation occurs in multi-actor settings, where the goals of each institution can vary (Petzold et al., 2023). State/public institutions are usually expected to act on public infrastructure or moderate institutional adaptation in the interest of society at large. Civic/civil society and market/private institutions are generally not held to such expectations and might act in their own best interests and immediate benefit (Petzold et al., 2023). With their primary focus on regulating socio-economic interactions and responding to public demands (state/public), promoting voluntary and social relationships (civic/civil society), or responding to commercial interests and generating profits (private/market), individual institutions may be constrained in the actions they can undertake to facilitate adaptation due to a lack of sufficient capacity or expertise (Agrawal, 2008). For example, while state/public institutions are often criticised for promoting economic development shaped by political interests that may not be in the interests of local communities (Park, 2023), civic/civil society institutions, such as humanitarian development organisations, are often criticised for responding primarily to the priorities of donors that may compromise the effectiveness of interventions (Dreher et al., 2024). Similarly, private/market institutions are often criticised for promoting products and

advisory services they can sell and offer as consultants (Quarshie et al., 2023; Tahiru et al., 2019). Institutions can, thus, spur, strengthen, or distort the emergence, adoption, and implementation of climate action and governance or hinder or weaken these processes (IPCC, 2022a).

Institutional accessibility examines the patterns through which specific types of institutions facilitate particular adaptation actions and explores the variety of tools institutions may implement to shape the type and extent of adaptation (Ray Biswas & Rahman, 2023). The intervention style and method can enable or constrain risk and vulnerability reduction by including or excluding specific socio-cultural groups within society (Petzold et al., 2023; Ulibarri et al., 2022; Thompson-Hall et al., 2016). The tools available to institutions include informationbased instruments (awareness creation or promoting actions through information provision), direct regulation (policy or law restricting or mandating actions), economic instruments (subsidies, insurance, taxes, or other financial mechanisms), capacity building (supporting individuals to adapt more effectively), development of plans (mandated or voluntary) and enhancement of social capital through support for networks (inter-organisational collaborations or community networks) (Taylor et al., 2012; Ulibarri et al., 2022). Musah-Surugu et al. (2019) summarise the range of interventions by institutions in building the adaptive capacity of smallholder farmers into climate advocacy, direct climate service provision, and local empowerment to help them make considered farm-level decisions (Yomo et al., 2020; Bahinipati et al., 2024).

Institutional linkages refer to relationships among institutions and with rural households. In areas with multiple institutions, their impact on adaptation varies significantly based on how connected they are, their coordination in response to climate hazards, and their articulation with external institutions and resources (Agrawal, 2008). Institutions that lack links or where interactions conflict with others tend to be less effective than those with multiple positive links with other institutions and target communities (Agrawal, 2008; Azhoni et al., 2024).

Realising complex and ambitious goals, such as effective adaptation (UNFCCC, 2020), climate equity and justice (Kerr et al., 2022), and the Sustainable Development Goals (SDGs) (United Nations [UN], 2015; Pradhan et al., 2025), requires institutions to continue to be active in promoting adaptation (IPCC, 2022a; Witinok-Huber et al., 2025). This study focused on the Talensi district in Ghana's northern savannah Agro-ecological Zone (AEZ) due to the high

vulnerability of its agriculture and the significance of formal institutional support (Abunyewah et al., 2024). The aim was to investigate how institutions enable smallholder farmers to navigate climate-related risks and effectively adapt. Though the Talensi district is home to many institutions offering diverse climate change interventions, such as capacity building and ecological restoration (Abunyewah et al., 2024; Opoku Mensah et al., 2024), there is a lack of empirical research on various institution-led adaptation actions, their outcomes, and the challenges limiting the implementation of adaptation actions. This case study of institutional interventions in the Talensi district focuses on the institutional landscape (nature and goals of the identified institutions), institutional accessibility (how adaptation actions are facilitated) and institutional linkages (coordination among institutions and connection to communities) for vulnerable smallholder farmers. It also documents the challenges faced by institutions in supporting smallholder farmers to adapt to climate change. The findings highlight the interfaces between institutional interventions and farmer adaptation behaviours.

#### **6.2 Methods and materials**

#### 6.2.1 Study area description

The Upper East region is one of sixteen regions of Ghana, which are further subdivided into 216 districts for administrative purposes. The Talensi district (Figure 13) is one of the 15 administrative districts of the Upper East region of Ghana. Bolgatanga serves as the regional capital of the Upper East region, whereas Tongo serves as the district capital of the Talensi district. This district was chosen because of its distinct local socio-economic and climatic characteristics, including exposure to climate change, ecological sensitivity, historical lack of development, the existence of institutions supporting improved agricultural practices and adaptation interventions, and its agro-pastoral livelihoods (Abunyewah et al., 2024; Opoku Mensah et al., 2025). The district experiences two distinct seasons: a dry season from November to April and an unpredictable rainy season from May to October. The Talensi district receives 950 mm of rain on average annually. March and April see the highest average yearly temperature of 45°C, while December sees the lowest temperature of 12°C (Talensi District Assembly [TDA], 2022; Ghana Statistical Service [GSS, 2014]). The district's dryland (non-irrigated) agricultural production system is environmentally fragile (Opoku Mensah et al., 2023).

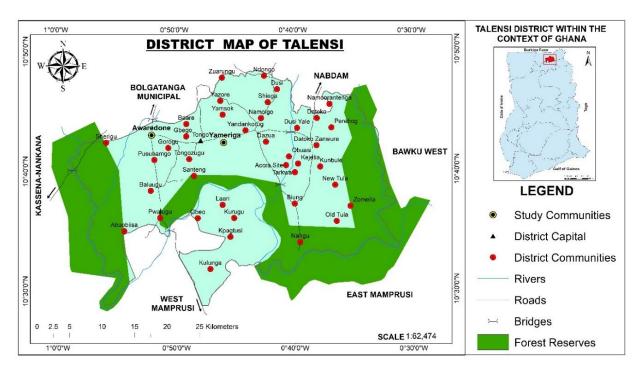


Figure 13: Map of the Talensi district, showing the locations of Awaredone and Yameriga Source: Opoku Mensah et al., 2023; Abunyewah et al., 2024.

Figure 14 shows the temperature and rainfall trends in the Talensi district during the past 42 years. Generally, temperature has increased over a 40-year period (see Figure 14 and Table 12). Figure 14 shows an increase in annual average precipitation with consistently high inter-annual rainfall variability across months and seasons in the district (Table 13). Inter-annual rainfall variability in the dry season is increasing with an increasing trend relative to the rainy season.

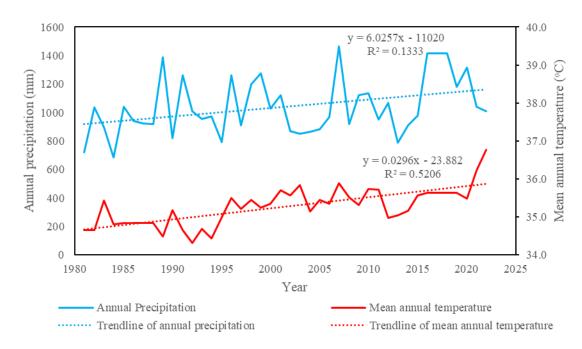


Figure 14: Precipitation and temperature change of the Talensi district for the past 42 years (1981–2022)

Source: Author's construct using meteorological data collected from the Upper East regional office of Ghana Meteorological Agency (GMet) (2022)

Table 12: Statistical summary of temperature in the Talensi district for the past 42 years (1981–2022)

Parameter (°C)	Min	Max	Mean	SD	CV	MK
Average annual temperature	34.3	36.8	35.27	0.50	0.01	4.94***
January	32.2	37.7	35.36	1.50	0.04	1.65*
February	35.0	40.1	37.73	1.20	0.03	2.73***
March	37.6	44.0	39.67	1.11	0.03	2.99***
April	37.0	47.4	39.58	1.57	0.04	1.01
May	33.0	38.4	36.41	1.16	0.03	1.02
June	32.1	35.0	33.48	0.70	0.02	1.18

July	30.1	33.1	31.40	0.76	0.02	3.15***
August	29.6	36.1	30.64	1.01	0.03	3.53***
September	28.5	34.0	31.55	0.82	0.03	0.95
October	32.3	36.0	34.23	0.90	0.03	1.83*
November	34.2	38.5	36.88	1.19	0.03	5.03***
December	34.0	37.8	36.34	0.97	0.03	2.50**

Note: \*, \*\*, \*\*\* indicate significant statistical levels of p < 0.1, p < 0.05, p < 0.01, respectively; CV < 0.20 = Low, 0.20 < CV < 0.30 = Moderate, CV > 0.30 = High

Source: Author's construct using meteorological data collected from the Upper East regional office of GMet (2022)

Table 13: Statistical summary of rainfall in the Talensi district for the past 42 years (1981–2022)

Parameter (mm)	Min	Max	Sum	Mean	SD	CV	MK
Average annual rainfall	57.1	122	3641.6	86.70	16.88	0.19	2.18**
Rainy season	623.9	1309.1	40420.4	962.39	188.32	0.20	1.66*
Dry season	6.4	182	3278.6	78.06	46.06	0.59	2.69***
January	0.0	1.2	1.4	0.03	0.19	6.33	-0.25
February	0.0	23.1	96.5	2.30	5.64	2.45	0.62
March	0.0	97.8	839.4	19.99	27.06	1.35	1.65*
April	2.8	176.5	2036.6	48.49	37.83	0.78	2.48**
May	32.6	199.8	4328.7	103.06	42.59	0.41	2.32**
June	36.8	275.5	5590.1	133.10	52.63	0.40	-0.20

July	74.8	446.5	8073.2	192.22	91.85	0.48	0.80
August	95.6	601.3	11247.4	267.80	109.79	0.41	0.61*
September	23.8	331.1	8542.0	203.38	74.40	0.37	-1.78*
October	0.0	236.1	2639.0	62.83	46.86	0.75	-1.88*
November	0.0	46.5	233.3	5.55	10.25	1.85	-0.81
December	0.0	44.6	71.4	1.70	7.85	4.62	-0.88

Note: \*, \*\*, \*\*\* indicate significant statistical levels of p < 0.1, p < 0.05, p < 0.01, respectively Source: Author's construct using meteorological data collected from the Upper East regional office of GMet (2022)

Significant impacts of climate change have been experienced in the Talensi district, including floods, wildfires, starvation, drought, crop loss, and pest infestations (TDA, 2022). Agriculture plays a significant role in the district, with 91% of households engaged. These households are mostly smallholders whose agricultural production depends on a favourable climate (TDA, 2022; GSS, 2014). The primary agricultural activity is agro-pastoralism, which involves crop farming and livestock production. Some silviculture and aquaculture are also practiced (TDA, 2022; GSS, 2014). The smallholder agro-pastoral farmers in the district have seen declining soil fertility, leading to loss of productivity, loss of forest cover, disappearance of biodiversity, and variability in annual rainfall (TDA, 2022). The Talensi district's agro-pastoral production system is among Ghana's most vulnerable to climate-related hazards, including seasonal temperature changes, rainfall variability, and extreme events. Additionally, the system is weakened by persistent poverty and inadequate infrastructure development (TDA, 2022). Institutional interventions are implemented for the smallholder farmers in the Talensi district to support adaptation and maintain sustainable livelihoods, which include ecological restoration and capacity building (Opoku Mensah et al., 2023; 2024). The Talensi district was considered an appropriate choice for the study because of its biophysical environment and strong institutional presence (Abunyewah et al., 2024).

#### 6.2.2 Survey design and data collection

This study adopted a qualitative research method to provide a nuanced understanding of the role of institutions in smallholder farmers' climate change adaptation practices in the Talensi district. This study utilised a case study approach (Chenani et al., 2021) of institutions to achieve its research objectives. Such an approach enables researchers to comprehensively understand society and its local actors' perceptions and access context-specific evidence and observations (Ford et al., 2010). A deductive approach (Bingham, 2023) was employed to qualitatively understand the contextual contributions of institutions to smallholder farmers' climate adaptation practices in semi-arid Ghana. The study adopted semi-structured interviews to collect primary qualitative data to analyse experiences, events and opinions and better understand how different respondents perceive and interpret these meanings (Dunn, 2021). Such interviews also provide nuanced qualitative insights into the experiences and perceptions of participants (Strijker et al., 2020).

Fieldwork was conducted between September 2022 and March 2023. The primary data collection consisted of in-depth interviews with institutions involved in climate change and agricultural production in the Talensi district. The lead researcher interviewed eight institutions based on their availability, applicability and willingness to participate in the study. To ensure that the data represented the institutional landscape in the district, a mix of the three institutional types—state/public (n=4), private/market (n=1), and civic/civil society (n=3)—were interviewed. These institutions have extensive experience, knowledge, and recognised involvement in climate change initiatives, agricultural production and rural development in the district. The lead researcher conducted all interviews to clarify discrepancies, minimise interpretation bias, and validate responses (Lawless et al., 2022). Representatives from identified institutions, who were mainly field staff, were interviewed. The interviews explored the nature and goals of the identified institutions (landscape), how they facilitate adaptation actions—as identified during the interviews—through implementation tools (accessibility), whether and how they coordinate their responses and whether they cover the most vulnerable smallholder farmers (linkages). The interviews were conducted in English, the official language of Ghana, and at the institutions' offices. The interviews lasted approximately an hour and were audio-taped with the consent of the participants. The study also utilised secondary data sources (Chatfield, 2020)—including

institutional websites, published reports, and programme/project documents—to better understand the structure and function of the institutions to support adaptation.

## 6.3 Data Analysis

The data were deductively analysed using thematic and narrative analysis (Bryman, 2012). Audio recordings were transcribed verbatim into text. The texts were compiled and compared against the recorded audio files to understand the varying opinions within the text and to ensure the accuracy of the data (Møller et al., 2018). This data set was meticulously read several times to identify and thoroughly understand the raw data (Møller et al., 2018). NVivo 14 was used to code the transcripts according to themes (Bryman, 2012). In emphasising stories articulated by respondents, narrative analysis using quotations was adopted to substantiate claims and illustrate the interconnections between themes (Bryman, 2012). To ensure rigour and trustworthiness, respondents' own words were maintained with low use of inference descriptors (Baxter & Eyles, 1997). Document review analysis was used to analyse the secondary data (see Davila et al., 2024). The various secondary data sources were reviewed to understand the structure and function of the institutions, focusing on their aims, focus of interventions, scale of operation and key challenges. The secondary data were also cross-referenced with the primary data to provide a comprehensive understanding of the structure and function of the institutions.

### 6.4 Ethics approval

The research received approval from the Human Research Ethics Committee (HREC) at the University of Technology Sydney (UTS), under approval number UTS HREC ETH22-7303. Before administering interviews, all respondents provided informed consent for their involvement.

#### 6.5 Results

## 6.5.1 Institutional landscape

The three categories of institutions, state/public, private/market, and civic/civil society, operated in the Talensi district to support smallholder farmers in changing the way they farm in response to the changing climate (including climate variability/seasonal variations, extreme weather

events, long-term temperature change etc.) (Table 13). Four of the eight institutions identified were state/public (TDA, Environmental Protection Agency [EPA], Department of Agriculture [DoA] and Ghana Meteorological Agency [GMet]). One was a market/private institution (Kundok Development Consult [KDC]). Three were civic/civil society institutions (Farmer Training Centre [FTC], Widows and Orphans Movement [WOM], and World Vision Ghana [WVG]). Table 14 summarises key details about each institution's operations, concentrating on their aims, focus of interventions, scale of operation and key challenges.

The aims of the institutions operating in the Talensi district were multi-purpose—to reduce general vulnerability and promote specific adaptation actions. Thus, the institutions rarely focused solely on adaptation; instead, they generally addressed broader livelihood issues to support the communities to respond to developmental and environmental challenges. Specifically, the institutions focused on climate resilience, environmental sustainability, climate-smart agriculture (under drought conditions), risk assessment and planning, alternative livelihoods (specifically for women) and agricultural productivity. The state/public institutions collectively focused on building climate resilience by promoting sustainable land use, water management, and climate-smart agricultural practices. The TDA, as the local government body, focused on infrastructure provision and service delivery. The EPA emphasised environmental regulation and monitoring. While the DoA provided technical assistance and extension/veterinary services, the GMet delivered climate information to help farmers manage climate risks. A TDA member stated:

Our mission is to ensure that development reaches every corner of the district. That means prioritising climate-resilient infrastructure and policies that help our communities adapt to the changing environment, improve their livelihoods and safeguard the future of farming in the Talensi district.

TDA staff member

In terms of the scale of operation, all the state/public institutions were mandated to provide support either regionally or for the entire Talensi district. For example, EPA and GMet operated in the whole Upper East region, with the former mainly focusing on high-risk environmental areas and the latter with weather stations in key areas. The Talensi district, however, did not have its own weather station and depended on information from a neighbouring district's weather

station. As a local government body, the TDA operated in all communities in the district and the DoA focused on agricultural communities and households across the district. The state/public institutions reported being challenged by limited financial and logistical resources and national-level administrative control, which affected their ability to engage with local communities and provide comprehensive services to all communities. Other challenges reported to hinder the effectiveness of their operations included limited transparency and accessibility of information.

Table 14: Key details of institutions operating in the Talensi district

Institutions	Aims	Focus of interventions	Scale of operation	Key challenges
State/public				
Talensi District Assembly	To provide local governance, development, and service delivery to improve livelihoods in the district	Climate-resilient infrastructure and local policies that support adaptation actions	District-wide, covering all communities	Faces funding and logistical constraints due to national-level control, limiting reach and engagement with farmer groups
Environmental Protection Agency	To protect the environment and promote sustainable development by regulating and monitoring environmental activities	Sustainable land use, soil conservation, and water management and environmental impacts of climate change	Regional-wide, with a focus on high-risk environmental areas	Limited collaboration with other institutions, impacting localised adaptation planning

Department of	To improve agricultural	Climate-smart agriculture	District-wide, with a	Faces issues with
Agriculture	productivity, promote	practices, including the	focus on agricultural	transparency in
	food security, and	use of drought-resistant	communities and	beneficiary selection
	support farmers	crops and improved	households	processes, impacting
	through technical	irrigation techniques		community trust and
	assistance and			participation
	extension/veterinary			
	services			
Ghana Meteorological	To provide accurate	Early warning systems,	Regional-wide, with	Limited local
Agency	weather and climate	weather forecasts, and	weather stations in	engagement; weather
	information to enhance	climate data for improved	key areas	data is not always easily
	planning and decision-	planning and risk		accessible to farmers
	making	management		
Market/private				
Kundok Development	To provide consultancy	Climate risk assessments	Operates in selected	Risk-averse due to
Consult	services that promote	and design of adaptation	communities in the	market-driven funding,
	sustainable	actions	district	which limits long-term
	development through			investments in uncertain
	climate-smart solutions			adaptation projects

# Civic/civil society

Farmer Training Centre	To build the capacity of farmers by providing training on sustainable agricultural practices and livelihood diversification	Sustainable farming techniques, agroforestry, and improved storage systems to enhance resilience	Operates in multiple communities across the district	Relies on community donations for demonstration activities, which may limit expansion to other areas
Women and Orphans	To empower women	Empowerment of	Operates in multiple	Demonstrating impact is
Movement	and orphans through	vulnerable groups (e.g.,	communities across	resource-intensive and
	livelihood training,	widows), climate-resilient	the district with a	crucial to maintaining
	support and advocacy,	farming and alternative	focus on specific	funding, which limits
	focusing on sustainable	livelihoods	vulnerable groups in	long-term continuity
	development and social		the district	
	inclusion			
World Vision Ghana	To improve child well-	Increased agricultural	Operates in multiple	Donor-driven priorities
	being and community	productivity and	communities across	sometimes misalign
	resilience through	community resilience to	the district with a	with local conditions,
	humanitarian and	climate shocks	focus on specific	impacting sustainability
	development		vulnerable groups in	and community
	interventions, including		the district	ownership of
	climate adaptation			interventions

The market/private institution, KDC, consulted with farmers on climate-smart technical solutions (Table 14). Unlike the state/public institutions that were mandated to promote the development of the entire district, the market/private institution selected communities based on the institution's strategic plan. KDC reported being limited by a risk-averse, market-driven funding approach, which restricted its ability to engage in long-term or widespread operations, especially in areas where financial returns were uncertain. The civic/civil society institutions primarily focused on building community resilience through capacity-building programmes, climate-resilient farming, livelihood diversification, and empowering vulnerable groups. Specifically, the FTC focused on training farmers in sustainable agricultural practices, agroforestry, and improved storage systems to enhance resilience to climate change. The WOM empowered vulnerable groups, particularly women and orphans, by providing training in climate-resilient farming practices and promoting alternative livelihoods. Similarly, WVG worked to improve agricultural productivity and community resilience to climate shocks, particularly through humanitarian and development interventions, including climate adaptation. A WOM staff member commented:

We focus on building community resilience because empowering vulnerable groups, like women and orphans, through capacity-building programmes and livelihood diversification is key to helping them adapt to climate change. By providing them with the necessary skills and tools, we ensure they can sustainably support themselves and their families in the face of environmental challenges.

#### WOM staff member

In common with the market/private institution, the civic/civil society institutions selected communities based on the institutions' strategic plans. For example, WOM and WVG assisted specific vulnerable groups within multiple communities across the district. While the civic/civil society institutions aimed to have a broad impact, their operations were reportedly constrained by resource limitations and donor-driven priorities. These constraints affected the scale and sustainability of their operations, particularly when it came to maintaining outcomes of intervention programmes and ownership by the communities.

#### 6.5.2 Institutional accessibility

Participants identified 36 actions their institutions promoted within the Talensi district (Table 14). The adaptation actions were tailored to address the district's vulnerability to climate change and variability, including droughts, heat waves, and flooding, which have significantly impacted agricultural productivity and livelihoods. These actions were categorised into four types of interventions: training and capacity building, technology transfer, input supply, and marketing and value chain integration. Actions under training and capacity building concentrated on training for farmers in either agricultural practices (e.g. agronomy, animal husbandry) or business management skills (e.g. microenterprises) with lesser emphasis on the provision of climate information and networking (e.g. farmer cooperatives and savings and loans group establishment). Actions under technology transfer focused on supplying farmers with essential technologies for enhancing their agricultural productivity. These technologies included the provision of irrigation equipment, water storage and management solutions, and small-scale farming machinery.

There was also some emphasis on post-harvest handling technologies, modern aquaculture technologies and practices, and financial technologies. Under input supply, actions centred on providing farmers with the necessary agricultural inputs, such as high-quality/improved seeds and basic farming equipment. Actions such as the supply of agrochemicals, including chemical fertilisers and pesticides, and specific inputs for animal production, including animal feed and health products, were limited. For marketing and value chain integration, key actions focused on promoting marketing techniques, linking farmers to ready markets, and establishing strong connections between farmers, distributors and institutions. This intervention also included actions to enhance the marketability of agricultural produce and small-scale enterprise or business development activities. There was some emphasis on connecting farmers to international markets and sustainable value chain development plans.

State/public institutions reported involvement in all types of interventions, although the level of involvement of specific institutions varied considerably (Table 15). DoA was the key public institution involved in all intervention types. It was involved in 37 of the 38 actions. The TDA was particularly involved in irrigation and input supplies. While the EPA was limited to actions on integrating trees into farming landscapes, environmentally friendly farming practices and

water resource management, GMet focused on climate information and its use. The civic/civil society institutions covered a similar range of actions with minor variations in emphasis, as shown in Table 4. KDC, the market/private institution, consulted on agronomy, seed technology, market establishment, and business development.

## 6.5.2.1 Capacity building

While the interviews revealed that the institutions collectively used a wide range of implementation tools (including capacity building, network establishment, economic instruments, real-time information, direct regulation and planning) to support adaptation actions, capacity building was the most common method of intervention. The institutions generally agreed that training increased farmers' ability to adopt and implement climate-smart and sustainable practices. A FTC staff member reported that:

By using capacity building instruments, we foster a culture of self-reliance among smallholder farmers. We equip them with the skills and resources necessary to adapt effectively to climate change without depending heavily on external inputs and interventions.

FTC staff member

Institutions reported using capacity building intervention to create awareness of and community sensitisation to climate impacts and adaptation options (refer to the first quote of Supplementary material 1). Awareness raising was achieved through community meetings, community information centres and radio broadcasts, extension services, farmer field visits, demonstration farms and school and youth programmes. However, electronic communications (e.g. through mobile phones, short message service (SMS), social media, and digital platforms) and printed materials (e.g. posters, flyers and brochures) were used minimally or not at all.

Table 15: Institutional adaptation actions in the Talensi district

Interventions	Adaptation actions	Implementing institutions							
				/Public		Market/	Civi	c/civil so	ciety
						private			
		TDA	DoA	EPA	GMet	KDC	FTC	WVG	WOM
Training and	Train farmers on good agronomic practices								
capacity building	Train farmers on animal husbandry production			Г					
	Train farmers on environmentally friendly farming practices								
	Train farmers on crops and livestock value chains								
	Train farmers on support services								
	Train farmers on best practices for seed planting and management								
	Train farmers on machine operation and maintenance								
	Provide farmers with real-time climate information								

	Train farmers on life skills and microenterprise						
	Train farmers on business management and vocational skills						
	Train farmers on microenterprise coaching and mentoring						
	Train farmers on integrating trees into farming landscapes						
	Form and support farmer-based organisations and cooperatives						
	Facilitate the creation of savings and loans groups						
	Impose mandatory obligations or restrictions						
	Develop climate change adaptation plans						
Technology transfer	Supply farmers with equipment for irrigation						
ıransıer	Provide water storage and management solutions						
	Transfer technologies for better post-harvest handling						
	Procure and supply small-scale farming machinery						

	Transfer modern aquaculture technologies and practices				
	Implement financial technologies tailored to the needs of farmers				
Input supply	Supply farmers with high-quality/improved/certified seeds				
	Supply farmers with chemical fertilisers				
	Supply farmers with pesticides, insecticides, fungicides and herbicides				
	Supply farmers with basic farming equipment/tools				
	Supply animal feed and health products				
Marketing and value	Promote effective marketing techniques				
chain value	Link farmers to ready markets				
integration	Establish linkages between farmers and buyers				
	Improve the marketability of agricultural produce				
	Motivate farmers to use input and output markets		 		

Establish strong linkages among farmers, aggregators and institutions				
Undertake small-scale enterprise or business development activities				
Connect farmers to international markets				
Design a sustainable value chain development plan				
Create tree and land-based jobs and income-generating opportunities				
Establish sustainable production of high-value dryland products				

Notes:	Institution implements adaptation action
	Institution supports in implementing adaptation action
	Institution neither implements nor supports adaptation action

The institutions also used networks as implementation tools to promote communal resource management practices such as natural regeneration, water-sharing systems, and collective storage solutions. For example, the civic/civil society institutions facilitated the creation of savings and loans groups to offer financial literacy activities to help farmers manage climate risks and invest in adaptive practices (refer to the second quote of Supplementary material 1). In addition to the institutions facilitating the creation of savings and loan groups, they also formed and supported farmer-based organisations and cooperatives (see Table 15). Civic/civil society institutions mostly used these implementation tools. The institutions revealed that promoting networking significantly reduced farmers' vulnerability to climate impacts. A FTC staff member emphasised the role of networking in facilitating knowledge exchange, resource access, and collaboration, all of which were crucial for helping farmers adapt to climate change:

Networking allows farmers to connect with others and link up with markets, extension services, and other institutions, making it easier for them to access information and technology that supports their adaptation efforts. Farmers learn from one another through these networks and collaborate on solutions that strengthen their ability to adapt to changing climate conditions.

FTC staff member

The interviews also revealed that all the institutions had plans or strategies as implementation tools for their adaptation actions. The institutions developed adaptation plans to address local climate impacts as part of their broader goals. For instance, state/public institutions like the TDA mainstreamed climate change adaptation into a broader District Medium Term Development Plan (DMTDP). Similarly, civic/civil society institutions like WVG mainstreamed climate change adaptation into its Area Programme Plans (APPs). The quote below from a TDA staff member highlighted how institutions used planning to integrate climate adaptation into district-wide strategies and provide tailored solutions that empowered farmers to adapt to changing conditions:

We use planning as a critical tool to align climate adaptation efforts with the broader district development goals. By integrating adaptation into our local plans, we ensure smallholder farmers can access coordinated support across agriculture, water management, and disaster preparedness.

TDA staff member

### 6.5.2.2 Technology transfer

Institutions indicated that technology transfer intervention was used mainly to reduce farmers' vulnerability to seasonal weather extremes, increase their productivity, and reduce post-harvest losses. These technologies were seen to empower smallholder farmers with modern skills and promote efficient resource use to foster effective adaptation. A WVG staff member explained:

By providing access to modern tools and infrastructure and efficient farming practices, we help farmers adapt to the impacts of climate change and ensure sustainable agricultural development by boosting productivity and reducing losses.

WVG staff member

While implementing financial technologies (economic instruments) such as mobile money platforms and microloans via mobile platforms was limited to the civic/civil society institutions, promotion of post-harvest handling technologies was limited to state/public institutions. Additionally, there was a lesser emphasis on modern aquaculture technologies across all institutions. In emphasising the importance of post-harvest handling technologies and why they are less promoted in the district, a DoA staff member commented:

The cost of implementing post-harvest infrastructure makes it difficult to prioritise these technologies at this time. While we understand the value of improving storage, most of our efforts have to go toward helping farmers increase production and become more resilient to climate change.

DoA staff member

In discussing the factors that collectively make aquaculture a less attractive option for institutions in the district, TDA staff revealed that it was primarily driven by geographic and environmental constraints, high investment costs, a lack of technical expertise, and a preference for supporting traditional farming practices (refer to the third quote of Supplementary material 1).

## 6.5.2.3 Input supply

Input supply interventions were implemented through the provision of supplies (agrochemicals, seeds, equipment) and economic instruments (subsidies, access to credit). Most commonly, DoA and TDA (state/public institutions) provided subsidised inputs,

although KDC (market/private institution) and all civic/civil society institutions were involved to a lesser extent. In emphasising the role of subsidies in reducing financial constraints and enabling farmers to adopt climate-resilient practices, a TDA staff member indicated:

Subsidies [for inputs] are crucial for helping farmers transition to sustainable methods, especially in a district where climate variability severely affects crop yields. Without financial support, most farmers would struggle to invest in the technologies and practices needed to adapt to the changing climate. These inputs allow farmers to maintain or increase their yields despite adverse climatic conditions, helping to secure their food supply and income.

TDA staff member

Although the institutions recognised subsidies' role in supporting farmers, they also acknowledged difficulties in ensuring the equitable distribution of subsidies, which hindered the ability to effectively support those in greatest need of assistance, as captured in the fourth quote of Supplementary material 1. Institutions reported that intervention through subsidies can inadvertently create dependency among farmers, and they were becoming increasingly sceptical about their long-term effectiveness as expressed by a TDA staff member:

Subsidies provide immediate support to farmers. However, we have become cautious about using subsidies because they often foster a culture of expectation, discouraging farmers from investing in local, self-reliant solutions vital for long-term adaptation.

TDA staff member

# 6.5.2.4 Marketing and value chain integration

Marketing and value chain integration intervention was implemented by linking farmers to markets, improving the marketability of their agricultural produce, and formulating sustainable value chain development plans. Marketing and value chain integration was used extensively, particularly by civic/civil society institutions, to support adaptation. The institutions revealed that exploiting business opportunities and market development were central to smallholder livelihoods. To reflect the strategic emphasis on implementing marketing and value chain integration, a WVG staff member stated:

Encouraging marketing and value chain integration is vital in our adaptation response. It connects farmers directly to broader markets, benefiting them from

economies of scale and access to new agricultural technologies. This strategy integrates them into a more sustainable agricultural value chain.

WVG staff member

The market/private and civic/civil society institutions (FTC and WVG) facilitated the design of sustainable value chain development plans as part of their adaptation actions to ensure that farmers integrate sustainable farming practices into profitable and resilient value chains. A staff member from KDC mentioned:

Our goal with these plans is to strengthen the entire value chain by empowering farmers with the skills and connections needed to market their produce. We develop such plans to guide the practice of eco-friendly farming practices and build a more sustainable future for our intervention communities.

KDC staff member

## 6.5.3 Institutional linkages

This section examines institutional responsibility for common adaptation actions (Table 15) to indicate potential linkages among institutions. These linkages and the connections between institutions and smallholder farmers are then further explored through interview analysis. Typically, institutions involved in adaptation actions could be separated into those that were responsible for implementing the actions and those supporting the actions' implementation (Table 14).

#### *6.5.3.1 Institution-to-institution linkages*

Some distinct patterns in institutional responsibility for interventions emerged in Table 15. For example, within the state/public institutions, DoA led adaptation actions focused on training farmers on various farming practices, including agronomic practices, animal husbandry with the support of the TDA and, to a lesser extent, EPA on environmental aspects of farming. GMet implemented training for farmers on support services and provided them with real-time climate information with DoA support. DoA's activities in capacity building overlapped with the civic/civil society institutions that were also actively engaged in implementing many aspects of agriculture-based training for farmers. However, civic/civil society institutions implemented actions where the training emphasised community development (such as life skills, microenterprise development, business management and

microenterprise coaching) with DoA in a supporting role. KDC's (market/private institution) role was limited to the implementation of training on agronomic and environmentally-friendly practices and it supported training on support services. The quote below from a WVG staff member highlighted why they work with state/public institutions.

We often work with state/public institutions because they provide policy and regulatory support and the authority we need to implement our adaptation actions. The state/public institutions also depend on our actions to reach more farmers with adaptation actions.

WVG staff member

For technology transfer actions, TDA played a more prominent role in implementation, keeping with its aim of providing equipment to smallholder farmers and collaborating with EPA through its role in water resources management (Table 14). DoA was involved in technology transfer of irrigation equipment supply and water management solutions. Except for post-harvest handling, DoA was the prominent support agency among state/public institutions. The civic/civil society institutions, particularly FTC and WVG, were also involved in implementing technology transfer actions (irrigation equipment supply and water management solutions), which overlapped with TDA's responsibilities. The civic/civil society institutions were solely responsible for implementing actions related to financial technologies. KDC (market/private institution) played no role in technology transfer.

For input supply, TDA and DoA implemented all actions on the provision of improved seeds, chemical fertilisers, pesticides, basic farming tools, animal feed, and health products. The three civic/civil society institutions played a role in the implementation of the supply of improved seeds and basic farming tools. KDC (market/private) implemented actions to provide farmers with improved seeds. The state/public institutions were not responsible for the implementation of actions under marketing and value chain integration, but TDA and DoA provided support for these actions. Conversely, the civic/civil society and market/private institutions were responsible for implementing these actions, emphasising linkages between farmers, buyers, distributors and institutions, establishing market linkages, promoting marketing techniques, and developing sustainable value chains (refer to the fifth quote of Supplementary material 1).

Despite the indication of overlapping and complementary roles in many types of intervention, the interviews suggested more complex relationships among institutions. These relationships were mediated by policy and regulatory support, timelines and mandates, lack of genuine integration, superficiality and differing aims or philosophies (such as market orientation). It was revealed that when the institutions implemented similar adaptation interventions such as training and capacity building, technology transfer and input supply, they often did so independently without collaboration or coordination (refer to the sixth quote of Supplementary material 1). The interviews showed that where the institutions interacted in implementing similar adaptation actions, such interactions were frequently superficial and cosmetic. For example, it was found that the civic/civil society institutions sometimes consulted with the state/public institutions for regulatory compliance but did not involve them in their planning, implementation, or evaluation. Similarly, state/public institutions invited civic/civil society institutions to meetings or events to showcase collaboration but rarely incorporated their input into their district-level policy or development plans. The quote below from a TDA staff member illustrates the superficial and cosmetic nature of their interactions:

We co-ordinate with civic/civil society institutions, but it is mostly for visibility and getting their endorsement rather than real collaboration. We consult them to fulfil our protocols. In reality, we do our activities independently, without integrating their advice or expertise into our interventions.

TDA staff member

It was also found that the market/private institution had limited involvement or interaction with the state/public and civic/civil society institutions. The staff of KDC stated how their market-oriented priorities and financial constraints affected their engagement with civic/civil society and state/public institutions:

We face financial and operational constraints, so we focus on commercially viable ventures and providing market-driven solutions. Collaborative community-based interventions often involve lengthy processes and uncertain outcomes, which limits our participation in those interactions.

KDC staff member

### 6.5.3.2 Institutions-to-farmers linkages

Geographically, all the state/public institutions were present in all communities in the Talensi district through their mandate to promote the development of the entire district. Conversely, the market/private and civic/civil society institutions selected communities based on their strategic plans. For example, WVG had an operational office in Tongo (the district capital) and implemented interventions in selected communities. Also, WOM had an operational office in Bolgatanga (the Upper East regional capital) and implemented interventions in selected communities. Institutions such as the DoA and all the civic/civil society institutions had decentralised structures that reached the lowest level of the farming communities. For example, while the DoA had agricultural extension agents, WVG had project officers based in the communities to provide ongoing support to farmers. The market/private institution (KDC) did not have an office in the district and operated from a different region. The staff admitted that this situation created communication barriers and reduced direct farmer interaction. He stated:

We have had fewer opportunities for routine face-to-face interactions for farmers to quickly and effectively communicate their needs, feedback, or issues to us. These issues are crucial for building trust, understanding local needs, and providing personalised support.

KDC staff member

The civic/civil society institutions had specific target groups within the communities that aligned with their mission. This situation was illustrated by WOM targeting farmers in households containing widows and orphans and WVG targeting farmers in households with vulnerable children (refer to the seventh quote of Supplementary material 1). A WOM staff member expressed:

As our name suggests, we target farm households that include widows and orphans. Thus, our reach is limited to specific segments of our intervention communities.

WOM staff member

Conversely, the state/public and market/private institutions did not target their activities to specific sub-groups in the communities. The state/public institutions revealed that they aim for district-wide, inclusive development to reach as many farmers as possible, regardless of their individual characteristics. A DoA staff member revealed:

As a state/public institution, our mandate is to serve all farmers across the district. We design our interventions as inclusive and broadly beneficial to reach as many people as possible rather than focusing on specific groups.

DoA staff member

Even though the state/public institutions were mandated to promote the development of the entire district, limitations in funding, personnel, and logistical capabilities restricted their ability to extend their impact to reach a more significant number of farmers or cover broader geographic areas simultaneously. Therefore, they focused on relatively small and easy-to-reach communities or specific groups of farmers (refer to the eighth quote of Supplementary material 1).

The market/private institution focused on interventions that maximised commercial viability across a broad farmer base without necessarily tailoring their support to specific groups. The KDC staff member stated:

Because we seek to maximise returns and market viability, we typically design interventions that target general farming practices and technologies that can benefit a wide range of farmers without necessarily tailoring our support to specific groups. Focusing on specific groups might limit our market scope and the scalability of our interventions.

KDC staff member

Dependence on local resources was not limited to state/public institutions but was necessary for all institutions to operate. The interview with FTC revealed how community-donated land was utilised for demonstration and training on sustainable agriculture practices, effective land management and water conservation techniques, organic farming, and crop rotation. A WVG staff member commented:

With the land donated by the Yameriga community, we have established a model community natural regeneration site that is governed as a common property resource. The site showcases sustainable land restoration and agricultural practice and is a testament to what we can achieve together in addressing the impacts of climate change.

WVG staff member

### 6.5.6 Adoption and sustainability of institutional adaptation actions

The interviews revealed several factors that affect the sustainability of institutional adaptation actions. The farmers reportedly adopted actions that were easier to practice. For instance, staff from WVG revealed why training farmers on integrating trees into farming landscapes through natural regeneration was an attractive and sustainable action for smallholder farmers.

Farmers prefer natural regeneration because it is simple and fits their traditional practices well. It requires little labour and makes their farms more resilient to changing weather patterns. Its benefits are seen quickly—the trees improve soil, provide shade for crops, and give firewood and fodder.

WVG staff member

The interview with WVG also revealed that due to the regrowth of forested land from natural regeneration practices, they introduced apiculture (beekeeping and honey production), especially in areas where good bee forage trees, including shea trees, had been regenerated. For example, WVG trained some farmers in Yameriga on beekeeping and sustainable honey harvesting and equipped them with beehives. It was revealed that farmers adopted apiculture due to its low cost and potential for high returns (refer to the first quote of Supplementary material 2).

The institutions mentioned that a ready market for adaptation actions offered farmers immediate and tangible economic benefits, motivating adoption. For example, the interview with WOM revealed that they supported women in shea butter production, which capitalised on the natural shea tree resources already abundant in the district. The production process required minimal inputs and could be scaled up to meet market demands (refer to the second quote of Supplementary material 2).

The institutions providing farmers with the necessary skills, knowledge, and technical support to implement adaptation actions were identified as crucial to their sustainability. Effective knowledge transfer reportedly helped build farmers' confidence and self-reliance, reducing dependency on external support and ensuring that adaptation actions continued after institutions exit. For example, the interviews with WVG revealed that the savings and loans groups they formed among farmers, especially women in Yameriga, remained functional even though direct support had stopped (refer to the third quote of Supplementary material 2).

Conversely, it was found that adaptation actions that failed to build the capacity of community leaders or groups to take over upon the institutions' exit or undermined farmers' agency often resulted in limited long-term success and dis-adoption. For example, it was found that irrigation schemes such as dams in Yameriga and Awaredone and a solar-powered mechanised borehole in Awaredone were currently not optimally functioning, and the communities were unable to repair them without support. An EPA staff member admitted:

Managing a new irrigation system centrally and not empowering community leaders to oversee and maintain the system is suicidal. When the institutions exit, the irrigation system may fall into disrepair and [become] abandoned. Currently, the communities cannot coordinate or troubleshoot issues on their own.

EPA staff member

## 6.5.7 Operational challenges of institutions

## 6.5.7.1 Donor priority

The civic/civil society institutions indicated that most actions were based on donor priorities and often not aligned with local conditions. The institutions noted that some donor actions were 'projectized, phased, or piloted'. They characterised such actions as problematic because their lessons and successes were rarely scaled up after funding ceases, especially if the projects ended before their intended completion dates. In explaining the impact of donor priorities versus local conditions on their climate change adaptation, a WOM staff member stated:

Our actions often have to align with the interests, priorities and reporting requirements of our donors, which do not always match the actual needs of farmers. This misalignment challenges our actions' long-term sustainability as they often do not fully apply to our communities' unique environmental and cultural contexts.

WOM staff member

#### 6.5.7.2 Market orientation

The market/private institution was challenged by its profit-driven focus, high costs, risk aversion, and limited collaboration with other institutions. In highlighting how the market orientation of this institution presented challenges in effectively supporting smallholder farmers, a KDC staff member narrated:

As a market/private institution, we focus on market-driven solutions that deliver immediate returns. Adaptation actions often require long-term investment, which can be risky. This situation creates a challenge in aligning our business goals with farmers' adaptation needs.

**KDC** staff member

#### 6.5.7.3 Resources

Resource limitations in funding, personnel, and logistics significantly challenged all institutions, particularly state/public institutions. For example, a staff member from the DoA advised:

Capacity building is not a one-time event. It requires ongoing support, monitoring, and follow-up to ensure that farmers can effectively implement what they have learned. However, we often lack the resources to support farmers after the initial training, especially in hard-to-reach communities.

DoA staff member

Some institutions reported that others provide transportation, travelling allowances, and meals to farmers when they attend their meetings, workshops, training sessions, or other related events, even in their resident communities. Such practices were described as counterproductive as not all institutions could provide the same, and farmers mostly boycotted their activities. These allegations were mainly raised against civic/civil society institutions (refer to the first quote of Supplementary material 3).

Information-based implementation tools, such as providing farmers with real-time climate information and training them on support services, were relatively uncommon among the institutional interventions (Table 15). They were used by the state/public institutions, mainly GMet and DoA. This situation was described as worrisome in a semi-arid area where such tools are necessary to enable farmers to make informed decisions to reduce the risks associated with unpredictable weather patterns. A GMet staff member commented on the lack of popularity of information-based tools among institutions in the district:

Information-based tools, such as real-time weather data and early warning systems, are not widespread among institutions. Many lack the technical capacity to integrate them into their adaptation interventions effectively. Additionally, there is a disconnect

between the information we provide and how it is communicated to farmers in an easily understood and applicable way.

GMet staff member

## 6.5.7.4 Policy support

As with information-based tools, direct regulation in the form of law or policy mandating or restricting actions was an uncommon intervention among the institutions. Where regulations covering aspects of adaptation exist, for example, the regulation of land use and forest conservation by state/public institutions, they were generally not enforced. The staff of the EPA highlighted the difficulties in enforcing regulations due to the informal nature of farming and the need for better communication and education to gain farmers' acceptance of regulatory policies.

Using direct regulations to promote adaptation among farmers is challenging because many smallholder farmers operate informally, making it difficult to enforce rules uniformly. Enforcing these regulations without sufficient education and incentives can lead to pushback, as many farmers perceive them as restrictive rather than supportive of their adaptation needs.

EPA staff member

#### 6.5.7.5 *Planning*

The interviews with the state/public institutions revealed that while civic/civil society institutions introduced useful adaptation actions, their work rarely aligned with the broader DMTDP, and the state/public institutions had little say in their implementation. Under current local development planning processes, all market/private and civic/civil society institutions are expected to integrate their adaptation plans into the DMTDP. This practice was, however, generally not adhered to. The lack of a binding formal mechanism for collaboration, synchronised planning, and shared objectives was revealed to hinder integration. A TDA staff member highlighted the procedural and systemic differences that impeded the effective integration of adaptation plans into a broader planning framework despite the potential benefits of such collaboration (refer to the second quote of Supplementary material 3).

Across all institutions, it was found that farmers played only a limited role in institutional adaptation planning. The institutions developed adaptation plans at the district level and these

rarely aligned with community adaptation needs. In emphasising the limited involvement of farmers in institutional adaptation planning, a KDC staff member stated:

The limited involvement of farmers in planning climate adaptation interventions leads to a mismatch between interventions and local needs, reduced ownership and buy-in, inflexible strategies, resistance to adoption, and increased dependency on external support. This situation ultimately compromises the implementation and sustainability of our efforts.

**KDC** staff member

### 6.5.7.6 Transparency

The institutions identified challenges for adaptation interventions in political interference and elite capture, particularly in state/public institutions. The institutions operated in an environment of high suspicion, secrecy, and a lack of transparency. Some institutions disclosed that they are aware of other institutions being confronted by communities because their beneficiary selection processes were perceived to be influenced by nepotism and favouritism and failed to benefit the truly needy farmers. Additionally, due to widespread allegations, farmers reportedly regarded some institutions with suspicion and disrespect (refer to the third quote of Supplementary material 3).

### 6.5.7.7 Group formation

The institutions mentioned that some farmers are unwilling to join groups and participate in their activities. For example, the civic/civil society institutions indicated that forming and working through groups was necessary to maximise the efficiency of their actions. A WOM staff member highlighted the difficulties they face in promoting effective adaptation strategies when farmers are unwilling to form or join groups.

Our interventions are designed to work best with farmer groups. However, many are reluctant to join due to complaints of distrust, fear of unequal benefits, a desire for independence, and past negative experiences. This unwillingness limits our ability to provide training, distribute resources efficiently, and implement collective actions.

WOM staff member

#### 6.6. Discussion

In the Talensi district, all three types of formal institutions (state/public, private/market, and civic/civil society) operated multifariously to support smallholder farmers in their adaptation efforts. However, to understand the role and influence of these institutions in climate change adaptation, three dimensions of their operations require consideration: scale, scope and sustainability.

#### 6.6.1 Scale

At district-scale, Talensi district attracted considerable institutional presence, which may be in response to its relatively high vulnerability to climate change (Abunyewah et al., 2024). Foremost among the types of institutions were the state/public institutions through their mandate to promote the development of the entire district (TDA, 2022). They implemented government policies and programmes to reach as many farmers as possible, and their interventions were broadly applicable at a wide scale (He et al., 2022). Because state/public institutions operate with public resources, they are often required to demonstrate that their interventions benefit entire communities and seek to avoid the perception of favouritism or exclusion (Rahman, 2021). He et al. (2022) found that in China, state/public institutions collectively focused on building climate resilience by promoting sustainable land use, water management, and climate-smart agricultural practices regionally or for the entire district, as was the case in Talensi.

The civic/civil society institutions in the Talensi district also operated across the district. However, these institutions tended to intervene in selected communities (e.g. WVG) or with specific social groups (e.g. WOM and women) guided by their strategic plans. Civic/civil society institutions primarily focused on building community resilience through capacity-building interventions, climate-resilient farming, livelihood diversification, and empowering vulnerable groups. Community-centric and grassroots approaches are commonly used by civic/civil society institutions (e.g., Tahiru et al., 2019; Rahman, 2021) due to their ability to engage closely with local needs, ensuring that the chosen interventions are relevant and impactful to the specified user group (in this instance vulnerable smallholder farmers).

Although not highly active, one market/private institution consulted with farmers on climatesmart technical solutions in selected communities based on its strategic plan and potential for commercial returns. This situation is not uncommon as market/private institutions rely heavily on market-driven funding mechanisms (Mendelsohn, 2006; Crick et al., 2018) ensuring they are risk-averse when investing in adaptation interventions involving uncertainties. The agriculturally risky Talensi district is placed at a relative disadvantage in attracting support from commercial entities because climate variability can dramatically affect agricultural outcomes (TDA, 2022; Abunyewah et al., 2024).

Spatial heterogeneity is a major feature of agricultural production systems that is critical in analysing adaptation (Antle et al., 2004; Liu & Masago, 2023). At community-level in the Talensi district, institutional presence was spatially 'patchy'. The reach and types of interventions available varied considerably across communities and groups. This spatial heterogeneity in institutional operations meant that not all farmers had access to the full range of support options for climate adaptation. Even though the state/public institutions were mandated to promote the development of the entire district, limitations in funding, personnel, and logistical capabilities restricted their ability to extend their impact to reach a more significant number of farmers or cover broader geographic areas simultaneously. Therefore, they focused on relatively small and easy-to-reach communities with some communities and farmers likely to be unable to access support.

The civic/civil society institutions targeted groups that aligned with their mission. Driven by specific development goals, such as empowering vulnerable groups, promoting gender equality, and supporting marginalised communities, they worked closely with local communities to identify the most vulnerable populations, such as women, widows, and vulnerable children, including orphans, to tailor their interventions to address their unique needs and challenges directly (Tahiru et al., 2019; Rahman, 2021). However, the communitycentric and grassroots approaches of civic/civil society institutions are not without challenges and their decision-making sometimes excludes parts of a region or community (Rahman, 2021). For example, according to Bebbington (2004), there are concerns about the uneven presence and activity of civic/civil society institutions across different spaces and scales countries, regions, districts, communities and households leading to an uneven distribution of resources, knowledge, ideas, power, and values often dictated by donor interest and priority (Bebbington, 2004; Rahman, 2021). Similarly, the civic/civil society institutions' interestbased selection of their beneficiaries has been criticised as biased, undermining the potential impact of adaptation interventions and their ability to meet long-term transformative goals (Bebbington, 2004; Banks et al., 2015; Rahman, 2021).

Not surprisingly, the commercial imperatives of the market/private institution ensured its presence was limited in the Talensi district to interventions that maximised returns and commercial viability, such as general farming practices and technologies across a broad farmer base without tailoring its support to specific groups (Mendelsohn, 2006; Crick et al., 2018). It often focused on areas with the potential for quick returns to seek a broad market appeal to justify its investments and achieve profitability. These practices limited its involvement with vulnerable smallholder farmers as focusing these groups specifically might limit their market scope and the scalability of their interventions.

#### 6.6.2 Scope

For smallholder farmers, institutions help define a framework where farmers can choose adaptation actions, with their responses to climate impacts shaped through interventions that build their adaptive capacity (Yomo et al., 2020; Musah-Surugu et al., 2019). Institutions operating in the Talensi district provided a variety of adaptation actions to support farmers in pursuing their adaptation objectives (cf. Table 15). These institutions intervened to address climate resilience, environmental sustainability, climate-smart agriculture (under drought conditions), risk assessment and planning, alternative livelihoods (specifically for women) and agricultural productivity. They sought to achieve improvements through a range of methods, including training and capacity building, technology transfer, input supply and marketing and value chain integration, which formed part of a matrix of support offered to assist farmers in everyday challenges and deal with climatic shocks (Yomo et al., 2020).

Within this available matrix of support, institutions in Talensi district played a multi-purpose role by implementing specific adaptation actions to reduce place-based climate change vulnerability and by supporting improvement in developmental and environmental challenges related to broader livelihood issues that went beyond impacts on agricultural production alone (Forkuor & Korah, 2023) (see Tables 14 and 15). The adaptation interventions offered by institutions in Talensi district align with Smith & Lenhart's (1996) specific options for water resources, forests, ecosystems and agriculture to reduce climate risks, and with the need for local empowerment, direct climate service provision, and climate advocacy to enhance adaptive capacities for community development (Musah-Surugu et al., 2019; Patnaik & Das, 2017).

Typically, civic/civil society institutions, although limited in scale to targeted communities, led interventions on community development, which included life skills, microenterprise

development, business management and microenterprise coaching, and reflected their more holistic approach to vulnerability reduction. Tahiru et al., (2019) and Haque et al. (2024), in working with farmers and communities in the Sahel Savannah of Ghana and the Coastal zone of Bangladesh respectively, recognised the commitment of resources by civic/civil society institutions to both on-farm (farming practices) and off-farm (support for livelihoods) adaptation interventions which can enhance the well-being and stability of smallholder farmers, and enable them to navigate developmental challenges and climate-related risks effectively (Forkuor & Korah, 2023; UNFCCC, 2024).

Béné et al. (2018) identified the need to align largely separate communities of practice related to social protection, disaster risk reduction and climate change adaptation to more effectively address chronic poverty, disasters and extreme events or long-term changes in climate conditions and their distribution over time and space respectively. They described the humanitarian-development continuum to improve resilience as a framework of response from coping through incremental adjustment to transformational responses, with the latter requiring interventions to address the long-term structural causes of vulnerability. Although the institutions in the Talensi district contributed to reducing vulnerability and enhancing the adaptive capacity of communities and farmers through their interventions, their current adaptation efforts were largely incremental adjustments relying on modifications to existing systems rather than aimed at achieving systemic transformation. Chowdhooree et al. (2020) and Rahman (2021) concluded that institutional actions, particularly those of civic/civil society institutions, are frequently small in scale, ineffective and unsustainable in providing the broad-scale benefits needed to foster transformation (Kates et al., 2012).

## 6.6.3 Sustainability

Although institutions contribute to minimising vulnerability and enhancing the adaptive capacity of communities and farmers through their interventions, they are confronted with several sustainability issues (Forkuor & Korah, 2023; Kabonga, 2023). Most often, among state/public institutions, already existing development interventions are rebranded as adaptation interventions and new adaptation interventions may be co-opted to support existing development agendas. These two processes dovetail into a form of 'retrofitting' and hinder addressing the root causes of vulnerability (Eriksen et al., 2021, p. 8). Here, funds meant for adaptation frequently support existing rebranded development initiatives because they address livelihoods or climate-sensitive sectors of the economy. In the Talensi district,

this situation was attributed mostly to state/public institutions not appropriately mainstreaming climate change adaptation into comprehensive planning processes (such as the DMTDP) and the procedural and systemic differences that impede the effective integration of civic/civil society and market/private institutions' adaptation plans into a broader planning framework in the district. Schipper et al. (2020) advised that where this situation occurs, adaptation interventions may not be designed with vulnerability reduction as a top priority; rather, climate change adaptation becomes a lower priority that can be overshadowed by other developmental or environmental objectives.

Mikulewicz (2020) stated that although often required, community-level participation in planning adaptation actions is frequently problematic as participating local farmers have limited agency within the process of framing and defining adaptation responses. More critically, though institutional interventions are to be planned for the most vulnerable individuals and households (Forkuor and Korah, 2023), they are the least involved in institutional responses and may not significantly benefit from interventions—especially in the global south (Petzold et al., 2023; Patnaik & Das, 2017). In such situations, some institutional interventions undermine farmers' agency by insisting on actions contrary to what farmers are comfortable with. According to Quarshie et al. (2023), such actions are often rejected by farmers, who cite incompatibility with existing farming systems, undermining their local adaptation actions and eroding their agency to manage production challenges. As identified by Forkuor & Korah (2023) and Alie et al. (2024), in this study, factors such as top-down planning, lack of participation platforms, market orientation and power dynamics limited the involvement of farmers in institutional adaptation planning.

While most studies concentrate on differences between adopters and non-adopters of agricultural technologies, dis-adoption or the reasons why smallholder farmers choose to stop using products or cease certain behaviours is less well understood (Wangithi et al., 2021). Chinseu et al. (2019) found that unfavourable experiences of farmers owing to a range of issues, including national policies, institutional arrangements, attributes of the technology and socio-cultural aspects, may all lead to dis-adoption. In Talensi, a lack of long-term success and dis-adoption was attributed primarily to a failure of institutions to build the capacity of community leaders or groups to continue adaptation actions after their exit. In such situations, when the external support for guidance, management and resources end, the actions typically collapse due to the absence of local ownership, leadership, knowledge, skills, and resources necessary to sustain them (e.g. Fitzpatrick, 2022). Institutions have expressed concern about

the dependency of smallholder farmers and communities on their on-going support for adaptation actions, especially when farmers' expectations of support are unmet (Chowdhooree et al., 2020). For example, in the Talensi district, the institutions noted that subsidies created a dependency cycle, discouraged local input systems, fostered a culture of expectation, and inhibited long-term, self-reliant adaptive behaviour.

In areas with multiple institutions, such as the Talensi district, their impact on adaptation varies significantly based on how connected they are, their coordination in response to climate hazards, and their articulation with external institutions and resources (Agrawal, 2008; Eriksen et al., 2021). Azhoni & Goyal (2018, p.474) described a lack of proper coordination and interaction among institutions as a 'lacuna' in effective adaptation framing. Institutional interactions may be limited by regulatory controls, bureaucratic rules and procedures, competing planning agendas and leadership, ambiguous mandates, competing priorities, and a lack of public support (Chenani et al., 2021). In the Talensi district, despite the appearance of limited overlap in operations, there was a lack of coordination, collaboration and partnership among the various institutions. Where cross-linkages of platforms and actions existed, it was generally between civic/civil society and state/public institutions, with the market/private institution having limited involvement or interaction with the other institutions due to their market-oriented priorities and financial constraints.

Institutional interactions in Ghana have been described as 'superficial, cosmetic and nothing beyond tokenistic' (Musah-Surugu et al., 2019, p. 321; Bawole & Hossain, 2015, p. 2071). The superficial and cosmetic nature of interactions among institutions in the Talensi district masks a lack of substantive, strategic alignment in their adaptation interventions, highlighting a gap in the district's overall approach to climate adaptation. This situation can result in fragmentation, lack of cross-linkages and learning among institutions, inefficiencies, limited resource sharing, and duplication of interventions (Tahiru et al., 2019). In the Talensi district, all institutions reported that limited resources heavily constrained their activities. Ultimately, a lack of alignment can result in the implementation of conflicting interventions that dilute the institutional impact and confuse farmers about the best actions to adopt (Quarshie et al., 2023; Tahiru et al., 2019). In addition, a lack of cross-linkages among institutions can result in institutions not knowing about each other's operations, challenging the importance of continuity and sustainability of interventions (Forkuor & Korah, 2023; Tahiru et al., 2019).

For institutional interactions to move beyond cosmetic to more sustainable and community-driven outcomes, there must be a shift toward genuine collaborative and integrative approaches in climate adaptation efforts, shared resource allocation, and a coordinated approach to addressing smallholder farmers' complex climate adaptation needs (Azhoni & Goyal, 2018; Eriksen et al., 2021). Institutions must be interconnected in adaptation planning and implementation to build a cohesive plan that aligns with local needs, is embraced by communities, and maximises resource use to effectively reduce farmers' vulnerability against climate shocks.

The range of challenges to the sustainability of interventions identified by institutions in the Talensi district highlight the multi-scale nature of adaptation influencing farmers' adaptation decisions, which operate not in isolation but rather in combinations with other factors and may inadvertently drive maladaptive outcomes that reinforce, redistribute or create new sources of vulnerability (Eriksen et al., 2021). Rahman (2021) found adaptation actions unsustainable where planning and implementation were improper or inadequate, with excessive focus on short-term targets and an inability to assess consequences prevailed. To properly respond to climate challenges, institutions must make bolder decisions and more significant changes that are harder and more audacious to promote system transformation (Kates et al., 2012; World Bank, 2024). Additionally, mainstreaming adaptation into development plans provides a potential way to enhance the adoption of adaptation actions (Eriksen et al., 2021). World Bank (2024) asserts that protecting communities from high climate risks requires the need to effectively mainstream adaptation and resilience into economic and development policies. It is critical to ensure that beneficiary selection is needbased to ensure adaptation is equitable (Rahman, 2021) so that vulnerable resourceconstrained farmers—disproportionately affected by climate change—are at the centre stage in adaptation to promote equity, consistency, efficiency, and reduced vulnerability (Forkuor & Korah, 2023; Pauw et al., 2022).

While institutional interventions play an essential role in supporting smallholder farmers to adapt to climate change, the sustainability of these interventions remains a critical challenge—and one with direct implications for farmers' agency. Lindegaard & Sen (2022, p. 1) describe this situation as interrupted agency—"externally driven formal interventions interrupt existing adaptation strategies—and agency—of local actors, potentially leading to maladaptation". Interrupted agency highlights how targeted formal adaptation interventions can disrupt individuals' everyday adaptation actions. Importantly, these actions that constitute

daily adaptive behaviours are not permanently stopped but are instead rearranged in ways that may lead to maladaptive outcomes (Rahman & Hickey, 2019; Eriksen et al., 2021; Lindegaard & Sen, 2022). When support from institutions is short-lived, fragmented, or misaligned with local realities, it can create cycles of dependency rather than empowerment to produce maladaptive outcomes, thereby increasing farmers' vulnerability to multiple livelihood stressors (Eriksen et al., 2021; Quarshie et al., 2023).

For example, farmers who begin to adopt certain climate-smart practices often do so based on the assumption that inputs, training, or market access will remain consistent. However, when donor priorities shift, funding ends, or coordination among institutions breaks down, these interventions become unsustainable. This situation interrupts the continuity of farmers' adaptation efforts and undermines their confidence in decision-making (Rahman & Hickey, 2019; Lindegaard & Sen, 2022). In such cases, farmers are forced to abandon or scale back strategies they had begun to integrate, not because they were ineffective, but because the support systems collapsed (Funder & Mweemba, 2019). This unpredictability constrains farmers' ability to plan long-term, experiment with new techniques, or fully take ownership of the adaptation process. In effect, it interrupts their agency—limiting their power to act autonomously and make informed choices in response to climate variability. Therefore, ensuring the sustainability of institutional interventions is not only a matter of programme effectiveness but a prerequisite for safeguarding the adaptive agency of smallholder farmers over time.

### 6.7 Conclusion, policy and practical implications

This study investigated the role institutions play in smallholder farmers' climate adaptation in the Talensi district of Ghana. To understand the role and influence of these institutions in climate change adaptation, three dimensions of their operations—scale, scope and sustainability were considered. The institutions played a multi-purpose role in addressing general adaptation to reduce vulnerability and specific adaptation to address the contextual effects of climate change. Thus, the institutions focused on the context of adaptation and generally addressed broader livelihood issues to support the communities to respond to developmental and environmental challenges.

The promotion of a range of adaptation interventions—training and capacity building, technology transfer, input supply and marketing and value chain integration—by various institutions in the Talensi district highlights the need for a coordinated and strategic approach

to enhance the effectiveness and sustainability of their adaptation actions. Such synergy can help build a robust and united front to tackle the complex challenges a changing climate poses to smallholder farmers and support sustainable agricultural development. In implementing their adaptation actions, the institutions were also confronted with several sustainability challenges—including donor priority, market orientation, resources, policy support, planning, transparency and group formation—that negatively impacted their ability to reduce vulnerability and build the adaptive capacity of farmers. Addressing institutional challenges in implementing adaptation interventions can create a more robust agricultural sector capable of adapting to climate change, ultimately improving the livelihoods and well-being of smallholder farmers and their communities.

To enhance smallholder farmers' adaptation decisions, it is recommended that all types of institutions—state/public, private/market, and civic/civil society—collaborate closely by aligning their efforts and sharing resources. The current study concentrated on formal institutions directly involved in promoting adaptation by smallholder farming communities. Clear communication and collaboration across institutions implementing similar adaptation actions can create a cohesive and comprehensive support system that ensures adaptation actions are well-coordinated, locally relevant, and sustainable. Most importantly, the design and implementation of actions must involve communities and farmers, especially the most vulnerable, to engender a sense of ownership and sustainability to achieve long-term adaptation needs. More equitable and sustained vulnerability reduction may be achievable if adaptation actions prioritise collaboration, experimentation and deeper learning among adaptation actors over delivering measurable material outputs under 'development as usual' standards (Eriksen et al., 2021, p.12). Shifting the terms of engagement between adaptation institutions and local farmers participating in adaptation interventions, especially the most vulnerable, is critical to have a deeper understanding of contextual vulnerability and engage with the definition of success for adaptation.

One potential limitation of this study is its exclusive focus on formal institutions, which may overlook the significant contributions and dynamics of informal institutions in the adaptation process (e.g. Abass et al., 2018; Haque et al., 2024). Future studies should integrate the roles of both formal and informal institutions to understand the diverse actors involved in climate change adaptation comprehensively. Incorporating informal institutions will offer a more nuanced and comprehensive understanding of the grassroots mechanisms and local knowledge systems that support smallholder farmers' adaptation decisions.

## **Chapter Seven**

### General discussion

### 7.1 Introduction

In this chapter, I summarize and integrate my research findings, explaining how each research question was addressed by referring to the empirical findings of the individual chapters. I provide my perspectives on the key outcomes of each chapter, leading to the overall conclusion of my thesis. This summary and integration serve to triangulate the discussion of my empirical findings, which focus on climate change adaptation, intersectionality, and institutional support for smallholder farmers in the Guinea Savannah agro-ecological zone of Ghana.

I gathered empirical evidence through a mixed-methods approach in the Talensi district of the Guinea Savannah agro-ecological zone of Ghana (see Chapter 3). Here, I document the contributions of the thesis to existing knowledge in three key areas of adaptation to climate change among small holder farmers:

- 1. Factors influencing climate change adaptation by smallholder farmers (see Chapter 4).
- 2. The role of intersectionality in shaping the adaptive capacity of smallholder farmers (see Chapter 5).
- 3. The role of institutions in enhancing climate change adaptation by smallholder farmers (see Chapter 6).

Chapter 4 examined how perception, livelihood capitals, and institutional interventions—both individually and in combination—influence smallholder farmers' adoption of a range of common adaptation actions to reduce their vulnerability to climate change. I also assessed the complementarity of multiple adaptation actions adopted by smallholder farmers. Furthermore, I discussed the rationale behind farmers' adoption practices, drawing on their lived experiences and unique contextual realities. In Chapter 5 (published as Opoku Mensah et al., 2025), I assessed how smallholder farmers' stocks of capital, along with other sociodemographic characteristics, intersect to either support or constrain their climate adaptation efforts. I also explored smallholder farmers' narratives of their lived experiences, providing deeper insights into the role of social categories and their intersections in shaping adaptation behaviours. Chapter 6 investigated various institutional-led adaptation interventions and their

outcomes for smallholder farmers, as well as the challenges that hinder the effective implementation of institutional adaptation measures.

In the following section, I provide a structured framework to integrate key insights from the empirical chapters, considering their implications for policy and practice.

### 7.2 Factors influencing climate change adaptation

While recognising the difficulty of capturing the full complexity of adoption decisions and limited consideration of technological and structural drivers (Rodríguez-Barillas et al. 2024; Ricart et al. 2025), Chapter 4 addressed research question 1 and three sub-questions:

**Research Question 1:** Which factors influence climate change adaptation by smallholder farmers?

# Sub-research questions:

- i. How do perception, livelihood capitals and institutional intervention, individually and in combination, influence smallholder farmers' adoption of a range of common adaptation actions to reduce their vulnerability to climate change?
- ii. Is smallholder farmers' adoption of multiple adaptation actions complementary?
- iii. What rationale—based on smallholder farmers' lived experiences of unique contexts and experiences—explains smallholder farmers' practice adoption?

Climate change encompassed climate variability, extreme weather events, and long-term temperature shifts. Here, I utilised primary data from 130 smallholder farmers and six focus groups to analyse the factors influencing their adoption of climate change actions to reduce the impacts of climate change and variability on their agricultural production and productivity. I adopted a combination of quantitative stepwise regression modelling and qualitative thematic and narrative analysis of discussions with farmers to identify the statistical associations between model variables and the adoption of climate change actions and explain the smallholder farmers' adaptation behaviours.

I found that smallholder farmers in the Talensi district were experiencing climate change and its impacts. The smallholder farmers were highly vulnerable to environmental threats and uncertainties, including drought, storms, heat waves, and flooding. These events were the district's most typical extreme climate events. I also found that farmers were experiencing

late onset, early cessation, and intense and short rainy seasons, which have been more frequent over the past ten years and caused significant impacts on farmers' agricultural production. I identified that the most commonly experienced climate impacts were crop failure, yield losses, decreased livestock productivity, unavailability of pasture and water scarcity.

Exposure to these impacts reduced agricultural production and threatened livelihoods, driving farmers in the Talensi district to seek innovative practices (see IPCC, 2023; Hanly & McDowell, 2025) to reduce their vulnerability. I identified a range of climate change actions such as changes in farming practices, the existence of complementary adoption of multiple actions and the rationales explaining practice adoption. My findings revealed that all farmers adopted one or more climate change actions, which included (from most to least common, Figure 3 in Chapter 4) planting improved crop cultivars, livelihood diversification, application of agrochemicals, practising agroforestry, planting calendar adjustments, and raising additional livestock. The findings also showed that, in keeping with previous studies (e.g. Gudina & Alemu, 2024), farmers' climate change actions were not mutually exclusive; they generally adopted multiple actions, providing evidence of complementarity among practices—12 of 15 pairwise correlation coefficients were positive and significant at P=0.01, indicating complementarity of adoption—(Figure 3 in Chapter 4).

The farmers' choices of climate change actions were also consistent with those identified under Climate-Smart Agriculture (CSA)—an overarching approach to marrying adaptation and mitigation strategies with food production (FAO, 2017; Kabato et al., 2025). I found that the climate change actions identified by farmers addressed at least two pillars of CSA, i.e., adaptation and increasing productivity. For example, adopting improved crop cultivars was associated with drought resistance, improved yields, and pest and disease resistance (Cishahayo et al., 2023). Senyolo et al. (2018) also found that while adopting improved crop cultivars was not expected to have a direct mitigating effect on drought, it does allow for harvesting even in adverse conditions and supports farmers in dealing with dry spells and adapting to rain shortfall.

I also identified the farmers' reasons for their complementarity in practice adoption. For example, the adoption of improved crop cultivars was most often accompanied by the application of agrochemicals and adjusting planting calendars to optimise the potential benefits of these high-yield varieties. It was also often accompanied by raising additional

livestock to diversify agricultural and livelihood practices to manage risks and promote diversified and sustainable farming systems. Farmers also adjusted their planting calendar to align crop sowing times with expected weather patterns, mitigating risks from unpredictable climate variations to enhance growth conditions and productivity (Asante et al., 2024). Additionally, the farmers often raised more livestock to diversify their agricultural practices, which helped them manage risks and enhance soil fertility through natural manures, thereby supporting their crop cultivation (Geda et al., 2024). With insights into the adaptation practices of smallholder farmers, understanding local adaptation contexts can ultimately inform farmer-led adaptation policies to empower smallholder farmers to adapt more effectively through the promotion of 'packages' of complementary technologies (Alvarez Carrillo et al. 2022, p. 378).

I also employed a stepwise logistic regression model to analyse the factors influencing farmers' adoption of climate change actions. I found that based on the value of the model coefficients, some climate change actions were influenced by a large number of complex interacting variables (e.g., planting improved crop cultivars) and others were less so (e.g., raising additional livestock). These variables were informed by the smallholder farmers' climate perceptions of precipitation, temperature and extreme events (Grothmann & Patt, 2005; Chimi et al., 2022; Azine et al., 2025), livelihood capitals—human, social, natural, physical and financial—(Ellis, 2000; Tong et al. 2024; Nath & Arrawatia, 2025), and institutional interventions—training and capacity building, technology transfer, input supply and marketing and value chain integration—(Agrawal 2010; Witinok-Huber et al., 2025; Puig et al., 2025) that significantly influenced their adoption of climate change actions.

In keeping with the contemporary understanding of farmers' adoption of agricultural innovations (Llewelyn & Brown, 2020), I found that in addition to how, in practice, the adoption of climate change actions was influenced variously by perception, livelihood capitals and institutional interventions, several distinctive characteristics of smallholder agriculture affected agricultural adoption and had relevance for climate change adaptation actions (Llewellyn & Brown, 2020; Matos, 2025). For example, the attributes of practices—relative advantage, complexity, compatibility, trialability and observability—influenced the extent of adoption (Rogers, 2003; Zhang et al., 2023; Matos, 2025). In particular, I found the compatibility of climate change actions with existing farming practices played a crucial role in their adoption.

Actions that seamlessly integrated into farmers' daily lives and routines without demanding significant changes to traditional methods (e.g., Farmer Managed Natural Regeneration [FMNR] as part of adopting agroforestry) were accepted and sustained (Opoku Mensah et al., 2024; Yiridomoh et al., 2025). Typically, farmers promoted FMNR through pruning, mulching and protection of natural regeneration of vegetation. Since planting trees was not required, FMNR was comparatively cheap and accessible, with a higher tree survival rate because species regenerated naturally and were locally adapted (Rinaudo et al., 2021). Such alignment with local norms and practices reduced resistance, as farmers were more comfortable with and confident in actions that reflected their established ways of farming and living (Fu & Huang, 2024; Suuk et al., 2025).

I argued that these findings are relevant for shaping policies that address the emotional, cognitive, livelihood, and institutional factors and the attributes of the practices that influence the adoption of climate change actions in the Talensi district. Agricultural policymakers, development practitioners, and decision-makers at different institutional levels must intensify their efforts to promote context-specific and targeted climate change actions through policy interventions that effectively transform agricultural systems to enhance sustainable agricultural productivity. It is critical to ensure that efforts to promote the adoption of climate change actions enhance farmers' awareness and understanding of climate risks and opportunities. These efforts should include providing smallholder farmers with timely, accessible and comprehensible climate-related information while appreciating their available livelihood capitals and institutional support—to reduce their vulnerability—as well as the potential benefits of adopting various climate change actions in a holistic and integrated approach.

Again, because the farmers' choices of climate change actions were not mutually exclusive, but they generally adopted multiple actions, these cross-correlations among climate change actions have significant policy implications. Specifically, a policy change affecting one action might have spillover effects on the adoption of other actions (Gudina & Alemu, 2024). Understanding these interactions is key to developing appropriate packages of climate change actions tailored to specific areas to intensify adoption and minimise climate risks to agricultural productivity. Also, I argued that insights from this research provide a starting point and a solid foundation for further research to inform rural development policies that identify and promote climate change actions to enhance the sustainability of smallholder farming in semi-arid regions.

In the following section, I discuss how the smallholder farmers' adoption of their adaptation actions is influenced by the characteristics of the farmers in Talensi district (intersectionality) and how their adaptation decisions are shaped by social inequalities. This section is important because adaptation is not uniform but varies based on social identities. Intersectionality, therefore, determines access to adaptation options, heightening adaptation constraints for some farmers while providing greater access to adaptation-enabling resources for others.

### 7.3 The role of intersectionality in shaping adaptive capacity

In Chapter 5 (Opoku Mensah et al., 2025), I explored how the socio-demographics of smallholder farmers in the Talensi district of Ghana intersected with their livelihood capitals to shape their capacity for climate adaptation. This chapter addressed my second research question and sub-questions:

**Research Question 2:** What role does intersectionality play in shaping adaptive capacity of smallholder farmers?

# Sub-research questions:

- i. How do indicators of smallholder farmers' stocks of capital and other sociodemographic characteristics intersect to either support or constrain their climate adaptation efforts?
- ii. What smallholder farmers' narratives about their lived experience provide insight into social categories and their intersections?

In line with the growing calls for empirically grounded intersectional research, I adopted a mixed-method approach to explore how intersecting identities shape adaptation in a highly diverse context. This approach also examines the policies that could promote more equitable adaptation within and across heterogeneous communities. By doing so, this study contributes to a more nuanced and critical analysis of climate change and inequality dynamics (Nyantakyi-Frimpong, 2020; Puig et al., 2025).

I drew from a systematic random sample of 130 smallholder farmers and six focus group discussions with smallholder farmers who rated locally-derived indicators of each of the five livelihood capitals, as to the level of support provided to adaptation. I employed descriptive and inferential statistics and narrative analysis to unpack how livelihood capital indicators

intersected with these farmers' socio-demographics, either supporting or constraining their climate adaptation efforts. Such an intersectionality approach allowed me to view vulnerability not just as the characteristic of some socio-demographic groups but as an outcome of interdependent and various societal stratification processes leading to multiple dimensions of vulnerability and revealing a more nuanced understanding of vulnerabilities and unpacked vulnerable groups (Nyantakyi-Frimpong, 2020; Yimam & Holvoet, 2023).

I found that while overall, the capitals appeared to provide limited support to adaptation (Figure 2 in Chapter 5), the considerable variation in the range of ratings assigned to individual indicators of each capital suggested that a deeper analysis was required to understand vulnerability and intersectionality. Accordingly, I further analysed the frequency distribution of ratings to categorise individual indicators into one of three groups. I found that two groups consisted of indicators skewed towards higher ratings (support for adaptation) and those skewed towards lower ratings (adaptation constraint) (Figure 3 and Table 2 in Chapter 5). Between these two extremes, I found a third group of indicators which appeared to show two distinct peaks, often at opposite ends of the rating scale, i.e. a bimodal pattern. This pattern suggests that the support for adaptation provided by these indicators was perceived differently by sub-groups of farmers within the sample (Table 5 in Chapter 5).

Specifically, the analysis of adaptive capacity showed that gender constrained women smallholder farmers more than their men counterparts. However, gender was not the only important factor. For example, where gender intersected with low economic status, age, and residential status, it heightened the constraint on adaptation experienced by women. I found that decisions over farmland constrained more women aged between 15 – 35 years and supported men 60 years or older (see also Lawson et al., 2020). Due to the patriarchal nature of the Talensi district (Koomson-Yalley & Kyei, 2022; Opoku Mensah et al., 2025), women farmers, particularly younger women, were unable to own land because they had to obtain it in ways that raised their insecurity, including depending on men relatives and leasehold agreements and borrowing from relatives, which impacted their capacity to implement innovative adaptation practices. Women's limited control and land ownership in patriarchal communities impede their adaptation because access to land in such communities is crucial for sustainable adaptation (Akugre et al., 2022).

I also found that while gender has been the subject of many studies on intersectionality and climate change vulnerability, other socio-demographic characteristics have received less

attention, especially in the Global South (Ravera et al., 2016; Erwin et al., 2021). Previous studies (e.g. Erwin et al., 2021; Yimam & Holvoet, 2023) emphasised how gender intersected with different identities to shape adaptive capabilities. I also revealed that it is important to account for community dynamics related to ageing in designing adaptation interventions.

Furthermore, in keeping with Assan et al. (2018) and Opoku Mensah et al. (2023), I found that access to credit supported women who belonged to community groups, while constraining men outside of these groups. Within the study communities, institutions, particularly civic/civil society institutions, supported farmers—particularly women farmers—to cultivate a savings culture and provided access to low-interest microcredit for starting new businesses and productive investments in agriculture. This finding supports the idea that women's circumstances are diverse (Nyantakyi-Frimpong, 2020) and that separating "being poor from being women or the generalisation.... that all women are poor and that the poor are always more vulnerable" (Arora-Jonsson, 2011, p. 746) could support the development of inclusive climate policies (Chaplin et al., 2019).

I found that the smallholder farmers' residential status also impacted access to resources (e.g. Erwin et al., 2021). Specifically, I found that residential status intersected with farmer networks and remittances to constrain migrants. These findings suggest that migrants may have been marginalised from these networks and could not draw on financial resources from remittances. Again, I found that women migrants were constrained by farmer networks. During the focus group discussions, I found that local farmer networks were tight-knit and tended to exclude migrants and limited their involvement in these networks where locals share resources and knowledge. This condition placed them in a disadvantaged position with comparatively less access to livelihood capitals (see Lawson et al., 2020).

In line with Fatuase & Ajibefun (2014) and Yimam & Holvoet (2023) who revealed a relationship between higher educational attainment, adaptation options and reduced vulnerability, I found that the farmers' level of education supported those with tertiary education and men with high economic status and constrained those with no formal education and women with low economic status. I found that the intersectionality between educational status and gender often led to divergent income diversification opportunities for men and women (see also Erwin et al., 2021). Unskilled women, in particular, found fewer opportunities to diversify their income, which impeded their individual and households' capacity to adapt. Such structural inequalities constrain marginalized groups from fully

engaging in adaptation. Through the focus group discussions, I discovered that farmers with higher levels of education owned land and earned salaries from jobs outside of agriculture. Thus, they had a secondary occupation that supported their capacity. Notably, such farmers reported employment in various fields, including nursing, teaching, civil/public services, entrepreneurship, banking and crafts.

In terms of social networks, I found that the farmers' economic status was a key indicator that influenced their access to social networks for climate change adaptation. Men with low economic status had more grassroots connections and influence within social networks, particularly male-dominated ones. These connections informally supported them through knowledge sharing and access to communal resources that were not readily available to farmers with high economic status. Farmers with high economic status were perceived as more distant or less in need of support. Such intersectional analysis and social differentiation determine who benefits from adaptation support and who is left behind.

I found that although the associations between ratings of adaptive capacity and sociodemographic characteristics were clearest for indicators with bimodal patterns—i.e. supporting for some while constraining for others—other indicators were also associated with socio-demographics. For example, I found that land tenure, which predominantly constrained farmers' adaptive capacity, was generally influenced by age and marital status (e.g. Lawson et al., 2020). Particularly, younger (36 – 59 years) and married and widowed women farmers rated land tenure lower than men farmers between 15 – 59 years and men who are married. This finding was likely due to the patriarchal nature of the Talensi district (Opoku Mensah et al., 2023; 2024), where it is socio-culturally against norms, customs and traditions for a widow to head a household. When a man succeeds a deceased household head, he automatically becomes the household head and gains more ownership and control over land (Alare et al. 2022). Also, improved agricultural practices and secondary occupation—indicators rated as predominantly supporting farmers—was primarily supporting farmers with high economic status and men, respectively.

Finally, I found that despite these differences, there were common indicators to consider when identifying possible intersectional impacts. These common indicators included climate variability and access to information, which constrained all smallholder farmers. An intersectional approach that identifies common factors prevalent across all locations and

among all smallholder farmers is essential to unpacking unique intersectional dynamics (Axelrod et al., 2022).

Based on these findings, the intersection of the farmers' socio-demographic characteristics and adaptive capacity is apparent and consistent with the understanding that vulnerability is socially heterogeneous. It may be experienced differently by sub-groups in a community according to socio-demographic characteristics (Yimam & Holvoet, 2023; Puig et al., 2025). Intersectionality creates unequal adaptation outcomes where marginalized groups are often more vulnerable. Differential vulnerabilities and social marginalization determine who can adapt, how they adapt, and the effectiveness of adaptation measures. Consequently, I argued that when indicators are categorised in this way, it influences how institutional adaptation responses are formulated. Where most farmers identified an indicator as constraining adaptation, a broad-scale response would appear desirable to build adaptive capacity. Where some indicators supported the majority of farmers, it suggests that efforts by institutions or local conditions have enhanced adaptive capacity.

The third group of indicators with a bimodal pattern presents the most problematic situation for building capacity. They require an institutional understanding of local conditions through engagement with disadvantaged social groups to formulate context-specific responses, which are seldom realised through centralised interventions (Nyantakyi-Frimpong, 2020; Puig et al., 2025). Thompson-Hall et al. (2016) posit that such nuanced interpretation of localised realities within specific agricultural contexts offers insights into how these settings fit and intersect within the larger agricultural landscape. Such understanding is vital for supporting and planning climate-sensitive interventions grounded in principles of social justice. Without a vulnerability analysis that unmasks differences or moves beyond binary gender categorisations, subsequent interventions might overlook the needs of numerous individuals and potentially exacerbate existing vulnerabilities (Nyantakyi-Frimpong, 2020).

My findings have significant implications for human-environment researchers, practitioners and policymakers in adaptation in theorising climate vulnerability and inequality and formulating effective adaptation policies and interventions that facilitate effective adaptation among smallholder farmers with diverse backgrounds. While the disparities between men and women can deeply shape their vulnerability, I suggested that other socio-demographic factors might hold equal or greater significance. Vulnerability assessments need to identify people or places that are most vulnerable to climate change and variability to identify vulnerability-

reducing actions (Luers, 2005). For example, social marginalization—based on factors such as age, gender, class, disability, political affiliation, ethnicity and sexuality—is a major cause of vulnerability and is present in all societies (Puig et al., 2025). It arises from existing structural inequalities that affect resource distribution and opportunities, a lack of recognition and representation in decision-making, biases driven by incumbency positions and information asymmetry (Swanson, 2021).

Therefore, human-environment researchers, particularly practitioners and policymakers in adaptation must consider additional factors like age, residential status, socio-economic status, and education level in designing adaptation interventions. Failure to consider these multiple and complex sources of vulnerability within a socio-ecological system and to enfranchise marginalised groups by promoting negotiation and deliberation to subvert exclusionary practices can result in misguided response strategies, potentially leading to significant unintended results or surprises (Adger, 2006; Puig et al., 2025).

Although such nuanced analysis is problematical for resource-constrained governments of SSA, incorporating these elements can lead to better adaptation outcomes (Thompson-Hall et al., 2016). From a policy perspective, the integration of intersectional analysis can be time-consuming and complicated (Hankivsky & Cormier, 2011). Nevertheless, avoiding simplistic analyses that overlook the various dimensions of intersectionality is decisive. The failure to do so can result in suboptimal policies that further marginalise specific groups of farmers through a failure to acknowledge their differential interests and varied access to adaptive strategies (Chaplin et al., 2019; Puig et al., 2025). By adopting an intersectional approach, policymakers can broaden their understanding of the differential needs of farmers at individual, household and community levels to better target resources and support diverse adaptive strategies. Recognising that vulnerability is socially heterogeneous (Puig et al., 2025), policies must be tailored to reflect different farmer groups' diverse needs and capacities. This approach will ensure that interventions are targeted, equitable, and inclusive to obviate farmers' vulnerability, particularly those marginalised by their socio-demographic characteristics to foster sustainable agricultural communities.

In the next section, I discuss how institutions enable smallholder farmers to navigate climate-related risks and effectively adapt. This is significant because realising complex and ambitious goals, such as effective adaptation (UNFCCC, 2020), climate equity and justice (Kerr et al., 2022), and the Sustainable Development Goals (SDGs) (United Nations [UN],

2015; Pradhan et al., 2025), requires institutions to continue to be active in promoting adaptation (IPCC, 2022b; Witinok-Huber et al., 2025).

### 7.4 The role of institutions in enhancing climate change adaptation

In Chapter 6, I sought to investigate the role and influence institutions play in smallholder farmers' climate adaptation in the Talensi district of Ghana, which addressed my third research question 3 and its sub-research questions:

**Research Question 3:** What roles do institutions play in enhancing climate change adaptation by smallholder farmers?

# Sub-research questions:

- i. What are various institutional-led adaptation actions and their outcomes for smallholder farmers?
- ii. What challenges limit the implementation of institutional adaptation actions?

In this chapter I adopted a qualitative research approach to provide a nuanced understanding of the role of institutions in smallholder farmers' climate change adaptation practices in the Talensi district. I utilised a case study approach of eight institutions to answer my research questions. I adopted semi-structured interviews to collect primary qualitative data to analyse experiences, events and opinions and better understand how different institutional respondents perceived and interpreted these meanings. In terms of analysis, I employed a deductive approach to qualitatively analyse the data and understand the contextual contributions of institutions to smallholder farmers' climate adaptation practices.

I found that the three principal types of formal institutions (state/public, private/market, and civic/civil society) operated in the Talensi district to support smallholder farmers in changing the way they farm in response to the changing climate (see Table 14 in Chapter 6). Four of the eight institutions identified were state/public (TDA, EPA, DoA and GMet). One was a market/private institution (KDC). Three were civic/civil society institutions (FTC, WOM and WVG). To understand the role and influence of these institutions in climate change adaptation, I considered three dimensions of their operations: scale, scope and sustainability.

### 7.4.1 Scale

I found that at the district scale, Talensi district attracted considerable institutional presence. This may be due to its relatively high vulnerability to climate change (Abunyewah et al., 2024). The aims of the institutions were multi-purpose—to reduce general vulnerability and promote specific adaptation actions. Thus, the institutions rarely focused solely on adaptation; instead, they generally addressed broader livelihood issues to support the communities to respond to developmental and environmental challenges. Specifically, the institutions focused on climate resilience, environmental sustainability, climate-smart agriculture (under drought conditions), risk assessment and planning, alternative livelihoods (specifically for women) and agricultural productivity (see Table 14 in Chapter 6). I found that the state/public institutions collectively focused on building climate resilience by promoting sustainable land use, water management, and climate-smart agricultural practices. While the market/private institution consulted with farmers on climate-smart technical solutions, the civic/civil society institutions primarily focused on building community resilience through capacity-building programmes, climate-resilient farming, livelihood diversification, and empowering vulnerable groups.

Foremost among the types of institutions were the state/public institutions. I found that they were mandated to promote the development of the entire district. They implemented government policies and programmes to reach as many farmers as possible, and their interventions were broadly applicable at a wide scale (He et al., 2022). The state/public institutions operated with public resources and were often required to demonstrate that their interventions benefited entire communities and sought to avoid the perception of favouritism or exclusion (Rahman, 2021). I also found that the civic/civil society institutions operated across the district. However, they tended to intervene in selected communities (e.g. WVG) or with specific social groups (e.g. WOM and women) guided by their strategic plans. I found that the civic/civil society institutions primarily focused on building community resilience through capacity-building interventions, climate-resilient farming, livelihood diversification, and empowering vulnerable groups. These institutions commonly used community-centric and grassroots approaches (e.g., Tahiru et al., 2019; Rahman, 2021) due to their ability to engage closely with local needs, ensuring that the chosen interventions are relevant and impactful to vulnerable smallholder farmers.

Although not highly active in the district, I found that the single market/private institution consulted with farmers on climate-smart technical solutions in selected communities based on its strategic plan and potential for commercial returns. The agriculturally risky Talensi district is placed at a relative disadvantage in attracting support from commercial entities—market/private institutions—because climate variability can dramatically affect agricultural outcomes (TDA, 2022; Abunyewah et al., 2024). This situation is not uncommon as commercial entities rely heavily on market-driven funding mechanisms (Mendelsohn, 2006; Crick et al., 2018) ensuring they are risk-averse when investing in adaptation interventions involving uncertainties.

At the community level, I found that institutional presence was spatially 'patchy'. This finding is critical as spatial heterogeneity is a major feature of agricultural production systems that is crucial in analysing adaptation (Antle et al., 2004; Liu & Masago, 2023). Specifically, I found that the reach and types of interventions available varied considerably across communities and groups. This spatial heterogeneity meant that not all farmers had access to the full range of support options for climate adaptation. Even though the state/public institutions were mandated to promote the development of the entire district, limitations in funding, personnel, and logistical capabilities restricted their ability to extend their impact to cover broader geographic areas or reach a more significant number of farmers simultaneously. Therefore, they focused on relatively small and easy-to-reach communities with some communities and farmers likely to be unable to access support. The civic/civil society institutions targeted groups that aligned with their mission. They were driven by specific development goals, such as empowering vulnerable groups, promoting gender equality, and supporting marginalised communities. They worked closely with local communities to identify the most vulnerable populations, such as women, widows, and vulnerable children, including orphans, to tailor their interventions to address their unique needs and challenges directly (e.g. Tahiru et al., 2019; Rahman, 2021).

I found that the community-centric and grassroots approaches of civic/civil society institutions were confronted with challenges and their decision-making sometimes excluded parts of a region or community. Such uneven presence and activity of civic/civil society institutions across different spaces and scales have been documented by Bebbington (2004) and Rahman (2021) to lead to uneven distribution of resources, knowledge, ideas, power, and values often dictated by donor interest and priority rather than local realities. Similarly, the civic/civil society institutions' interest-based selection of their beneficiaries has been

criticised as biased, undermining the potential impact of adaptation interventions and their ability to meet long-term transformative goals (Bebbington, 2004; Banks et al., 2015; Rahman, 2021). Unsurprisingly, I found that the commercial imperatives of the market/private institution (Mendelsohn, 2006; Crick et al., 2018) ensured its presence was limited to interventions that maximised returns and commercial viability, such as general farming practices and technologies across a broad farmer base without tailoring its support to specific groups. It often focused on areas with the potential for quick returns to seek a broad market appeal to justify its investments and achieve profitability. These practices limited its involvement with vulnerable smallholder farmers, as focusing on these groups specifically might limit their market scope and the scalability of their interventions.

### 7.4.2 Scope

In terms of scope, I found that the institutions supported a variety of adaptation actions for farmers in pursuing their adaptation objectives (see Table 15 in Chapter 6) through a range of interventions, including training and capacity building, technology transfer, input supply and marketing and value chain integration. These interventions formed part of a matrix of support offered to assist farmers in everyday challenges and deal with climatic shocks (see Yomo et al., 2020). Within this available matrix of support, the institutions played a multi-purpose role by implementing specific adaptation actions to reduce place-based climate change vulnerability and by supporting improvement in developmental and environmental challenges related to broader livelihood issues that went beyond impacts on agricultural production alone (see Tables 14 and 15 in Chapter 6) (e.g. Forkuor & Korah, 2023). These adaptation interventions align with Smith & Lenhart's (1996) specific options for water resources, forests, ecosystems and agriculture to reduce climate risks, and with the need for local empowerment, direct climate service provision, and climate advocacy to enhance adaptive capacities for community development (Musah-Surugu et al., 2019; Patnaik & Das, 2017).

In relation to the civic/civil society institutions, although limited in scale to targeted communities, I found that typically they led actions on community development, including life skills, microenterprise development, business management and microenterprise coaching. These actions reflected their more holistic approach to vulnerability reduction. The commitment of resources by civic/civil society institutions to both on-farm (farming practices) and off-farm (support for livelihoods) adaptation interventions can enhance the well-being and stability of smallholder farmers and enable them to navigate developmental

challenges and climate-related risks effectively (UNFCCC, 2024; Haque et al., 2024). Béné et al. (2018) identified the need to align largely separate communities of practice related to social protection, disaster risk reduction and climate change adaptation to more effectively address chronic poverty, disasters and extreme events or long-term changes in climate conditions and their distribution over time and space respectively. They described the humanitarian-development continuum to improve resilience as a framework of response from coping through incremental adjustment to transformational responses, with the latter requiring interventions to address the long-term structural causes of vulnerability.

### 7.4.3 Sustainability

Here, I found that although the institutions contributed to minimising vulnerability and enhancing the adaptive capacity of communities and farmers through their interventions, they were confronted with several sustainability issues. Most often, among state/public institutions, already existing development interventions were rebranded as adaptation interventions and new adaptation interventions were co-opted to support existing development agendas. These two processes dovetail into a form of 'retrofitting' and hinder addressing the root causes of vulnerability (Eriksen et al., 2021, p. 8). This situation arose because state/public institutions did not appropriately mainstream climate change adaptation into comprehensive planning processes. Also, I identified procedural and systemic differences that impeded the effective integration of civic/civil society and market/private institutions' adaptation plans into a broader planning framework in the district. Schipper et al. (2020) advised that where this situation occurs, adaptation interventions may not be designed with vulnerability reduction as a top priority; rather, climate change adaptation becomes a lower priority that other developmental or environmental objectives can overshadow. Also, I found that the institutions' current adaptation efforts were largely incremental adjustments relying on modifications to existing systems rather than aimed at achieving systemic transformation (see Di Fant et al., 2025; Callahan, 2025). Chowdhooree et al. (2020) and Rahman (2021) concluded that institutional actions, particularly those of civic/civil society institutions, are frequently small in scale, ineffective and unsustainable in providing the broad-scale benefits needed to foster transformation (Kates et al., 2012; Di Fant et al., 2025; Callahan, 2025).

Factors such as top-down planning, lack of participation platforms, market orientation and power dynamics were found to limit the involvement of farmers in institutional adaptation planning. In such situations, some institutional interventions undermined farmers' agency by

insisting on actions contrary to what farmers are comfortable with. Such actions were often rejected by farmers, who cite incompatibility with existing farming systems, undermining their local adaptation actions and eroding their agency to manage production challenges (Quarshie et al., 2023). Similarly, Mikulewicz (2020) stated that although often required, community-level participation in planning adaptation actions is frequently problematic as participating local farmers have limited agency within the process of framing and defining adaptation responses. More critically, though institutional interventions are to be planned for the most vulnerable individuals and households (Forkuor and Korah, 2023; Puig et al., 2025), they are the least involved in institutional responses and may not significantly benefit from interventions—especially in the global south (Patnaik & Das, 2017; Petzold et al., 2023).

A lack of long-term success and dis-adoption was attributed primarily to a failure of institutions to build the capacity of community leaders or groups to continue adaptation actions after their exit. In such situations, when the external support for guidance, management and resources end, the actions typically collapse due to the absence of local ownership, leadership, knowledge, skills, and resources necessary to sustain them (e.g. Fitzpatrick, 2022). Also, the institutions expressed concern about the dependency of smallholder farmers and communities on their on-going support for adaptation actions, especially when farmers' expectations of support are unmet (see Chowdhooree et al., 2020). Specifically, the institutions noted that subsidies created a dependency cycle, discouraged local input systems, fostered a culture of expectation, and inhibited long-term, self-reliant adaptive behaviour.

In areas with multiple institutions, their impact on adaptation varies significantly based on how connected they are, their coordination in response to climate hazards, and their articulation with external institutions and resources (Agrawal, 2008; Eriksen et al., 2021). However, I found that, despite the appearance of limited overlap in operations, there was a lack of coordination, collaboration and partnership among the various institutions. Where cross-linkages of platforms and actions existed, it was generally between civic/civil society and state/public institutions. The market/private institution had limited involvement or interaction with the other institutions due to their market-oriented priorities and financial constraints. Azhoni & Goyal (2018, p.474) described such a lack of proper coordination and interaction among institutions as a 'lacuna' in effective adaptation framing. This 'superficial' (Musah-Surugu et al., 2019, p. 32), 'cosmetic and nothing beyond tokenistic' (Bawole & Hossain, 2015, p. 2071) nature of interactions among institutions in the Talensi district

masked a lack of substantive, strategic alignment in their adaptation interventions, highlighting a gap in the district's overall approach to climate adaptation. This situation can result in fragmentation, lack of cross-linkages and learning among institutions, inefficiencies, limited resource sharing, and duplication of interventions (Tahiru et al., 2019).

The institutional interactions were limited by regulatory controls, bureaucratic rules and procedures, competing planning agendas and leadership, policy gaps, ambiguous mandates, competing priorities, and a lack of public support (see Chenani et al., 2021). Weak institutional mechanisms and co-ordination may reinforce inequalities by failing to reach those most in need. For example, institutional policies often fail to account for differential vulnerabilities and social marginalization, creating adaptation gaps (Puig et al., 2025). Ultimately, a lack of alignment can result in the implementation of conflicting interventions that dilute the institutional impact and confuse farmers about the best actions to adopt (Quarshie et al., 2023; Tahiru et al., 2019). In addition, a lack of cross-linkages among institutions can result in institutions not knowing about each other's operations, challenging the importance of continuity and sustainability of interventions (Forkuor & Korah, 2023; Tahiru et al., 2019). This range of challenges to the sustainability of institutional interventions highlights the multi-scale nature of adaptation influencing farmers' adaptation decisions, which operate not in isolation but rather in combinations with other factors and may inadvertently drive maladaptive outcomes that reinforce, redistribute or create new sources of vulnerability (Eriksen et al., 2021). To prevent maladaptation, adaptation actions should be designed to address long-term adaptation needs while accounting for a range of possible future scenarios (Di Fant et al., 2025).

Based on the findings above, I argued that addressing institutional challenges in implementing adaptation interventions can create a more robust agricultural sector capable of adapting to climate change, ultimately improving the livelihoods and well-being of smallholder farmers and their communities. I recommended that promoting a range of adaptation interventions—training and capacity building, technology transfer, input supply and marketing and value chain integration—by various institutions in the Talensi district highlights the need for a coordinated and strategic approach to enhance the effectiveness and sustainability of their adaptation actions. Such synergy can help build a robust and united front to tackle the complex challenges a changing climate poses to smallholder farmers and support sustainable agricultural development. Therefore, to enhance smallholder farmers' adaptation decisions, I recommended that all types of institutions—state/public,

private/market, and civic/civil society—collaborate closely by aligning their efforts and sharing resources.

Similarly, clear communication and collaboration across institutions implementing similar adaptation actions can create a cohesive and comprehensive support system that ensures adaptation actions are well-coordinated, locally relevant, and sustainable. For institutional interactions to move beyond cosmetic to more sustainable and community-driven outcomes, there must be a shift toward genuine collaborative and integrative approaches in climate adaptation efforts, shared resource allocation, and a coordinated approach to addressing smallholder farmers' complex climate adaptation needs (Azhoni & Goyal, 2018; Eriksen et al., 2021). Institutions must be interconnected with each other in adaptation planning and implementation to build a cohesive plan that aligns with local needs, is embraced by communities, and maximises resource use to effectively reduce farmers' vulnerability against climate shocks.

To properly respond to climate challenges, institutions must make bolder decisions and more significant changes that are harder and more audacious to promote system transformation (Kates et al., 2012; IPCC, 2022b; World Bank, 2024; Callahan, 2025). Implementing adaptation actions requires creating enabling conditions and addressing such governance and institutional barriers (Pradhan et al., 2025). Additionally, mainstreaming adaptation into development plans provides a potential way to enhance the adoption of adaptation actions (Eriksen et al., 2021). World Bank (2024) asserts that protecting communities from high climate risks requires the need to effectively mainstream adaptation and resilience into economic and development policies, which is essential for developing comprehensive models that address vulnerability at a systemic level. Additionally, it is crucial to ensure that these policies are coordinated with national and international climate agreements and aligned with global commitments. This approach can foster a resilient agricultural sector capable of adapting to climate change and variability while securing sustainable livelihoods for smallholder farmers (Azine et al., 2025).

It is critical to ensure that beneficiary selection by institutions is need-based to ensure adaptation is equitable (Rahman, 2021) so that vulnerable resource-constrained farmers—disproportionately affected by climate change—are at the centre stage in adaptation to promote equity, consistency, efficiency, and reduced vulnerability (Pauw et al., 2022; Forkuor & Korah, 2023). Most importantly, I argued that the design and implementation of

adaptation actions must involve communities and farmers, especially the most vulnerable, to engender a sense of ownership and enfranchise marginalised groups to achieve sustainability and long-term adaptation needs (Adger, 2006; Puig et al., 2025). Institutional interventions can either alleviate or exacerbate differential vulnerabilities and social marginalization. They are, therefore, crucial in bridging the gap between policy and practice, ensuring that climate adaptation is inclusive and equitable. More equitable and sustained vulnerability reduction may be achievable if adaptation actions prioritise collaboration, experimentation and deeper learning among adaptation actors over-delivering measurable material outputs under 'development as usual' standards (Eriksen et al., 2021, p.12). Shifting the terms of engagement between adaptation institutions and local farmers participating in adaptation interventions, especially the most vulnerable, is critical to have a deeper understanding of contextual vulnerability and engage with the definition of success for adaptation.

In the following section, I reflect and synthesize the core findings from my empirical chapters—Chapters 4, 5 and 6—connecting the relationships between climate change adaptation, intersectionality, and institutional support for smallholder farmers in the Guinea Savannah agro-ecological zone of Ghana. These relationships influence and interact—reinforcing the need for an integrated and inclusive approach to vulnerability reduction in smallholder farming systems. This reflection extends beyond a summary of findings to critically examine their implications, challenges, and contributions to knowledge, policy, and practice. It also highlights the interplay of the various dimensions shaping farmers' adaptive capacities, emphasizing the importance of integrated and equitable approaches to climate adaptation.

# 7.5 Interconnections between adaptation, intersectionality and institutional support

The research findings showed that smallholder farmers in the Talensi district employ diverse adaptation actions in response to climate change—including variability, extreme weather events, and long-term temperature shifts. However, adaptation is not a straightforward process. Instead, it is shaped by a combination of socio-demographic factors, access to livelihood resources, and the role of institutional support. For example, the findings highlighted that key socio-demographic factors (e.g., gender, age, education, and economic status) shaped farmers' adaptive capacities and demonstrated how these social variables interacted, creating inequalities in access to resources and opportunities. These resources and opportunities are critical for adaptation. According to IPCC (2022b), climate impacts are

present, pervasive, and predicted to persist and progress. In response, individuals and groups engage in climate adaptation—adjusting to actual or expected climate and its effects to moderate harm or exploit beneficial opportunities. As shown in Figure 15, these findings underscore the need for a holistic approach to adaptation that integrates individual-level adaptation behaviours, intersectionality, and institutional frameworks at community scale. By integrating these three dimensions, we can develop inclusive and sustainable adaptation policies that recognize the diverse vulnerabilities and capabilities of smallholder farmers.

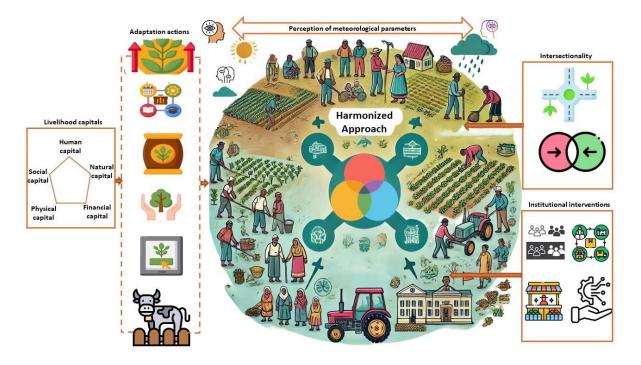


Figure 15: Conceptual diagram illustrating interconnections between smallholder farmers' adaptation actions, intersectionality, and institutional support

Source: Author's construct, 2025

Note: The icons and images were made from www.flaticon.com and Dall.e

Figure 15 visualises the interconnections between adaptation, intersectionality and institutional support. It illustrates the multifaceted influence of farmer adaptation behaviours, intersectionality, and institutional interventions. The 'adaptation actions' section depicts farmers working on their farms. It shows the adoption of various adaptation actions—plant improved crop cultivars, livelihood diversification, application of agrochemicals, practising agroforestry, planting calendar adjustments, and raising additional livestock under the influence of resource availability. These actions represent how smallholder farmers actively respond to their perception of meteorological parameters—precipitation, temperatures and

extreme events—as climate risks. The 'intersectionality' section illustrates how diverse groups of farmers (men, women, elderly, youth, etc.) with varying socio-demographic backgrounds face different social and economic challenges. It shows that within a community of smallholder farmers, some groups are more vulnerable and face greater barriers to adaptation than others due to socio-economic inequalities. This section symbolizes how farmers' socio-demographics shape their adaptive capacity, emphasising that different farmers have varying levels of access to adaptation opportunities.

The 'institutional support' section demonstrates how institutions implement interventions through training and capacity building, technology transfer, input supply and marketing and value chain integration to support smallholder farmers in adopting specific adaptation actions. It shows how they enable or hinder adaptation for different social groups. The 'harmonized approach' section as depicted in the centre of Figure 15 shows the interplay between adaptation actions, socio-economic vulnerabilities leading to intersectionality and institutional support. It shows how adaptation decisions are shaped by both social inequalities and institutional interventions. It suggests an integrated approach where adaptation is shaped by intersectional factors and enhanced by institutional interventions. This infographic integrates these elements explored in this thesis to explain the importance of a context-sensitive and policy-supported adaptation framework. In the following sections, I formulate recommendations that could enable the realization of a more harmonious approach to adaptation by smallholder farmers.

# 7.6 Moving beyond 'one-size-fits-all' adaptation interventions

One of the most significant insights from this research is the inadequacy of universal adaptation interventions that assume all smallholder farmers have the same needs, capabilities, and constraints (Yimam & Holvoet, 2023; Puig et al., 2025). Farmers are not equally vulnerable to climate impacts (Nyantakyi-Frimpong, 2020; Opoku Mensah et al., 2025). My findings highlight that adaptation decisions are influenced by a complex interplay of factors, including personal and institutional factors. These factors create significant disparities in adaptive capacity among farmers (Opoku Mensah et al., 2025). Interventions that fail to recognize these differences risk exacerbating existing inequalities rather than mitigating climate vulnerabilities (Puig et al., 2025). A major implication of this research is that adaptation cannot be generalized across smallholder farmers and farmer groups. For example, some farmers, especially women, migrants, and young farmers, face barriers due to

entrenched social inequalities (e.g. Erwin et al., 2021; Lawson et al., 2020). Social inequalities shape adaptation decisions, with marginalized farmers facing greater challenges in accessing adaptation opportunities (Alare et al., 2022; Puig et al., 2025). If adaptation interventions are not sensitive to these realities, they risk reinforcing structural inequalities.

Such a context-specific and intersectional approach is essential for making adaptation efforts more inclusive, effective, and sustainable. Moving beyond a 'one-size-fits-all' model acknowledges that smallholder farmers are not a homogeneous group and that adaptation interventions must reflect these diverse socio-economic and institutional realities (Thompson-Hall et al., 2016; Nyantakyi-Frimpong, 2020). I suggest that tailoring interventions to local contexts and specific farmer needs can help ensure that climate adaptation is both equitable and transformative in the long run. Based on the findings of this thesis, I make five recommendations to address these structural barriers constraining adaptation:

- i. Invest in climate education, skill development, and farmer-led innovations to help farmers make informed adaptation choices (e.g. Morrison et al., 2025; Baffour-Ata et al., 2025).
- i. Promote gender-responsive adaptation interventions to ensure that women have secure access to land and credit (e.g. Forkuor & Korah, 2023; Opoku Mensah et al., 2025).
- ii. Create women-led agricultural cooperatives to facilitate knowledge-sharing and collective bargaining (e.g. Soto Alarcón & Sato, 2019; Sarkki et al., 2024).
- iii. Target young farmers and migrants through social protection policies and offering them support for climate-resilient farming (e.g. Mukwedeya & Mudhara, 2024; Asare-Nuamah et al., 2025).
- iv. Expand education and skill-building programmes to empower farmers with knowledge on climate adaptation (e.g. Asante et al., 2024; Alhassan et al., 2025).

# 7.7 Institutional coordination and policy integration

While institutions play a critical role in supporting adaptation, their effectiveness varies. Institutions can enable or hinder adaptation actions, depending on how well they address farmers' needs (Chowdhooree et al., 2020; Fitzpatrick, 2022). Some farmers may benefit from well-established agricultural extension services and input supply interventions, while others in remote or marginalized communities may struggle with poor institutional reach,

lack of market access, or weak policy implementation (Stringer et al., 2020; Fitzpatrick, 2022). A uniform policy that does not account for such institutional disparities may leave the most vulnerable farmers behind (Puig et al., 2025). To ensure equitable and effective adaptation outcomes, institutions must move toward context-specific, inclusive, farmer-centered and intersectional approaches. This means that institutions must develop differentiated adaptation support mechanisms by designing tiered support interventions that address the varying levels of resources and capacities among smallholder farmers (e.g. Opoku Mensah et al., 2025).

Accordingly, adaptation interventions should be gender-responsive, socially inclusive, and locally tailored. For instance, institutions must support commercial-oriented smallholders with market access, value chain integration, and technology adoption. Also, institutions should ensure equal and targeted access to land, credit, services, training, etc., for resource-poor farmers such as women. Here, it is critical to conduct participatory vulnerability assessments to identify disadvantaged farmers and farmer groups and offer them adaptation incentives. Thus, institutions should seek to reduce adaptation inequalities by targeting marginalized groups, or they may reinforce inequalities if their interventions fail to be inclusive (Forkuor and Korah, 2023; Petzold et al., 2023).

It must, however, be acknowledged from the ensuing discussion that institutions operate within resource constraints, which can limit their ability to implement differentiated adaptation support mechanisms fully. While I emphasize the need for context-specific, inclusive, and intersectional adaptation interventions, it is important to recognize that institutional capacity, funding limitations, and competing priorities often shape the extent to which these interventions can be realized (e.g., Tahiru et al., 2019; Rahman, 2021). Institutions, therefore, need to balance these constraints while striving to enhance equitable adaptation outcomes for smallholder farmers.

My research also highlighted that a fragmented institutional landscape weakens adaptation efforts. Strengthening multi-stakeholder partnerships ensures better resource allocation, knowledge dissemination, and long-term sustainability of adaptation measures. Cross-institutional collaboration is, therefore, important to support smallholder farmers effectively. Weak institutional coordination has led to fragmented and sometimes conflicting adaptation interventions. In relation to interventions on adaptation by formal institutions, I suggest policymakers should:

- i. Enhance collaboration between institutions, particularly state/public and civic/civil society institutions, to provide integrated support (e.g. Azhoni & Goyal, 2018; Puig et al., 2025).
- ii. Mainstream climate adaptation into development policies rather than treating it as a separate issue (e.g. Eriksen et al., 2021; World Bank, 2024).
- iii. Ensure equitable resource allocation so marginalized farmers are not excluded from institutional support (e.g. Pauw et al., 2022; Puig et al., 2025).

# 7.8 Rethinking the sustainability of institutional interventions

Many adaptation interventions lack long-term sustainability because they are often short-term, donor-driven, and externally imposed. This thesis suggests that locally-led adaptation efforts (e.g. Pilgreen et al., 2025; O'Brien et al., 2025) that build on farmer knowledge and traditions have greater potential for sustainability. Here I make a series of recommendations to improve the sustainability of institutional interventions on adaptation:

- ii. Move beyond short-term adaptation actions to long-term capacity-building efforts (e.g. Kates et al., 2012; Callahan, 2025).
- iii. Promote community-led adaptation planning to increase local ownership (e.g. Eriksen et al., 2021; Puig et al., 2025).
- iv. Reduce dependence on external donor funding by integrating adaptation into national development agendas (e.g. World Bank, 2024; Azine et al., 2025).
- v. Bridge adaptation inequalities to reduce differential vulnerabilities and social marginalization (e.g. Puig et al., 2025; Opoku Mensah et al., 2025).
- vi. Overcome intersectional barriers by providing targeted interventions that consider marginalized farmer groups' needs (e.g. Nyantakyi-Frimpong, 2020; Opoku Mensah et al., 2025).
- vii. Create equitable adaptation outcomes and enhance climate resilience (e.g. Rahman, 2021; Pauw et al., 2022; Forkuor & Korah, 2023).
- viii. Bridge the gap between available adaptation options and farmers' ability to implement them to ensure equitable adaptation outcomes (e.g. Tahiru et al., 2019; Quarshie et al., 2023)
- ix. Support farmer-to-farmer learning exchanges (e.g. Martini et al., 2023; Morrison et al., 2025).

x. Promote the use of traditional knowledge alongside modern adaptation techniques (e.g. Guodaar et al., 2021; Baffour-Ata et al., 2025; Maskell et al., 2025).

### 7.9 Conclusion

This reflection highlights how my findings on adaptation, intersectionality, and institutional support are deeply interconnected. Understanding such interconnection is necessary to explain the importance of a context-sensitive and policy-supported adaptation framework. The relationship between these three factors emphasises that effective climate change adaptation must be socially inclusive and institutionally supported (IPCC, 2022b; Puig et al., 2025; Witinok-Huber et al., 2025). An integrated approach that aligns adaptation actions, intersectionality, and institutional support is necessary for effective and inclusive climate adaptation interventions. Policies should integrate targeted institutional interventions that address the intersectional barriers faced by different farmer groups, ensuring equitable access to adaptation resources (Nyantakyi-Frimpong, 2020; Opoku Mensah et al., 2025). An integrated approach, where adaptation is driven by both individual capacities (intersectional factors) and shaped external enablers (institutional interventions) is critical.

Smallholder farmers' adaptation actions are shaped by socio-economic and institutional factors that influence their ability to respond to climate risks (He et al., 2022). Institutions play a critical role in supporting adaptation, but structural inequalities and coordination challenges limit the effectiveness of interventions (Tahiru et al., 2019; Rahman, 2021). Addressing these challenges requires a shift toward inclusive, context-specific, and long-term adaptation interventions. Recognizing the diverse vulnerabilities of farmers, strengthening institutional coordination, and addressing structural barriers will be key to vulnerability reduction in Ghana's smallholder farming communities. Effective climate change adaptation for smallholder farmers requires a coordinated approach that integrates individual adaptation efforts, institutional interventions, and an understanding of differential vulnerabilities (Puig et al., 2025). Inclusive policies, tailored support, and equity-driven interventions can result in more effective climate adaptation for smallholder farmers.

In the next chapter, I discuss the overall conclusion of my thesis. I summarize the significance of my study in relation to the research methods, empirical evidence, and theoretical insights. I also offer recommendations for future studies.

# **Chapter Eight**

### Conclusion

### 8.1 Introduction

In this thesis, I examined the complex dynamics of climate change adaptation among smallholder farmers in the Talensi district of Ghana, focusing on three core areas: factors influencing adaptation, the role of intersectionality, and institutional support. Through a hybrid research design that combined qualitative and quantitative methodologies (mixed-methods approach), I generated empirical evidence that deepens understanding of how smallholder farmers navigate climate change challenges, how socio-demographic intersections shape their adaptive capacity, and how institutional interventions enhance or constrain adaptation efforts. This methodological integration demonstrates that vulnerability and adaptation cannot be fully understood through singular methodological lenses. Adopting a mixed-methods approach allowed me to dissect the complex climate realities and contexts within which the rural people of the Talensi district live. This research exemplified how qualitative narratives complemented quantitative assessments to reveal nuanced insights into the factors shaping adaptation decisions and outcomes.

The triangulation of methods—enhanced the validity and credibility of research findings by cross-verifying data from different data sources (data triangulation) and combined qualitative and quantitative methods to comprehensively address the research questions (methodological triangulation) (Donkoh & Mensah, 2023; Kálmán & Malomsoki-Sántha, 2023)—enhanced the validity and reliability of my findings, enabling a robust examination of adaptation behaviours, social inequalities, and institutional frameworks. This research approach was particularly useful in the complex social contexts and the multicultural and interdisciplinary nature of this study, as it allowed me to capture diverse perspectives and a more holistic view of research questions to produce more nuanced insights and robust conclusions (e.g. Flick, 2017; Meydan & Akkaş, 2024). The mixed-methods approach also addressed the limitations of purely quantitative or qualitative studies by providing richer contextual understanding and explanatory depth (Creswell & Creswell, 2023).

Furthermore, the research operationalized an intersectionality approach (McCall, 2005; Hankivsky & Cormier, 2011) in adaptation studies (e.g. Erwin et al., 2021), an approach that remains underutilized in climate research, particularly in African contexts (e.g. Nyantakyi-

Frimpong, 2020; Opoku Mensah et al., 2025). The institutional analysis also extended traditional governance research by mapping how various institutions—state/public, private/market and civic/civil society—operated in a multi-scalar adaptation landscape.

In this concluding chapter, I synthesize the empirical, theoretical, and practical contributions of my research, acknowledge its limitations, and outline potential directions for future research.

# 8.2 Empirical contributions

The research contributes to knowledge by confirming three major empirical findings within the Ghanaian context. First, it identified the specific factors that influence climate change adaptation among smallholder farmers, including perception of climate change, livelihood capitals, and institutional support. The study confirms that adaptation actions are not undertaken in isolation but rather in complementary ways (e.g. Adeagbo et al., 2023; Gudina & Alemu, 2024; Atta-Aidoo & Antwi-Agyei, 2025), with farmers often adopting multiple strategies. Understanding local adaptation contexts can ultimately inform farmer-led adaptation policies to empower smallholder farmers to adapt more effectively through the promotion of 'packages' of complementary technologies (Alvarez Carrillo et al. 2022, p. 378). The findings also reveal that the extent of adaptation was determined by the availability and accessibility of livelihood resources, as well as institutional support mechanisms.

Second, the research highlights the role of intersectionality in shaping farmers' adaptive capacities. It demonstrated that adaptation is not uniform across farmer groups but is instead shaped by intersecting socio-demographic characteristics such as gender, age, economic status, and residential tenure (e.g. Yimam & Holvoet, 2023; Opoku Mensah et al., 2025). By applying an intersectional lens, the research contributes to a more nuanced understanding of adaptation inequalities and highlights the need for differentiated adaptation policies.

Third, the research provides empirical insights into the role of institutions in shaping climate adaptation in smallholder farming systems (He et al., 2022; Azhoni et al., 2024). It identified institutional interventions as crucial enablers of adaptation as well as institutional challenges. The findings emphasized that while institutions play an essential role in facilitating adaptation, their effectiveness is contingent on overcoming their capacity constraints and structural and governance challenges.

### 8.3 Theoretical contributions

The thesis advances theoretical debates on vulnerability and adaptation in several ways. By integrating concepts from climate adaptation, intersectionality, and institutional governance, the study contributes to an interdisciplinary understanding of adaptation dynamics. The research reinforces theories of adaptive capacity by illustrating how access to resources, information, and institutional support mediate farmers' ability to respond to climate risks (Tong et al., 2024; Nath & Arrawatia, 2025; Witinok-Huber et al., 2025). Additionally, the research builds on the intersectionality approach by demonstrating that adaptation constraints are not merely determined by exposure and sensitivity to climate risks but are also deeply embedded in socio-economic and political structures (e.g. Thompson-Hall et al., 2016; (Nyantakyi-Frimpong, 2020; Puig et al., 2025). This theoretical extension provides a more holistic understanding of climate vulnerability by acknowledging the interlocking systems of disadvantage that shape adaptation outcomes. Furthermore, the institutional analysis in this study aligns with governance theories on adaptation, emphasizing the importance of institutional landscapes, accessibility, and linkages in shaping adaptation actions. By identifying institutional barriers and enablers, the research contributes to ongoing discussions about the role of institutions and governance in vulnerability reduction.

Theoretically, climate change adaptation, intersectionality, and institutional support are deeply intertwined, creating feedback loops of vulnerability that disproportionately affect the most marginalized farmers and communities. This thesis has demonstrated how these elements interact and reinforce one another, often perpetuating cycles of disadvantage and vulnerability. By exploring these interactions, this research identifies key leverage points that can drive more inclusive and effective interventions, ultimately fostering transformative change.

# 8.4 Practical implications: Bridging research, policy and practice

The findings of this research have significant policy and practice implications. For adaptation strategies to be effective, they must be tailored to the diverse needs and constraints of smallholder farmers. I conclude that policymakers should:

i. Enhance institutional coordination: Given the fragmented nature of institutional interventions, there is a need for greater synergy among the various institutions to ensure a holistic and sustained approach to adaptation. Strengthening institutional

- coordination, integrating local knowledge into adaptation planning, and fostering multi-stakeholder collaboration are essential steps toward more sustainable adaptation governance.
- ii. *Promote inclusive adaptation policies:* Recognizing the intersectional barriers faced by different farmer groups, adaptation interventions should be designed with a focus on equity, ensuring that marginalized farmers, particularly women and youth, have access to adaptation resources and decision-making processes.
- iii. Organize technology fairs/field days and educational campaigns: To encourage the adoption of improved agricultural practices, technology fairs/field days and educational campaigns can be organized to showcase the benefits and practical applications of modern agricultural practices that are appropriate to a developing world context. These initiatives should incorporate local languages and culturally relevant materials to make the adaptation actions more accessible and foster their successful implementation and maintenance.
- iv. Strengthen local capacity: Investment in farmer training and education on climate adaptation techniques is crucial to empowering smallholders with the knowledge and skills needed to implement effective adaptation strategies.
- v. Promote farmer-centred and participatory methods: Smallholder farmers should be actively engaged in adaptation planning, with their local knowledge and experiences informing policy decisions.
- vi. Develop context-specific adaptation packages: The research highlights that farmers often adopt multiple adaptation actions simultaneously. Future adaptation policies should promote integrated and complementary adaptation packages rather than isolated interventions.
- vii. Address structural barriers: Policy reforms should focus on improving land tenure security, financial inclusion, and market access to support smallholder adaptation efforts.
- viii. *Invest in rural infrastructure:* Investing in community-based infrastructure—including irrigation facilities, roads and storage facilities—while actively involving local farmers in their planning and implementation processes to would enhance the effectiveness of adaptation actions.

# 8.5 Looking ahead: Limitations and future research directions

While this thesis provides a firm foundation and valuable insights into the interplay between climate change adaptation, intersectionality, and institutional support for smallholder farmers in the Guinea Savannah agro-ecological zone of Ghana to inform targeted interventions and adaptation actions in the most affected areas, its limitations must be acknowledged. These limitations present opportunities for future research to expand and refine the findings. First, while the mixed-methods approach provided depth, the reliance on cross-sectional data limits the ability to capture long-term adaptation dynamics. The research presents a snapshot of adaptation strategies, intersectionality and institutional responses at a specific point in time. However, adaptation is a dynamic process that evolves as climate risks change and new policies or interventions emerge. A longitudinal study would provide a more comprehensive understanding of how adaptation behaviours, intersectionality, and institutional support evolve, particularly in light of ongoing changes to climate in Ghana. Also, a longitudinal social network analysis (e.g. Maya-Jariego & Holgado, 2015; Valente et al., 2015; Popelier, 2018) could be used to monitor and evaluate institutional interventions and their potential impact over time. Understanding such an evolution could provide deeper insights into the sustainability of adaptation actions, with lessons for SSA more generally.

Second, the research is limited to two communities in the Talensi district in Ghana's Guinea Savannah agro-ecological zone. While the findings provide rich, context-specific insights, the generalizability of these results to other agro-ecological zones and socio-political contexts remains uncertain. Different regions may have unique socio-economic conditions, governance structures, and climate risks that influence adaptation differently. Comparative studies across different agro-ecological zones in Ghana and other regions in Africa could provide broader insights into adaptation patterns and institutional effectiveness.

Third, one of the limitations of this study is the lack of in-depth exploration of how the specific attributes of climate change adaptation actions influence their adoption by smallholder farmers. While this research has examined key factors such as perceptions, livelihood capitals, and institutional support, it did not assess how the characteristics of adaptation actions themselves—such as their cost, complexity, relative advantage, perceived effectiveness, compatibility with existing farming practices, trialability and observability—affect adoption decisions (Rogers, 2003; Zhang et al., 2023; Matos, 2025). Adaptation actions are not adopted in isolation; rather, their inherent attributes interact with external socio-

economic and institutional conditions to determine whether farmers will take them up. Future research should build on the findings of this study by explicitly investigating how the attributes of different adaptation actions influence their adoption rates among smallholder farmers. Similarly, it will be critical to examine how institutional support mechanisms influence farmers' perceptions of the attributes of adaptation actions and, consequently, their adoption rates.

Fourth, the research applied an intersectional approach to analyze how different sociodemographic identities shape adaptation capacity. The research focused on agro-pastoral households, defined as those who considered crop farming as their primary source of income and owned at least five head of cattle and a herd of sheep or goats (Zampaligré et al., 2014). Since agricultural activities and adaptive capacities within the communities are not limited to only these respondents, the descriptive power of the results may not extend to the two study communities as a whole or to other similar communities beyond the case study areas. A future intersectional analysis of a broader set of household members/community members might reveal additional layers of inequalities in decision-making power that would significantly impact the adaptive capacities of the groups and community-level resilience to climate change. Also, deeper power dynamics within households and communities—such as decision-making hierarchies, intra-household bargaining, and political influence over resource allocation—remain underexplored. Understanding these hidden power relations could further explain disparities in adaptation access and effectiveness.

Fifth, the study focused on formal institutions, but informal institutions and traditional knowledge systems also play a crucial role in shaping adaptation behaviours (Abass et al., 2018; Haque et al., 2024). Future research could explore how customary practices, indigenous knowledge systems and local governance structures influence adaptation decisions. More critically, future studies should integrate the roles of both formal and informal institutions to understand the diverse actors involved in climate change adaptation comprehensively. Incorporating informal institutions will offer a more nuanced and comprehensive understanding of the grassroots mechanisms, local knowledge systems and institutional dynamics that support smallholder farmers' adaptation decisions.

Finally, future research should investigate the impact of emerging climate adaptation financing mechanisms, such as climate insurance and carbon credit schemes, on smallholder adaptation. Such investigation could offer new perspectives on adaptation sustainability.

There is also a need for further exploration of how digital and mobile-based climate information services can enhance adaptive capacity among farmers.

By addressing these limitations, future research can contribute to a more nuanced understanding of the decision-making process behind climate adaptation, ensuring that interventions are better designed and targeted, contextually relevant, and effectively implemented to enhance resilience in smallholder farming systems.

In the last section, I reflect on the findings of my research. I provide a comprehensive summary, highlight key contributions, and offer reflections on the study's significance. Also, I provide a final, impactful statement that ties everything together, ensuring that my research is coherent, meaningful, and valuable to both academia and practice. As a hybrid thesis, I ensure that the thesis is seen as an integrated body of work rather than a collection of separate papers.

# 8.6 Final thoughts: Towards an inclusive adaptation pathway

In summary, this thesis has provided a comprehensive analysis of smallholder farmers' climate change adaptation in the Talensi district, emphasizing the interconnected roles of smallholder farmers' adaptation to climate change, the role of intersectionality in shaping adaptive capacities, and the influence of institutional interventions. The localized nature of vulnerability and the socio-economic contingencies and specific local conditions or contexts of adaptive capacity (Adger et al., 2004) are key concerns that this research addresses. By identifying effective adaptation actions and their drivers, this research provides valuable insights for developing targeted interventions and policies to address the specific challenges faced by vulnerable farming communities. Furthermore, this research lays the foundation for future research by highlighting the need for methodological advancements, deeper sociocultural and demographic analyses, and the exploration of institutional interventions. By bridging the gap between empirical findings and practical applications, this research contributes to the broader goal of building sustainable and resilient agricultural systems in the face of climate change (Azine et al., 2025).

The findings demonstrate that climate adaptation is not a one-size-fits-all solution but rather a multidimensional process shaped by farmers' perceptions, access to livelihood resources, and institutional frameworks. By adopting a mixed-methods approach, the study has shed light on the complexities of climate vulnerability and adaptation, highlighting both the structural

constraints and the opportunities that exist within smallholder farming systems. The research underscores the need for integrated, inclusive, and well-coordinated adaptation strategies that address both the structural and social dimensions of climate vulnerability. A key takeaway from this research is the need for context-specific adaptation actions that recognize the diversity of smallholder farmers and ensure that they exercise their agency in selecting adaptation solutions that are best for their circumstances rather than being handed interventions (see Quarshie et al., 2023). While all farmers engage in adaptation actions to mitigate climate risks, their choices and effectiveness vary significantly based on their sociodemographics and access to institutional resources. This research underscores the importance of equitable adaptation policies that acknowledge social inequalities and ensure that vulnerable groups—such as women and resource-poor farmers—receive targeted support.

Ultimately, this thesis emphasises the urgency of building inclusive, and well-supported adaptation systems for smallholder farmers. Climate change presents an ongoing challenge (IPCC, 2022b; O'Brien et al., 2025), but with targeted policies, institutional support, and an intersectional approach, smallholder farmers can be empowered to navigate climate uncertainties effectively. Bridging research, policy, and practice is essential to ensuring that adaptation interventions are not only effective in the short term but also sustainable and transformative in the long run. By contributing to empirical knowledge, theoretical advancement, and practical applications, this study lays the foundation for tailored, inclusive, and context-specific adaptation policies that can enhance the resilience of smallholder farmers in Ghana and beyond.

Climate change is an ongoing and evolving challenge (IPCC, 2022b), requiring continuous research, adaptive policy frameworks, and innovative governance models. As we move forward, the co-creation of knowledge with farmers, institutional actors, and policymakers will be essential in developing equitable, transformative, and sustainable adaptation pathways (Taylor et al., 2025; Cartagena et al., 2025). Addressing structural inequalities, power imbalances, and financial constraints will be key to ensuring that smallholder farmers are not just adapting but also thriving in a changing climate. Future research must continue to challenge assumptions, refine methodologies, and push the boundaries of knowledge to ensure that adaptation efforts do not leave the most vulnerable behind but instead empower them to be active agents of resilience and transformation.

# Appendix I: Focus group guide



# FOCUS GROUP DISCUSSION TOOL

nterview Date:	/2022	
nterview Time:	Startpm	Endpm
Community Name:		لالالالالالالالالالالالالالالالالالا
Community Code:		
Name of Moderator:		
Name of Note Taker:		

#### 1. CLIMATE CHANGE AND EXTREME EVENTS

- 1. Have you noticed any changes in the climate in this area over your lifetimes?
- 1b. What are some of the changes in climate that you have personally experienced living in this area? (Hint: Could be extreme climate event(s) or slow changes)
- 1c. Which of the changes does this community experience more frequently?
- 2. Apart from the climatic-related event(s) discussed above, which other non-climatic events have you experienced living in this area that is affecting your agricultural activities?
- 2a. What are the impacts of these non-climate events on your agriculture activities?

### 2. COMMUNITY ADAPTIVE CAPACITIES

1. What resources/assets are available locally to support your agriculture activities?

(Hint: Natural capital: renewable and non-renewable resources and environmental services which generate useful resources for livelihoods. They include water, trees, land, minerals, and their derived services like nutrient cycling, clean air, and land productivity; Physical capital: the built infrastructure and equipment that support livelihoods and enable access to other assets and increase productivity. They include roads, buildings, water, technology, transport systems, energy, communication systems, and machinery; Social capital: membership and participation of people in networks and groups based on identity ties and common social and economic objectives that enable them to access a wider range of resources. They include participation in community boards, political parties, and religious and cultural groups, a sense of belonging, organizational structures, trust, and collaboration. Social capital can also include access to actors in the private, governmental, and non-governmental sectors; Human capital: individual capabilities that are necessary to appropriate and transform other forms of capital. They include skills, experience, knowledge, abilities, education, and health that enable an individual to engage in productive activities; Financial capital: available stocks (resources accessible for use or easily transferrable to liquid assets like cash, profits, savings, investments, capital, credit, or jewellery etc.) and the regular inflows of money (rents, pensions and remittances, etc.)

S/N	Assets/Resources	Available assets/resources
1.	Natural	
2.	Physical	
3.	Social	
4.	Human	
5.	Financial	

la. How do the changes in climate you have experienced affect the way you use your assets/resources?

S/N	Assets/Resources	Effects
1.	Natural	
2.	Physical	
3.	Social	
4.	Human	
5.	Financial	

## 3. ADAPTIVE ACTIONS AND INSTITUTIONAL ACCESS/SUPPORT

/ associations]) are promoting practices to help you change the way you farm in response to the changing climate

	listrict in this community?				
	olease look out for practices th	at are promote	d as climate char	ige strategi	es as well as those not promo
	ate change strategies)				
S/N	Institution			Practice	s promoted
la Fori	how long have you been recei	iring and imple	monting these w	actions?	
S/N	Practices promo		menting trese pr		h of time
5/21	Tractices promo	teu		Lengt	n or time
	•	•			
	w widely are the promoted pra				
S/N	Practices promot	ted	How wide	ly used	Why
S/N	at benefits has the community		plementing these	practices?	Benefits
2/14	Fractio	es promoted			Denents
					'Yes, please explain how institutions? Please explain.
	he community play any role in here condition(s) attached to r Institution	eceiving suppo			
S/N	here condition(s) attached to r Institution  ou encounter any challenges in	receiving suppor	rt from any of th Condition	e identified	institutions? Please explain.  Rationale for condition (if known)
S/N	here condition(s) attached to r Institution  ou encounter any challenges in	receiving support	rt from any of th Condition	e identified	institutions? Please explain.  Rationale for condition (if known)
S/N	here condition(s) attached to r Institution  ou encounter any challenges in	receiving support	rt from any of th Condition	e identified	institutions? Please explain.  Rationale for condition (if known)  at are they?
S/N  Do you S/N  a. How	here condition(s) attached to r Institution  ou encounter any challenges is Institutio	n getting suppor	rt from any of th Condition	e identified	institutions? Please explain.  Rationale for condition (if known)  at are they?  hallenge
S/N  Do you	here condition(s) attached to r Institution  ou encounter any challenges is Institutio	n getting support	rt from any of th Condition	e identified	institutions? Please explain.  Rationale for condition (if known)  at are they?
S/N  Do you S/N  a. How	here condition(s) attached to r Institution  ou encounter any challenges is Institutio	n getting support	rt from any of th Condition	e identified	institutions? Please explain.  Rationale for condition (if known)  at are they?  hallenge
S. Are to S/N  Do you S/N  Sa. How S/N  i. In adhat help	ou encounter any challenges in Institution  V can these challenges be addr  Challenge ddition to the practices promot p farmers cope with variations	n getting support	rt from any of the Condition  rt from the institutions, are there any eather conditions	e identified utions? Wh C	institutions? Please explain.  Rationale for condition (if known)  at are they?  hallenge  ddress challenge
. Are to S/N . Do you S/N . A. How S/N	here condition(s) attached to r Institution  ou encounter any challenges is Institution  v can these challenges be addr Challeng	n getting support	rt from any of the Condition  rt from the institu	e identified utions? Wh C	institutions? Please explain.  Rationale for condition (if known)  at are they?  hallenge  ddress challenge
. Are to S/N  . Do you S/N  a. How S/N  i. In adhat help S/N	ou encounter any challenges in Institution  V can these challenges be addr  Challenge ddition to the practices promote p farmers cope with variations Local Practices	receiving support on getting support ressed? re ted by institution in seasonal we	ent from any of the Condition  In the institution of the institution o	How to a	institutions? Please explain.  Rationale for condition (if known)  at are they?  hallenge  ddress challenge  ming practices developed location.  Why
S. Are to S/N  Do you S/N  S. In adhat help S/N	ou encounter any challenges in Institution  Very can these challenges be addressed in Challenge	receiving support on getting support ressed? getted by institution in seasonal we see the seasonal we see	ent from any of the Condition  The Condition of the Condi	How to a	institutions? Please explain.  Rationale for condition (if known)  at are they?  hallenge  ddress challenge  ming practices developed location.  Why

5b. Do the practices promoted by institutions work well with those developed locally or are they incompatible? Do you need to alter them at all?

S/N	Practices promoted	Adapted (changed/modified)	How
	Promoted Practices		
	Locally developed farming practices		

Thank you for your participation



## INSTITUTIONAL SURVEY TOOL

Date of I	Interview:	/202	22/2023	1		
Time of	Interview:	Start	amp	m End	ampm	
Name of	Institution:		الاالاالاالاال			
Institutional Code:						
Name of	f Interviewer:					
1.	INSTITUTION	AL ACCESS	SUPPORT	Γ		
the way t weather (Hint 1: ) as clima (Hint 2:	they farm in resp event(s), long-ter please look out fo te change strateg	onse to the cha on temperature or practices that ties) the explanato	anging clim e change etc at are promo	ate (including climat :.) in this district? ted as climate chang	munities/households to help them change te variability/seasonal variations, extreme te strategies as well as those not promoted tes of mobility, storage, diversification	
lb. How	long have you b	een promoting	these pract	ices?		
S/N	Pract	ices promoteo	d		Length of time	
le. In wh (Hint: T)	hat form is the pr he form could be	actices promot financial supp	ted? ort, capacii	ty building, training,	supplies, infrastructure provision etc.).	
S/N	Pract	ices promoteo	d	Form		
ld. How	widely are the p	romoted practi	ces used an	nong the beneficiary	communities/households and why?	
S/N	Practices pr	omoted		Spread	Reason	
$\vdash$						
					ified) to suit local conditions and actions	
2. How d	lo you decide wh	ich practices to	promote (	or not) in different lo	cations?	
				ties/households hav	re to meet before they receive you	
4. What	challenges does y	our institution	face in wor	king with agro-pasto	ral communities/households?	
5. How o	an these challen	ges be address	ed?			
2.	INSTITUTION	AL ARTICU	LATION/I	NTERFACE		
-				al and informal [e.g. omoting in the local	governmental / NGO / FBOs / CSOs / area?	
S/N	1	nstitution		_	Practice	

3. Does your organisation work with other institutions to promote these practices? If so, how?

3a. What are the advantages or disadvantages from this interaction to your institutions and the beneficiary communities/households?

4. Are your activities linked to existing national policies/programmes/plans targeted at promoting practices to help farmers change the way they farm and how?

5. Was your organisation involved in the preparation/development of these policies? If so, how? If not, why?

Thank you for your participation



## HOUSEHOLD SURVEY TOOL

Interview Numbe	er:
Interview Date:	//2022/2023
Interview Time:	Start
Name of Commu	nity:
Community Code	
Name of Interview	
rvame of Interview	ner. UUUUUUUUUUUUUU
1. SOCIO-I	DEMOGRAPHIC CHARACTERISTICS
1. Age of respond	
	30 [] c. 31 - 45 [] (d) 46 - 60 [] g. > 60 []
<ol><li>Sex of responde</li><li>(a) Male [ ] (b) Fe</li></ol>	
3. Marital status	emate [ ]
	) Single [ ] (c) Widowed [ ] (d) Divorced [ ] (e) Separated [ ]
<ol><li>Ethnic origin</li></ol>	
	[](b) Akan [](c) Ga-Dangbe [](d) Ewe (e) Guan [](f) Gurma [](g) Grusi [](h) Mande
[](i) Others [ ](s	specify)
(fint: piease reje appropriately)	r to the explanatory sheet to know which tribe belongs to which ethnic group and select
5. Religious affilia	tion
	(b) Islam [ ] (c) Traditional [ ] (d) No religion [ ] (e) Others [ ](specify)
	attended school or pre-school?
(a) Yes [ ] (	(b) No
	of school you attained
	, JSS/JHS, Middle) (b) Secondary (SSS/SHS, Technical/Vocational) (c) Tertiary [ ] (d) Other
[ ] (specify)	
7. Occupation Primary Occupation	on
	ntion
	old income per month?
9. Average earning	gs from each occupation per month?
Primary Occupation	ao
	tion
	the average earnings must correspond to the answer in Question 8)
	to any formal and/or informal group or organization?
	(b) No
(a) Farmer based a	roup do your group belong to? group [ ] (b) Communal based group [ ] (c) Faith based-group [ ] (d) Other (specify)
10b. What is the na	ame of the group or organization?
10c. What benefit(	s) do you obtain from the group?
10d. What challen	ge(s) do you group or organization face?
10e. How do you a	address these challenges as a group?
	ld Size (including yourself)
	b. 18-30 [ ]c. 31 - 45 [ ]Bd. 46 - 60 [ ]g. > 60 [ ]
remales: < 18[]	b. 18-30 [ ] c. 31 - 45 [ ]Bd. 46 - 60 [ ] g. > 60 [ ]
2. HOUSEI	HOLD PRODUCTION CHARACTERISTICS
a) Land	

#### a) Land

1. What is the estimated size (in hectares) of your farmlands? (Hint 1: 1 hectare = 2.47 acres).

(Hint 2:	If the same piece of land is used for bo	oth crop farming and animal rearing, record the size for one and				
	for the other).					
la. For	For crop farming					
	livestock rearing					
	is the main land tenure arrangement for					
		(c) Inherited land [ ] (d) Rented land [ ] (e) Others [ ]				
	')					
	has been the trend in the overall size of					
(а) Ехра	anding[] (b) Shrinking[] (c) No	change [ ] (d) Don't know [ ]				
3a. If ex	tpanding, what are the main reasons?					
	ıllow multiple responses)					
		er management of lands [ ] (c) Good climatic conditions [](d)				
		ation/Reforestation/Regeneration [ ] (f) Better land management				
	s [ ] (g) Others [ ] (specify)					
	rinking, what are the main reasons?					
	illow multiple responses)					
		gement of lands [ ] (c) Poor climatic conditions [ ] (d) Expansion				
		] (f) Better land management practices [ ] (g) Encroachment ments [ ] (j) Increasing family size [ ](k) Others [ ](specify)				
[ ](n)1	oush ourning [ ] (i) Expansion of settle	ments [ ] () increasing family size [ ](k) Others [ ](specify)				
b)	Crop Production					
1 77	1	- 2				
	many years have you been in crop farm	_				
		ars [ ] d. 21-30 years [ ] e. >30 years [ ]				
	types of crops do you mainly grow?					
	illow multiple responses)	d) Bambara beans [ ] (e) Sorghum [ ] (f) Rice [ ] (g) Vegetables				
	Tree crops/cash crops [ ] (i) Others [ ]					
	was the estimated yield of the crops yo					
S/N	Crop Produced	Estimated yield in appropriate unit				
3a.	Maize					
3b.	Millet					
3c.	Soya beans					
3d.	Bambara beans					
3e.	Sorghum					
3f.	Rice					
3g.	Vegetables					
3h.	Tree crops/cash crops					
3i.	Others					

4. Out of the crops you produced last season, what quantity was consumed by your household?

S/N	Crop Produced	Estimated consumption in appropriate unit
3a.	Maize	
3b.	Millet	
3c.	Soya beans	
3d.	Bambara beans	
3e.	Sorghum	
3 <b>f</b> .	Rice	
3g. 3h.	Vegetables	
3h.	Tree crops/cash crops	
3i.	Others	

5. Out of the crops you produced the last season, what quantity was sold by your household?

S/N	Crop Produced	Estimated sale in appropriate unit
4a.	Maize	
4b.	Millet	
4c.	Soya beans	
4d.	Bambara beans	
4e.	Sorghum	

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4f.	Rice	
4g.	Vegetables	
4h.	Tree crops/cash crops	
4i.	Others	

4i. Otters	
<ol><li>What major constraint(s) do your household fa</li></ol>	ace in your crop farming activities?
(Hint: allow multiple responses)	
(a) Pests and diseases [ ] (b) Unimproved techn	iology [ ] (c) Reduced soil fertility [ ] (d) Soil erosion [ ] (e)
Unfavourable land tenure arrangements [ ] (f)	land conflicts [ ] (g) Bush fires [ ] (h) Deforestation [ ] (i)
Land degradation [ ] (j) Poor agriculture suppo	ort (both policy and institutional) [ ] (k) Low input use [ ] (I)
	s to agricultural services and information [ ] (k) Poor access to
market [ ] (m) Labour constraints (n) Floods	s [ ] (o) Drought [ ] (p) Land degradation [ ] (q) Limited
education (r) gender inequalities and marginaliza	ation [ ](s) Others [ ](specify)
6a. How do you address these constraints?	
c) Livestock Production	

•	**					
	How many y	ngarang kapang	anom boo	10 110 E1T	roetooks r	rearmed?
٠.	Those many	reals marr	e you dee	и ш и	resource i	rearms:

(a) < 1 year [ ] b. 1-10 years [ ] c. 11-20 years [ ] d. 21-30 years [ ] e. >30 years [ ]

What major livestock type(s) do you rear?

(Hint: allow multiple responses)

(a) Cattle [ ] (b) Goats [ ] (c) Sheep [ ] (d) Pigs [ ] (e) Guinea fowls [ ] (f) Chickens [ ] (g) Draught animals (horses, camels, bullocks and donkeys) (h) Others [ ] (specify)......

3. What is the current number of your livestock?

S/N	Livestock	Current number
2a.	Cattle	
2b.	Goats	
2c.	Sheep	
2d.	Pigs	
2e.	Guinea fowls	
2f.	Chickens	
2g.	Draught animals (horses, camels, bullocks	
	and donkeys)	
2h.	Others	

<sup>4.</sup> Why do you rear livestock?

(Hint: allow multiple responses)

- (a) To consume its products (e.g. milk, meat, egg etc.) [] (b) As source of income [] (c) For traction power []
- (d) For transportation [ ] (e) As source of wealth status/cultural value (f) Others [ ] (specify)...
- 5. What is/are the main source(s) of feed/fodder/pasture for your livestock?

(Hint: allow multiple responses)

- (a) Open rangelands [ ] (b). Enclosure Private [ ] (c) Enclosure communal [ ] (d) Hay and feed supplements [ ] (f) Others [ ] (specify)......
- What major constraint(s) does your household face in your livestock rearing activities? (Hint: allow multiple responses)
- (a) Pests and disease [ ] (b) Unfavourable land tenure arrangements [ ] (c) land conflicts [ ] (d) Changes in the availability of feed/fodder/pasture [ ] (e) Livestock theft [ ] (f) Poor access to financial resources [ ] (g) Poor access to agricultural services and information [ ] (h) Poor agriculture support (both policy and institutional) [ ]
- (i) Poor access to market [ ] (j) Labour constraints [ ] (k) Floods [ ] (l) Drought [ ] (m) High stocking rate
- (n) Limited education [ ] (o) Gender inequalities and marginalization [ ] (p) Others [ ] (specify).....
- 6a. How do you address these constraints?....

### 3. AWARENESS AND CLIMATE CHANGE IMPACTS

- 1. Have you noticed any changes in climate in this area over your lifetime?
- (a) Yes [ ] (b) No [ ] (c) Don't know [ ]
- la. How would you describe the changes?
- (a) Noticeable but not substantially affecting agriculture (b) Noticeable and having some effects on agriculture
- (c) Noticeable and substantially affecting agriculture (d) Noticeable and completely changed agricultural practices
- 2. Which climate event(s) is/are common in this community?

(Hint: allow multiple responses)

a) Drought [ ] (b) Flooding [ ] (c) Storms [ ] (d) Heat spells [ ] (e) Others [ ] (specify)
3. Which impact(s) of these event(s) does your household frequently experience?
Hint: allow multiple responses)
a) Crop losses/failure [ ] (b) Yield loss [ ] (c) Decreased livestock productivity [ ] (d) Water scarcity [
e) Unavailability of feed/fodder/pasture [ ] (f) Others [ ] (specify)
To what extent do you agree with the following statements?

S/N	Statement	Agreement 1 (strongly disagree), 2 (disagree), 3 (neutral/don't know), 4 (agree), 5(strongly agree)							
4a.	Rainfall (rainfall variability) over your lifetime is more unpredictable	1		3	4	)			
4b.	Average temperature over your lifetime has been higher								
4c.	There has been changes in the length of the cropping season over your lifetime								
4d.	Extreme events (e.g. droughts, floods, storms, heat spells) over your lifetime are more frequent								
4e.	Extreme events (e.g. droughts, floods, storms, heat spells) are problems for my agricultural activities								
4f.	Non-climatic events/changes (e.g. lack and/or limited institutional support, unfavourable land tenure arrangement and land conflict, poor access to agricultural services and information, Gender inequalities and marginalization) are problems for my agricultural activities.								

## 4. HOUSEHOLD ADAPTATION STRATEGIES

<ol> <li>Have you changed the way you farm in response to the changing climate (including climate variability/seasona variations, extreme weather event(s), long-term temperature change etc.)?</li> <li>(a) Yes [ ] (b) No</li> </ol>
la. If 'No', why have you not changed the way you farm?
lb. If 'Yes', how have you changed the way you farm?
(Hint: allow multiple responses)
(a) I plant late or early/adjust planting calendar [ ] (b) I plant improved, drought tolerant and early maturing
crops [ ] (c) I change my herd size/livestock/poultry [ ] (d) I undertake free range animal rearing [ ] (e)
apply agrochemicals (chemical fertilizer) [ ] (f) I undertake irrigation [ ] (g) I use and modern technologies [
(h) I mange trees/forest [] (i) I diversify my livelihood [] (i) I use local knowledge and actions [] (k) Other
(specify)
lc. If a respondent mentions (f), probe to know what percentage of farmland is under irrigation
ld. If a respondent mentions (g), probe to know the modern technologies used.
le. If a respondent mentions (i), which of the following livelihood activities are you engaged in?
(Hint: allow multiple responses)
(a) Sell farm assets [ ] (b) Sell non-farm assets [ ] (c) Engage in small-scale mining [ ] (d) Migrate to worl
elsewhere [ ] (e) Burn and sell charcoal [ ] (f) Engage in wage labour [ ] (g) Engage in handicrafts (e.g
weaving and wood carving) [ ] (h) Engage in petty trading [ ] (i) Engage in logging [ ] (j) Engage in
processing (e.g. shea butter, rice, dawadawa etc.) [ ] (k) Brew local alcohol/pito [ ] (l) Others [ ] (specify)
1f. If a respondent mentions (j), probe to know the local knowledge and actions
lg. Are these practices commonly used in this community?
(a) Yes [ ] (b) No
lh. Have these practices been effective in helping you farm better?
(a) Yes [ ] (b) No
lha. How effective have these practices been in helping your agriculture activities?
(a) Very ineffective [ ] (b) Ineffective [ ] (c) Neutral/don't know [ ] (d) Effective [ ] (e) Very effective
lhb. Please explain your answer
Qli. What motivated you to use these practices?
(a) It is our locally developed farming practices [ ] (b) It was introduced to us [ ] (c) Both [ ] (d) Others [
(specify) (Hint: If a respondent is motivated by (b) or (c), ask Question Ij and section 5. Also, if a respondent is motivates
(11tm). 13 a respondent is motivated by (0) or (0), ask Question 13 and section 5. Also, if a respondent is motivated by (a) or (d), skin to section 6)

lj. Are the practices introduced by institutions compatible with local knowledge and practice?	
(a) Yes [ ] (b) No	
lja. Please explain your answer	

2. Please complete the table using a Likert scale of 0-5 (0 = constraining effective climate adaptation and <math>5 = constraining effective climate adaptation)

Capital	Indicator	- 1	Capa	city s	corin	le	Reason for score	
		0	1	2	3	4	5	
	Farming experience							
	Level of education							
Human	Household size							
	Gender							
	Age							
	Community group							
	Access to information							
Social	Access to institutional support							
	Social networks							
	Farmer networks							
	Land tenure system							
	Management of trees/forest							
Natural	Farmland area							
	Decision over farmlands							
	Climate variability							
	Communication systems							
TH : 1	Infrastructure							
Physical	Farm machinery and tools							
	Improved practices							
	Secondary occupation							
	Access to credit	$\top$						
Financial	Agricultural subsidy							
	Remittances	$\top$						
	Value of livestock							

## 5. INSTITUTIONAL SUPPORT

<ol> <li>Which institutions (formal and informal [e.g. governmental / NGO / FBOs / CSOs / CBOs / groups /</li> </ol>
cooperatives / association]) introduced you to these practices?
2. How long have you been practicing them?
(a) < I year [ ] (b) 1-3 years [ ] (c) 4-6 years [ ] (d) 7-9 years [ ] (d) ≥ 10 years
3. Why did you accept help from those institutions?
4. How difficult/easy is it to get help about farming from the institutions when you need it?
(a) Very difficult [ ] (b) Difficult [ ] (c) Neutral/don't know [ ] (d) Easy [ ] (e) Very easy [ ]
4b. Please explain.
5. Are there condition(s) attached to receiving support from any of the identified institutions?
(a) Yes [ ] (b) No
5a. What are the conditions?
6. Does your household encounter any constraints in working with the institutions?
(a) Yes [ ] (b) No
6a. What are these constraints?
6b. How can these constraints be addressed?

## 6. ACCESS TO CLIMATE INFORMATION AND SERVICES

<ol> <li>Do you have access to weather-related information to be able to predict the weather conditions?</li> </ol>
(a) Yes [ ] (b) No
la. How do you access weather-related information?
(Hint: allow multiple responses)

(a) I depend on local knowledge [ ] (b) I depend on meteorological and weather forecasts given to us in the community [ ] (c) I depend on meteorological and weather forecasts from traditional and electronic media such as radio, TV, newspapers, mobile phones, etc.) [ ] (d) I depend on information from friends/family/neighbours [ ] (e) I depend on information from community and group leaders (f) I depend on information from other institutions (formal and informal [e.g. governmental/NGO/FBOs/CSOs/CBOs/groups/cooperatives/association]) apart from the Ghana Metrological Agency [ ] (g) Others [ ] (specify)  1b. If a respondent chooses (a), probe for some of the local ways by which s/he is able to predict the weather
(Hint: The communication gadgets may include but not limited to radio set, $TV$ set, newspapers, mobile phones,
etc.)  le. How confident are you in using available weather-related information for decision making on your farm?  (a) Not at all confident [ ](b) Not confident [ ] (c) Neutral/don't know [ ] (d) Confident [ ] (e) Very confident [ ]  lea. Please explain.
2. Do you have access to extension services/advice for your agriculture activities?
(a) Yes [ ] (b) No
2a. If 'Yes', what kind of services/advice?
2b. How often do extension officers support you in your agriculture activities?
(a) Rarely [ ] (b) Sometimes [ ] (c) Don't remember [ ] (d) Often [ ] (e) Very often [ ]
2c. How satisfied are you with the extension services/advice you received?
(a) Very unsatisfied [ ] (b) Unsatisfied [ ] (c) Neutral/don't know [ ] (d) Satisfied [ ] (e) Very satisfied [ ]
2ca. Please explain.
Do you have access to credit for your agricultural activities?
(a) Yes [ ] (b) No
3a. Where do you get credit from?
lender (individual) [ ] (e) Savings Group [ ] (f) Don't need/want to borrow money [ ] Other (Specify) [ ]
3aa. Please explain why this source.
3ab. If (f) is select, probe to know why
3b. Are you able to access the credit when you need it and the amount you need?
(a) Some of the time [ ] (b) Most of the time [ ] (c) All of the time [ ]
3c. When do you get this credit?
(a) Beginning of farming season [ ] (b) Middle of farming season [ ] (c) End of farming season [ ] After the
farming season [ ]
4. Do you receive remittances from family or friends?
(a) Yes [ ] (b) No
4b. How often do you receive such remittances?
(a) Rarely [ ] (b) Sometimes [ ] (c) Don't remember [ ] (d) Often [ ] (e) Very often [ ]
4c. How much do you receive as remittances per year?

Thank you for your participation

## Appendix IV: Ethics approval

#### HREC Approval Granted - ETH22-7303

From Research.Ethics@uts.edu.au <Research.Ethics@uts.edu.au>

Date Tue 20/09/2022 13:47

To Research Ethics <research.ethics@uts.edu.au>; Brent Jacobs <Brent.Jacobs@uts.edu.au>; Seth Opoku mensah <Seth.Opokumensah@student.uts.edu.au>

1 attachment (438 KB)

Ethics Application.pdf;

#### Dear Applicant

Re: ETH22-7303 - "Institutions and Adaptive Capacity to Climate Change in Agro-Pastoral Production Systems in the Semi-Arid Guinea Savannah Agro-Ecological Zone of Ghana."

Thank you for your response to the Committee's comments for your project. The Committee agreed that this application now meets the requirements of the National Statement on Ethical Conduct in Human Research (2007) and has been approved on that basis. You are therefore authorised to commence activities as outlined in your application.

You are reminded that this letter constitutes ethics approval only. This research project must also be undertaken in accordance with all <u>UTS policies and guidelines</u> including the Research Management Policy.

Your approval number is UTS HREC REF NO. ETH22-7303.

Approval will be for a period of five (5) years from the date of this correspondence subject to the submission of annual progress reports.

The following standard conditions apply to your approval:

- Your approval number must be included in all participant material and advertisements. Any advertisements on Staff Connect without an approval number will be removed.
- The Principal Investigator will immediately report anything that might warrant review of ethical approval of the project to the <u>Ethics Secretariat</u>.
- The Principal Investigator will notify the Committee of any event that requires a modification to the protocol or other project documents, and submit any required amendments prior to implementation. Instructions on how to submit an amendment application can be found <a href="here">here</a>.
- The Principal Investigator will promptly report adverse events to the Ethics Secretariat. An
  adverse event is any event (anticipated or otherwise) that has a negative impact on
  participants, researchers or the reputation of the University. Adverse events can also include
  privacy breaches, loss of data and damage to property.
- The Principal Investigator will report to the UTS HREC or UTS MREC annually and notify the Committee when the project is completed at all sites. The Principal Investigator will notify the Committee of any plan to extend the duration of the project past the approval period listed above.
- The Principal Investigator will obtain any additional approvals or authorisations as required (e.g. from other ethics committees, collaborating institutions, supporting organisations).

 The Principal Investigator will notify the Committee of his or her inability to continue as Principal Investigator including the name of and contact information for a replacement.

This research must be undertaken in compliance with the <u>Australian Code for the Responsible</u> Conduct of Research and National Statement on Ethical Conduct in Human Research.

You should consider this your official letter of approval. If you require a hardcopy please contact the Ethics Secretariat.

If you have any queries about your ethics approval, or require any amendments to your research in the future, please don't hesitate to contact the Ethics Secretariat and quote the ethics application number (e.g. ETH20-xxxx) in all correspondence.

Yours sincerely, The Research Ethics Secretariat

On behalf of the UTS Human Research Ethics Committees C/- Research Office University of Technology Sydney E: Research.Ethics@uts.edu.au

Ref: E38

## Appendix V: Participant information sheet



#### PARTICIPANT INFORMATION SHEET

## ETH22-7303 - INSTITUTIONS AND ADAPTIVE CAPACITY TO CLIMATE CHANGE IN AGRO-PASTORAL PRODUCTION SYSTEMS IN THE SEMI-ARID GUINEA SAVANNAH AGRO-ECOLOGICAL ZONE OF GHANA

#### WHO IS CONDUCTING THIS RESEARCH?

My name is [Seth Opoku Mensah] and I am a student at UTS. My supervisor is A/Prof. Brent Jacobs [Email: brent.jacobs@uts.edu.au; Mobile: +61

#### WHAT IS THE RESEARCH ABOUT?

The purpose of this research is to investigate the role of local institutions and faith-based organizations in facilitating agro-pastoral households' adaptation responses to climate change impacts. This research seeks to address three interrelated aspects of vulnerability: (i) the determinants of vulnerability to climate change of agro-pastoral households in the Talensi district of Ghana; (ii) institutional role in addressing climate change in the Talensi district; and (iii) the contribution of faith-based organizations (as institutions) in reducing climate change vulnerability of agro-pastoral households in the Talensi district.

#### WHY HAVE I BEEN INVITED?

You have been invited to participate because of your agro-pastoral livelihood activities as a household/community and/or your support to agro-pastoral households/communities as an institution in building their adaptive capacities.

Before you decide to participate in this research study, please confirm you are an agropastoral household and/institutions (including faith-based organizations) supporting agropastoral households and communities to build their adaptive capacities.

#### **FUNDING**

Funding for this project has been received from the Institute for Sustainable Futures, University of Technology Sydney, Australia.

#### WHAT DOES MY PARTICIPATION INVOLVE?

If you decide to participate in the household interviews, it will be conducted in your home either very early mornings or evenings so the interview process does not interrupt your activities. It is expected to last for at least 45 minutes to an hour.

All focus group discussions will be organized late afternoons after you have returned from their farming activities to ensure your full and effective participation. It will be done at the community level. The discussion is expected to last averagely three hours each. For the purposes of later transcription, the discussions will be tape recorded and photos taken with prior notification when necessary to take any photo.



All face-to-face institutional interviews are expected to last an hour. However, where face-to-face institutional interviews are practically impossible, institutional surveys tools will be provided to complete at your convenience and collected by me at an agreed location, date and time. You will have the opportunity to review all interview transcripts and have access to their final transcripts if needed. Please revert to me per my contact details for any clarifications.

#### ARE THERE ANY RISKS/INCONVENIENCE?

Yes, there are some inconvenience. I will need your time throughout the interview process. If at any point in time you experience fatigue and need a break or you totally want to discontinue the interview, please alert me

#### DO I HAVE TO TAKE PART IN THIS RESEARCH PROJECT?

Participation in this study is voluntary. It is completely up to you whether or not you decide to take part. If you decide not to participate, or to withdraw from the study, it will not affect your relationship with the researcher or the University of Technology Sydney.

#### WHAT IF I WITHDRAW FROM THIS RESEARCH PROJECT?

If you wish to withdraw from the study once it has started, you can do so at any time without having to give a reason, by contacting me in person or at mobile: +233 or email: seth.opokumensah@student.uts.edu.au. If you withdraw from the study, your data that has already been collected will be deleted or destroyed.

#### WHAT WILL HAPPEN TO INFORMATION ABOUT ME?

By signing the consent form you consent to the research team collecting and using personal information about you for the research project. All this information will be treated confidentially. Your information will only be used for the purpose of this research project and it will only be disclosed with your permission, except as required by law.

It is anticipated that the results of this research project will be published and/or presented in a variety of forums. In any publication and/or presentation, information will be provided in such a way that you cannot be identified, except with your permission. All information collected will be de-identified and stored securely on OneDrive as well as Dropbox.

In accordance with relevant Australian and/or NSW Privacy laws, you have the right to request access to the information about you that is collected and stored by the research team. You also have the right to request that any information with which you disagree be corrected. Please inform the research team member named at the end of this document if you would like to access your information.

The results of this research may also be shared through open access (public) scientific databases, including internet databases. This will enable other researchers to use the data to investigate other important research questions. Results shared in this way will always be de-identified by removing all personal information (e.g. name, address, date of birth etc.).



#### WHAT IF I HAVE ANY QUERIES OR CONCERNS?

If you have queries or concerns about the research that you think I can help you with, please feel free to contact me in person or at mobile: + 233 or email: seth.opokumensah@student.uts.edu.au. You can also speak to a local independent contact, Dr. Addaney Michael, Lecturer at University of Energy and Natural Resources, Sunyani at mobile: +233 or email: michael.addaney@uenr.edu.gh.

You will be given a copy of this form to keep.

#### NOTE:

This study has been approved in line with the University of Technology Sydney Human Research Ethics Committee [UTS HREC] guidelines. If you have any concerns or complaints about any aspect of the conduct of this research that you wish to raise independently of the research team, please contact the Ethics Secretariat on ph.: +61 2 9514 2478 or email: Research.Ethics@uts.edu.au], and quote the UTS HREC reference number. Any matter raised will be treated confidentially, investigated and you will be informed of the outcome.



### CONSENT FORM

## ETH22-7303 | INSTITUTIONS AND ADAPTIVE CAPACITY TO CLIMATE CHANGE IN AGRO-PASTORAL PRODUCTION SYSTEMS IN THE SEMI-ARID GUINEA SAVANNAH AGRO-ECOLOGICAL ZONE OF GHANA

I	[participant's name] agree	to participate in the research pro	ject being
, ,		n@student.uts.edu.au and +61 ded by Institute for Sustainable Futur	es.
I have read the Participant I	nformation Sheet or someone	e has read it to me in language that I u	ınderstand.
I understand the purpose Information Sheet.	s, procedures and risks of	the research as described in the	Participant
I have had an opportunity t	o ask questions and I am satis	fied with the answers I have received	i.
,		cribed and understand that I am free t searcher or the University of Technolo	
I understand that I will be g	iven a signed copy of this doc	ument to keep.	
I am aware that I can conta the research.	ct Seth Opoku Mensah and D	r. Addaney Michael if I have any cond	erns about
Name and Signature [partic	ipant]	// Date	
Name and Signature (resea	rcher or delegate]	// Date	
Name and Signature [witne	ss*]	// Date	

#### \* Witness to the consent process

If the participant, or if their legally acceptable representative, is not able to read this document, this form must be witnessed by an independent person over the age of 18. In the event that an interpreter is used, the interpreter may not act as a witness to the consent process. By signing the consent form, the witness attests that the information in the consent form and any other written information was accurately explained to, and apparently understood by, the participant (or representative) and that informed consent was freely given by the participant (or representative) (delete this section and the 'Signature of witness' section above if this form does not need to be signed by a witness to the consent process).

# Supplementary materials

# **Chapter Four**

# **Supplementary material 1: Description of variables**

Type	Variable	Description						
Explained	Plant improved crop cultivars	Whether the household planted improved crop cultivars (Yes = 1, No = 0)						
Variables	Diversify livelihood	Whether the household diversified their livelihoods into non-farm activities (Yes = $1$ , No = $0$ )						
	Apply agrochemicals	Whether the household applied agrochemicals (Yes = 1, No = 0)						
	Practice agroforestry	Whether the household practiced agroforestry (Yes = $1$ , No = $0$ )						
	Adjust planting calender	Whether the household adjusted planting calender (Yes = $1$ , No = $0$ )						
	Raise more livestock	Whether the household raised more livestock (Yes = 1, No = 0)						
Institutional	Training and capacity building	Whether the household participated in training and capacity building (Yes = 1, No = 0)						
interventions	Technology transfer	Whether the household benefitted from technology transfer (Yes = 1, No = 0)						
	Input supply	Whether the household received input supply (Yes = 1, No = 0)						
	Marketing and value chain	Whether the household was introduced or linked to marketing and value chain (Yes = 1, No =						
	integration	0)						
Climate perception	Precipitation	Household perception of variation in precipitation (Decrease = 1, No change = 2, Increase = 3)						
variables	Temperature	Household perception of variation in temperature (Decrease = 1, No change = 2, Increase = 3)						
	Extreme events	Household perception of variation in extreme events such as drought and floods (Decrease						
		1, No change = 2, Increase = 3)						
Human capital	Farming experience	Number of farming years						
	Household size	Number of persons in the household						
	Age	Age of household head						
	Level of education	Education level of the household head by assigned value (No formal education = 0, Primary =						
		1, Junior High School = 2, Senior High School = 3, Tertiary = 4)						

	Gender	Gender of the household head (Male = 1, Female = 0)
Social capital	Community group	Household belonged to community group? (Yes = 1, No = 0)
	Farmer networks	Household belonged to farmer networks? (Yes = 1, No = 0)
	Social networks	Household belonged to social networks? (Yes = 1, No = 0)
	Access institutional support	Household ever received support from any institution? (Yes = 1, No = 0)
	Access to information	Household had access to information? (Yes = 1, No = 0)
Natural capital	Manage tree/forest	Household managed tree/forest on farmlands? (Yes = 1, No = 0)
	Decision over farmlands	Household had decision-making control over farmland? (Yes = 1, No = 0)
	Farmland area	Household farmland area in hectares
	Land tenure system	Household main land tenure arrangement for your farmlands (Inherited land = 0, Family-
		owned land = $1$ , Own land = $2$ )
	Climate variability	Household were affected by climate variability (Yes = 1, No = 0)
Physical capital	Improved agricultural practices	Household was introduced to improved agricultural practices (Yes = 1, No = 0)
	Farm machinery and tools	Household had access to farm machinery and tools (Yes = 1, No = 0)
	Communication systems	Whether the household had communication systems such as radio, television and mobile
		phones $(Yes = 1, No = 0)$
	Infrastructure	Whether the household had access to infrastructure such as irrigation facilities, dams, roads,
		etc.) $(Yes = 1, No = 0)$
Financial Capital	Secondary occupation	Household engaged in secondary occupation (Yes = 1, No = 0)
	Value of livestock	Types and number of livestock holding (Tropical Livestock Unit [TLU]) <sup>25</sup>
	Access to credit	Household had access to credit (Yes = 1, No = 0)
	Agricultural subsidy	Household received agricultural subsidy (Yes = 1, No = 0)
	Remittances	Household received remittances (Yes = $1$ , No = $0$ )

 $<sup>^{25}</sup>$  The average number of livestock owned by the sampled farmers is expressed in Tropical Livestock Units (TLU). TLU standardizes different types of livestock into a common unit for easier comparison. The conversion factors used are as follows: cattle = 0.7, sheep = 0.1, goats = 0.1, pigs = 0.2, and chickens = 0.01 (Benoit & Veysset, 2021; Gebre et al., 2023; Zeleke et al., 2024).

# **Supplementary material 2: Institutional interventions in the Talensi district**

Interventions	Activity
Training and capacity building	Train farmers on good agronomic practices
	Train farmers on animal husbandry production
	Train farmers on environmentally friendly farming practices
	Train farmers on crops and livestock value chains
	Train farmers on support services
	Train farmers on best practices for seed planting and management
	Train farmers on machine operation and maintenance
	Provide farmers with real-time climate information
	Train farmers on life skills and microenterprise
	Train farmers on business management and vocational skills
	Train farmers on microenterprise coaching and mentoring
	Train farmers on integrating trees into farming landscapes
	Form and support farmer-based organisations and cooperatives
	Facilitate the creation of savings and loans groups
	Impose mandatory obligations or restrictions
	Develop climate change adaptation plans
Technology transfer	Supply farmers with equipment for irrigation
	Provide water storage and management solutions
	Transfer technologies for better post-harvest handling
	Procure and supply small-scale farming machinery
	Transfer modern aquaculture technologies and practices
	Implement financial technologies tailored to the needs of farmers
Input supply	Supply farmers with high-quality/improved/certified seeds

Supply farmers with chemical fertilisers

Supply farmers with pesticides, insecticides, fungicides and herbicides

Supply farmers with basic farming equipment/tools

Supply animal feed and health products

Marketing and value chain integration Promote effective marketing techniques

Link farmers to ready markets

Establish linkages between farmers and buyers

Improve the marketability of agricultural produce

Motivate farmers to use input and output markets

Establish strong linkages among farmers, aggregators and institutions

Undertake small-scale enterprise or business development activities

Connect farmers to international markets

Design a sustainable value chain development plan

Create tree and land-based jobs and income-generating opportunities

Establish sustainable production of high-value dryland products

## Supplementary material 3: Estimation results for variables that influenced households to adopt climate change actions

Types	Variables	Plant impro	ved crop cultiv	ars	Diversify liv	velihoods		Apply agrochemicals Practice agrof		oforestry		Adjust plan	Adjust planting calender			Raise more livestock			
		Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Intervention	Training and capacity			0.225**			0.100*			0.082*			0.239***			0.129*			-0.118**
	building			(1.252)			(1.105)			(1.085)			(1.270)			(1.138)			(0.889)
	Technology transfer			0.141***			0.181*			-0.051			-0.025			0.002			0.075
				(1.151)			(1.198)			(0.950)			(0.975)			(1.002)			(1.078)
	Input supply			0.084**			0.174			0.134**			0.127**			0.016			0.040*
				(1.088)			(1.190)			(1.143)			(1.135)			(1.016)			(1.041)
	Marketing and value			0.123*			0.262***			0.171			0.105**			0.045			-0.024
	chain integration			(1.131)			(1.300)			(1.186)			(1.111)			(1.046)			(0.976)
Human	Farming experience		0.092**	0.003**		0.146	0.132		0.158*	0.142*		0.134**	0.086**		0.054***	0.085***		0.030**	0.044**
capital			(1.096)	(1.003)		(1.157)	(1.141)		(1.171)	(1.153)		(1.143)	(1.090)		(1.055)	(1.089)		(1.030)	(1.045)
	Household size		-0.073	-0.033		0.027**	0.056**		-0.047	-0.059		-0.031	-0.004		0.007	-0.001		-0.034	-0.031
			(0.930)	(0.968)		(1.027)	(1.058)		(0.954)	(0.943)		(0.969)	(0.996)		(1.007)	(0.999)		(0.967)	(0.969)
	Age		-0.018	0.002		0.044*	0.040**		-0.009	-0.008		0.023	0.006		0.033**	0.039**		0.010	0.014
			(0.982)	(1.002)		(1.045)	(1.041)		(0.991)	(0.992)		(1.023)	(1.006)		(1.034)	(1.040)		(1.010)	(1.014)
	Level of education		0.016***	0.011***		0.003***	0.001***		0.001**	0.006***		-0.007	-0.006		0.015**	0.019**		0.011	0.013
			(1.016)	(1.011)		(1.003)	(1.001)		(1.001)	(1.006)		(0.993)	(0.994)		(1.015)	(1.019)		(1.011)	(1.013)
	Gender		0.025	0.013*		0.047	0.144***		0.068	0.060		0.055**	0.062**		-0.029	-0.027		0.003	0.002
			(1.025)	(1.013)		(1.048)	(3.139)		(1.070)	(1.062)		(1.057)	(1.064)		(0.971)	(0.973)		(1.003)	(1.002)
Social	Community group		0.036	0.032		0.091*	0.094**		0.056	0.055		-0.029	-0.028		0.048**	0.049**		-0.057	-0.058
capital			(1.037)	(1.033)		(1.095)	(1.099)		(1.058)	(1.057)		(0.971)	(0.972)		(1.049)	(1.050)		(0.945)	(0.944)
	Farmer networks		0.016*	0.027**		0.041	0.023		-0.014	-0.010		0.026	0.618**		0.031	0.029		0.012	0.003
			(1.016)	(1.027)		(1.042)	(1.023)		(0.986)	(0.990)		(1.026)	(1.855)		(1.031)	(1.029)		(1.012)	(1.003)

			0.002447	0.00544		0.0224	0.0124		0.04.5	0.006		0.055	0.072		0.00144	0.00544			
	Social networks		0.003***	0.007***		0.022*	0.013*		-0.015	-0.006		-0.057	-0.073		0.024***	0.027***		0.014	0.014
			(1.003)	(1.007)		(1.022)	(1.013)		(0.985)	(0.994)		(0.945)	(0.930)		(1.024)	(1.027)		(1.014)	(1.014)
	Access institutional		0.012**	0.009***		0.044*	0.049**		0.002	0.003		0.043	1.343**		0.014	0.012		0.012	0.009*
	support		(1.012)	(1.009)		(1.045)	(1.050)		(0.998)	(1.003)		(1.044)	(3.831)		(1.014)	(1.012)		(1.012)	(1.000)
	Access to		-0.149***	-0.091**		0.376	0.393		0.205	0.175		0.443	0.405		0.063**	0.089**		-0.054	-0.031
	information		(0.862)	(0.913)		(1.456)	(1.481)		(1.228)	(1.191)		(1.557)	(1.499)		(1.065)	(1.093)		(0.947)	(0.969)
Natural	Manage tree/forest		0.075	1.040**		0.039*	1.012**		-0.031	-0.027		0.144**	0.174***		0.026	0.013		0.019**	0.010***
capital	- · ·		(1.078)	(2.829)		(1.040)	(2.751)		(0.969)	(0.973)		(1.155)	(1.190)		(1.026)	(1.013)		(1.019)	(1.010)
	Decision over		0.029*	0.014*		0.118	0.124		-0.028	-0.038		0.026**	0.018**		-0.003	0.005		-0.005	0.002
	farmlands		(0.971)	(1.014)		(1.125)	(1.132)		(0.972)	(0.963)		(1.026)	(1.018)		(0.997)	(1.005)		(0.995)	(1.002)
	Farmland area		-0.034*	-0.007		0.133	0.142		-0.057	-0.073		0.043	0.055		0.012	0.025		0.023**	0.033**
			(0.967)	(0.993)		(1.142)	(1.153)		(0.945)	(0.930)		(1.044)	(1.057)		(1.012)	(1.025)		(1.023)	(1.034)
	Land tenure system		-0.020***	-0.043**		0.055**	0.050**		-0.052	-0.075		-0.076**	0.043		-0.008	0.018		0.032	0.048
			(0.980)	(0.958)		(1.057)	(1.051)		(0.949)	(0.928)		(0.927)	(1.044)		(0.992)	(1.018)		(1.033)	(1.049)
	Climate variability		-0.107***	-0.117**		0.009***	0.052***		0.224**	0.271**		-0.119	-0.140		0.060***	0.046***		0.070**	0.054**
			(0.899)	(0.890)		(1.009)	(1.053)		(1.251)	(1.311)		(0.888)	(0.869)		(1.062)	(1.047)		(1.073)	(1.055)
Physical	Improved agricultural		0.033	0.982***		0.012	0.008		0.019*	0.002***		0.003*	0.004***		0.060	0.076		0.041*	0.046**
capital	practices		(1.034)	(2.670)		(1.012)	(1.008)		(1.019)	(1.002)		(1.003)	(1.004)		(1.062)	(1.079)		(1.042)	(1.047)
	Farm machinery and		-0.047**	-0.164*		-0.055	-0.907		-1.223	-1.070		1.271	1.113**		-0.946	-1.137		-0.659	-0.690
	tools		(0.954)	(0.849)		(0.946)	(0.404)		(0.294)	(0.343)		(3.564)	(3.043)		(0.388)	(0.321)		(0.517)	(0.502)
	Communication		-0.054	-0.038		0.048	0.041		-0.081	-0.068		0.130	0.134		0.145*	0.138*		0.082	0.076
	systems		(0.947)	(0.963)		(1.049)	(1.042)		(0.922)	(0.934)		(1.139)	(1.143)		(1.156)	(1.148)		(1.085)	(1.079)
	Infrastructure		-0.052***	-0.026**		-0.011**	-0.001*		-0.090	-0.065		0.040	0.031		0.027	0.016		0.008	0.002
	_		(0.949)	(0.974)		(0.989)	(0.999)		(0.914)	(0.937)		(1.041)	(1.031)		(1.027)	(1.016)		(1.008)	(1.002)
Financial	Secondary		0.074**	0.019**		0.081***	0.065***		0.194**	0.188**		0.057	0.033		-0.049	-0.033		0.012**	0.015**
capital	occupation		(1.077)	(1.019)		(1.084)	(1.067)		(1.214)	(1.207)		(1.059)	(1.034)		(0.952)	(0.968)		(1.012)	(1.015)
	Value of livestock		0.110***	0.043***		0.079***	0.053***		0.180	0.176		0.026	-0.002		0.021	0.040		0.001***	0.002***
			(1.116)	(1.044)		(1.082)	(1.054)		(1.197)	(1.192)		(1.026)	(0.998)		(1.021)	(1.041)		(1.001)	(1.002)
	Access to credit		0.024	0.502**		0.018*	0.005**		0.019*	0.022**		0.013	-0.004		-0.011	-0.004		-0.022	-0.021
			(1.024)	(1.652)		(1.018)	(1.005)		(1.019)	(1.022)		(1.013)	(0.996)		(0.989)	(0.996)		(0.978)	(0.979)
	Agricultural subsidy		-0.033*	-0.021		-0.000	-0.025		0.017*	1.016**		0.086	0.070		0.006	-0.004		0.023	0.014
			(0.968)	(0.979)		(1.000)	(0.975)		(1.017)	(2.762)		(1.090)	(1.073)		(1.006)	(0.996)		(1.023)	(1.014)
	Remittances		0.026***	0.007***		0.027*	0.025*		0.027*	0.036*		0.017	0.015		0.018	0.012		0.004**	0.003***
			(1.026)	(1.007)		(1.027)	(1.025)		(1.027)	(1.037)		(1.017)	(1.015)		(1.018)	(1.012)		(1.004)	(1.003)
Climate	Precipitation	0.068***	0.065**	0.048***	0.044**	0.036*	0.037**	0.002	0.027	0.029	-0.041	-0.075	-0.049	0.435***	0.396***	0.387***	0.455***	0.422***	0.415***
Perception	_	(1.070)	(1.067)	(1.049)	(1.045)	(1.037)	(1.038)	(1.002)	(1.027)	(1.029)	(0.960)	(0.928)	(0.952)	(1.545)	(1.486)	(1.473)	(1.576)	(1.525)	(1.514)
	Temperature	0.030***	0.076**	0.011**	0.437***	0.299***	0.273***	0.372	0.256	0.321	0.253*	0.200*	0.181**	0.012***	0.070***	0.098***	0.004***	-0.032***	-0.048**
		(1.030)	(1.079)	(1.011)	(1.548)	(1.349)	(1.314)	(1.451)	(1.292)	(1.379)	(1.288)	(1.221)	(1.198)	(1.012)	(1.073)	(1.103)	(1.004)	(0.969)	(0.953)
	Extreme events	-0.097**	-0.181**	0.117	0.398***	0.253***	0.233***	-0.391**	-0.233**	-0.288	0.411	0.371	0.365	0.037***	0.099***	0.125***	-0.011**	-0.056**	-0.071**
		(0.908)	(0.834)	(1.124)	(1.489)	(1.288)	(1.262)	(0.676)	(0.792)	(0.750)	(1.508)	(1.449)	(1.441)	(1.038)	(1.104)	(1.133)	(0.989)	(0.946)	(0.931)
	Wald chi <sup>2</sup>	9.12	23.59	23.59	11.06	17.6	17.6	7.03	21.57	21.57	2.25	7.97	7.97	66.15	73.23	73.23	78.66	84.03	84.03
	Prob > chi <sup>2</sup>	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Pseudo R <sup>2</sup>	0.043	0.360	0.594	0.043	0.377	0.419	0.027	0.331	0.359	0.046	0.289	0.324	0.610	0.754	0.765	0.748	0.810	0.817

Note: \*, \*\*, \*\*\* indicate significant statistical levels of p < 0.1, p < 0.05, p < 0.01, respectively. Estimated Coefficient ( $\beta$ ) and Odds Ratio (O.R.) are illustrated outside and within parentheses.

Supplementary material 4: Qualitative analysis of variables associated with strategy adoption

Influence of livelihood capitals on the adoption to plant improved crop cultivars

Level of education

In particular, farmers who had completed tertiary studies in agriculture reported advantages as follows:

... I had the opportunity to study agricultural science [after secondary school]. I gained a deeper understanding of the scientific principles behind farming...about the genetics of crops, soil health, and how to manage pests and diseases more effectively. This knowledge has been invaluable in helping me select and plant improved crop cultivars best suited to our local conditions.

Awaredone Youth FGD

Social networks

Farmers reported benefits from membership in these groups:

It is challenging to be a woman in a patriarchal community like ours, especially when accessing new agricultural technologies and knowledge. However, I have found strength and shared previously inaccessible knowledge by joining our women's farming group... This solidarity has enhanced my farm's productivity and given me a voice in a space where women are often overlooked.

Yameriga Female FGD

Land tenure

Women and youth typically expressed the following comment during the discussions.

The biggest hurdle we face as youth and women is securing land for agriculture in our patriarchal communities, where land ownership is predominantly in the hands of older men. It is disheartening to have the knowledge and the drive to make a difference but be held back by outdated practices...

Yameriga Youth FGD

*Infrastructure* 

Some farmers reported watching helplessly as inadequate water resources damaged their

crops.

Our hopes were high with the completion of a new dam in our communit to support

our irrigation needs. Unfortunately, shortly after its completion, the dam broke setting

back our immediate planting plans and raising serious concerns about our

community's capacity to support sustainable agricultural advancements.

Yameriga Male FGD

Remittances

A farmer reported:

The remittances I receive from my son enabled me to invest in improved crop

cultivars, which were once beyond my reach. Furthermore, the extra money has

allowed me to hire additional labour during peak seasons, ensuring the crops are

well-tended and harvested at the right time.

Awaredone Female FGD

Influence of livelihood capitals on the adoption of livelihood diversification

Level of education

Farmers that had completed higher levels of education reported advantages as follows:

Completing my university studies in business administration opened my eyes to the

vast potential outside traditional agriculture. I have set up a small supply chain for

agricultural inputs, diversifying my income and supporting the local farming

community by selling essential inputs.

Awaredone Youth FGD

Climate Variability

A farmer commented:

Climate variability has been a harsh teacher, but it has also opened my eyes to the

potential of combining agriculture with new income-generating activities.

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Awaredone Female FGD

Secondary occupation

Working as a carpenter has opened my eyes to the opportunities outside my farm's confines. The income I gained from carpentry enabled me to invest in poultry farming, which requires less land and is less affected by the erratic weather patterns that challenge our crop production. My experience has taught me that success in our changing world.

Awaredone Youth FGD

*Value of livestock* 

One farmer said:

I have started a small agribusiness that processes and sells livestock and livestock products. Livestock's stability, regarding its market, income and food security, has enabled me to take risks and invest in this new venture.

Awaredone Male FGD

Influence of climate perception on the adoption to adjust planting calendar

*Temperature* 

A farmer expressed:

To counter the impacts of rising temperatures, I have started planting later in the season when the temperatures are slightly cooler and more conducive to seedling growth.

Awaredone Male FGD

Extreme events

The discussions in Awaredone revealed:

Experiencing a devastating drought and a destructive flood within two years compelled me to rethink when and what I plant. To adapt, I shifted my planting to later in the season, aiming to avoid the peak times for these extreme events.

Awaredone Youth FGD

Influence of livelihood capitals on the adoption to adjust planting calendar

Farming experience

A smallholder farmer reported:

My decades of farming in this community have shown me the critical need to be flexible with my planting calendar. This strategic flexibility, born from years of observing and learning from the land, has been vital in maintaining my farm productivity.

Yameriga Male FGD

Social networks

A farmer commented:

Being a member of our women's group has been invaluable for sharing insights and strategies about when to plant, especially as the weather patterns become more unpredictable. During our meetings, experienced farmers share their observations on the changing climate, prompting us to adjust our planting calendar to better match the onset of the rains. This collective wisdom has helped me avoid planting too early or too late, ensuring my crops have the best chance to thrive.

Awaredone Female FGD

Climate variability

The farmers commented:

We no longer rely on our old calendar, which dictated planting times. I closely monitor seasonal forecasts and adjust my planting schedule accordingly. Last season, I delayed planting my groundnuts by several weeks to avoid the dry conditions predicted by the local weather service. This adjustment paid off, as my crop took full advantage of the late rains. Adapting our planting calendar based on current weather trends and reliable information is essential for our survival and success in farming.

Yameriga Male FGD

Influence of climate perception on the adoption to raise more livestock

*Temperature* 

A farmer stated:

With temperature increasing year by year, my crops suffered tremendously, leading me to rethink my reliance on crop farming alone. I noticed that my small herd of goats was faring much better, even in drier conditions, prompting me to expand my livestock holdings. The decision to raise more livestock, particularly goats and sheep that are more resilient to variable weather conditions, has provided a more stable and reliable source of income for my household.

Awaredone Male FGD

Influence of livelihood capitals on the adoption to raise more livestock

Value of livestock

This statement was encapsulating during the discussions:

After I became aware of the potential of livestock to provide a regular income through the sale of meat, milk, and other livestock products—even when crops fail—motivated me to raise more livestock to enjoy the multiple benefits of a crop-livestock integrated farming system.

Yameriga Youth FGD

Chapter Five
Supplementary material 1. Description of selected indicators of adaptive capacity

Capitals	Description	Indicators of adaptive capacity	Implications for adaptive capacity	Sample sources
Human	Human capital encompasses	Farming experience	Human capital encompasses the	DFID, 2000; Pagnani et al., 2021;
	individuals' skills, health, and	Level of education	necessary expertise and an optimal	Ngaiwi et al., 2023; Tangonyire &
	education, contributing to labour	Household size	blend of individuals capable of	Akuriba, 2021
	productivity and the capacity to	Gender	understanding the impacts of stressors	
	enhance, manage, and optimise	Age	and mobilising resources in response to	
	benefits derived from their		multiple challenges.	
	resources.			
Social	Social capital encompasses the	Community group	Social capital facilitates connections	DFID, 2000; Pagnani et al., 2021;
	networks and supportive	A 4 - : - G 4 :	between local organisations and their	Chepkoech et al., 2018; Zakaria et
	relationships among individuals	Access to information	external counterparts, thereby improving	al., 2020; Sarku et al., 2022
	and organisations, facilitating	Access to institutional support	the quality of communication and	
	collaboration, idea sharing, and	~	networking among local and external	
	mutual assistance.	Social networks	entities.	
		Farmer networks		
Natural	Natural capital signifies the assets	Land tenure system	Natural capital forms the basis for	Choden et al., 2020; Nawrotzki et
	inherent to the nature of a specific		households' livelihood activities, well-	al., 2012; Pagnani et al., 2021;
	locale. It represents the	Management of trees/forest	being and employment.	Zhang et al., 2022; Kandel et al.,
	productivity of land, actions to	Farmland area		2022
	maintain this productivity, and the			
	utilisation of water and biological	Decision over farmlands		
	resources on which rural			

Physical	Physical capital consists of assets generated by economic activities using other forms of capital. These assets may include infrastructure that supports other forms of capital, equipment, and enhancements to genetic resources such as crops and livestock.	Communication systems Infrastructure Farm machinery and tools Improved agricultural practices	Physical capital bolsters other forms of capital and connects local inhabitants, institutions, or businesses to the broader world.	
Financial	Financial capital refers to the level, variability, and diversity of income sources and access to other financial resources, such as credit and savings, collectively contributing to wealth.	Secondary occupation  Access to credit  Agricultural subsidy  Remittances  Value of livestock	Prudent use and investment of existing funds and the pursuit and acquisition of new funding sources enhance adaptive capacity.	Azad & Pritchard, 2022; Opoku

## **Supplementary material 2. Intersection of indicators and socio-demographics**

# Human Capital

Indicator	Intersecting factor(s)	Rating									χ2	P-value
							Wome	en		Men		
		0					699	%		31%		
Gender	gandar	1	Dargantaga				549	%		46%		
Gender	gender	3	Percentage count				689	%		32%	12.943	0.012
		4	Count				289	%		72%		
		5										
			_	Women				Men				
				15 - 35	36 -	- 59	≥60	15 - 35	36 - 59	≥60 years		
			_	years		ears	years	years	years			
Gender	gender, age	0	Percentage	12%		2%	15%	12%	19%		32.489	0.038
3011461	8-114-1, 48-	1	count	14%		3%	16%	12%	30%		22	0.020
		3		5%		0%	32%	5%	5%			
		4		3%		4%	20%	21%	7%			
		5		8%		5%	27%	20%	10% Men	30%		
					Women economic	TT: _1	L : -	Low eco		III ala anno ancia		
				Low	status	Higi	h economic status	Low eco	onomic status	High economic		
		0			50%		19%		23%	status 8%		
Gender	status	der, economic 0	Percentage count	t	47%		1976 7%		44%	2%	49.274	0.001
	Status	3			18%		50%		9%	23%		
		-			20%		7%		21%	52%		
		4 5			20% 0%		40%		21%	32% 40%		
		3		No F		Prima		JHS	SHS	Tertiary		
					cation	1 111116	ary	J113	3113	Tertiary		
Level of	level of education	0	Percentage	Edd	60%	2.	5%	10%	5%	0%		
education	level of education	1	count		42%		5%	21%	6%	6%	12.354	0.033
cducation		2	Count		7%		1%	17%	26%	39%		
		4			12%		12%	14%	19%	43%		
		4		Women	1270	1	1270	Men	19%	43%		
Level of			Percentage	15 – 35	36 – 3	50	≥60	15 – 35	36 – 59	≥60 years		
education	gender, age		count	years			≥00 years		33.543	33.543	0.004	
Caucation		0		10%			39%		2%	15%		
		7		10/0	50	, <b>J</b>	37/0	1/0	2/0	15/0		

		1		8%	21	% 35	5%	4%	13%	19%		
		2		21%	15	% 4	1%	35%	19%	6%		
		4		19%	5	% 5	5%	36%	28%	7%		
				W	omen				Men			
				Low econ	nomic ]	High econd	mic	Low econ	omic	High economic		
Level of	gender, economic		Percentage		status		atus		tatus	status		
education	status	0	count		49%	3	0%		15%	6%	38.519	0.001
caucation		1	Count		41%	2	3%	2	21%	15%		
		2			8%	2	27%	23%	23%	42%		
		4			5%	4	25%		17%	53%		
					15 - 3	5 years		36 - 59	years	≥60 years		
		0				14%			39%	47%		
A 00	0.00	1 Percer	Percentage			8%			23%	69%	25.612	0.001
Age	age	age	count			48%	48%		35%	17%	23.012	0.001
						67%			18%	15		
		4		61%					31%	8%		
				Women				Men				
				15 – 35	36 – 59	≥60	) 1.	5 – 35	36 - 59	≥60 years		
				years	years	years	S	years	years			
Λαο	gender, age	0	Percentage	7%	32%	29%	Ó	7%	7%	18%	50 737	0.001
Age	genuer, age	1	count	8%	15%	69%	Ó	0%	8%	0%	50.737	0.001
		2		18%	30%	0%	Ó	30%	5%	17%		
		3		23%	7%	0%	Ó	44%	11%	15%		
		4		25%	13%	3%	Ó	36%	18%	5%		

Note: 1) The Chi-square test's absolute numbers were presented as percentages to facilitate direct group comparison.

<sup>2)</sup> To satisfy the condition of the Chi-square test, which stipulates that no group should have very few counts (refer to Onchiri, 2013), the P-value of the Fisher's Exact Test was reported in cases where any cell contained fewer than five counts rather than using the Pearson Chi-Square P-value.

# Social capital

Indicator	Intersecting factor(s)	Rating								χ2	P-value
				Women			Men				
Access to	candan famuland ana		Percentage	≤ 2 hectares		> 2 hectares	≤ 2 hectares		> 2 hectares		
information	gender, farmland area	0	count	37%		12%	31%		20%	11.337	0.697
		1		16%		46%	8%		15%		
				Wome	en		Me	en			
				Indiger	ne	Migrant	Indiger	ie	Migrant		
Farmer networks	gender, residential status	1	Percentage count	17%	<b>6</b>	49%	3%	ó	31%	9.804	0.013
		3		36%	6	5%	54%	ó	5%		
		4		39%	6	1%	53%	ó	7%		
				Wome	en		Me	en			
Social	gender, economic		Percentage	Low econom		gh economic status	Low econom statu	•	gh economic status	44.000	0.004
networks	status	1	count	9%	⁄o	42%	6%	ó	43%	14.908	0.021
		4		379	%	19%	269	%	18%		
		5		11%	<b>6</b>	11%	78%	ó	0%		
				Women			Men				
Access to institutional	gender, age		Percentage count	15 – 35 years	36 – 59 years		15 – 35 years	36 – 59 years	≥60 years	18.072	0.002
support		0	Count	3%	25%	33%	9%	11%	19%		
		1		9%	14%	36%	5%	9%	27%		

	4 5		12% 13%	25% 27%	8% 7%	23% 40%	28%	4% 0%		
			Women			Men				
			Yes		No	Yes		No		
Access to institutional group membership	0	Percentage	14%		47%	11%		28%	18.121	0.034
support	1	count	27%		32%	18%		23%	10.121	0.05
	4		33%		12%	38%		17%		
	5		50%		7%	40%		3%		

Note:

<sup>1)</sup> The Chi-square test's absolute numbers were presented as percentages to facilitate direct group comparison.

<sup>2)</sup> To satisfy the condition of the Chi-square test, which stipulates that no group should have very few counts (refer to Onchiri, 2013), the P-value of the Fisher's Exact Test was reported in cases where any cell contained fewer than five counts rather than using the Pearson Chi-Square P-value.

## Natural capital

Indicator	Intersecting factor(s)	Rating									χ2	P-value
						Women				Men		
Land	and an	0	Percentage			81%				19%		
tenure	gender	1	count			82%				18%	69.849	0.001
		2				6%				94%		
				Women			N	len 💮				
				15 - 35	36 - 59	≥60 years	15	-35 years	36 - 59	≥60 years		
Land	gender, age		Percentage	years	years				years		72.654	0.001
tenure	gender, age	0	count	15%	45%	21%		4%	13%	2%	72.034	0.001
		1		15%	46%	21%		3%	12%	3%		
		2		0%	4%	2%		44%	42%	8%		
				Women			Men					
Land	gender, marital		Percentage	Single	Married	Widowed	Single	Married	Widowed	Divorced		
tenure	status	0	count	2%	55%	24%	4%	15%	0%	0%	81.885	0.001
tenure	status	1	Count	6%	30%	46%	0%	12%	6%	0%		
		2		0%	4%	2%	10%	66%	16%	2%		
				Women			Men					
				15 - 35	36 - 59	≥60 years	15 - 35	36 - 59	≥60 years			
Decision			Percentage	years	years		years	years				
over	gender, age	0	count	41%	25%	13%	13%	8%	0%		35.229	0.002
farmlands		2	count	6%	56%	13%	0%	25%	0%			
		3		13%	17%	26%	0%	9%	35%			
		4		8%	6%	22%	9%	19%	36%			
				Women			Men					
Climate			Dercentage	15 - 35	36 - 59	≥60 years	15 - 35	36 - 59	≥60 years			
variability	gender, age		Percentage count —	years	years		years	years			4.231	0.517
variability		0		7%	27%	13%	23%	24%	6%	0/0/0		
		1		13%	34%	15%	13%	23%	2%			

Note:

<sup>1)</sup> The Chi-square test's absolute numbers were presented as percentages to facilitate direct group comparison.
2) To satisfy the condition of the Chi-square test, which stipulates that no group should have very few counts (refer to Onchiri, 2013), the P-value of the Fisher's Exact Test was reported in cases where any cell contained fewer than five counts rather than using the Pearson Chi-Square P-value.

## Physical capital

Indicator	Intersecting factor(s)	Rating							χ2	P-value	
					Wo	omen		Men			
Communication	aan dan	0	Percentage			63%		37%			
system	gender	1	count			46%		54%	7.978	0.019	
		2				17%		83%			
				Women		Men					
			_	Low economic	High economic	Low economic	Hig	gh economic			
Communication	gender, economic		Percentage _	status	status	status		status			
system	status	0	count	51%	12%	23%		14%	19.673	0.003	
		1		31%	15%	42%		12%			
		2		0%	17%	33%		50%			
				No Formal	Primary	JHS	SHS	Tertiary			
C:			D	Education							
Communication	level of education	0	Percentage -	40%	20%	17%	17%	6%			
system		1	count	49%	19%	23%	4%	5%	17.674	0.024	
		2		8%	17%	17%	25%	33%			
					Low economic st	atus ]	High econ	omic status			
		0	_		10	00%		0%			
Improved		1	D (		10	00%		0%			
agricultural	economic status	2	Percentage			29%		71%	1.4.000	0.015	
practices		3	count			18%		82%	14.089	0.015	
		3 4		47% 53%							
			5		26% 74%						

Note: 1) The Chi-square test's absolute numbers were presented as percentages to facilitate direct group comparison.

2) To satisfy the condition of the Chi-square test, which stipulates that no group should have very few counts (refer to Onchiri, 2013), the P-value of the Fisher's Exact Test was reported in cases where any cell contained fewer than five counts rather than using the Pearson Chi-Square P-value.

## Financial capital

Indicator	Intersecting factor(s)	Rating								χ2	P-value	
						Women			Men			
Secondary		2				44%			56%			
occupation	gender	3	Percentage coun	nt.		36%			64%	19.751	0.001	
occupation		4	i creentage coun	11		37%			63%	19./31	0.001	
		5				22%			78%			
			No Formal Educati		Primary	JHS	SHS	Tertiary				
Secondary		2	Percentage		64%	18%	18%	0%	0%			
occupation	level of education	3	count		7%	9%	15%	21%	48%	17.880	0.008	
occupation		4	count		4%	9%	18%	29%	40%			
		5			9%	9%	18%	19%	45%			
				Women		Men						
				Yes	No				No			
Access to	gender, group membership		0	Percentage	0%	43%	18%			39%	25.333	0.003
credit			1	count	21%	36%	16%			27%	23.333	0.003
		3		30%	23%	29%			18%			
		4		56%	11%	22%			11%			
				Women			Men					
			Daraantaga	15 - 35	36 - 59	≥60 years	15 - 35	36 - 59	≥60 years			
Remittances	gender, age		Percentage count —	years	years		years	years		8.842	0.047	
		0	Count	10%	15%	33%	5%	13%	24%			
		4		21%	12%	7%	34%	24%	2%			
				1 to 5		o 10	11 to 15		16 to 20			
Remittances	household size	0		57%		33%	9%		1%	2.513	0.022	
		4		2%	1	10%	43%		45%			
				Women			Men					
Remittances	residential status		Percentage	Indigene	Mig		Indigene		Migrant	11.125	0.011	
Kennuances	residential status	0	count	5%	- 4	53%	1%		41%	11.123	0.011	
	CI	4		36%		5%	45%		14%			

Note: 1) The Chi-square test's absolute numbers were presented as percentages to facilitate direct group comparison.

2) To satisfy the condition of the Chi-square test, which stipulates that no group should have very few counts (refer to Onchiri, 2013), the P-value of the Fisher's Exact Test was reported in cases where any cell contained fewer than five counts rather than using the Pearson Chi-Square P-value.

## **Chapter Six**

## Supplementary material 1

Institutional accessibility

Capacity building

### 1. A KDC staff member shared:

Our awareness and sensitisation programmes focus on practical, climate-smart agriculture techniques, reaching hundreds of farmers across the district. We have seen remarkable progress in how these farmers adapt to the impacts of climate change on their livelihoods.

KDC staff member

**2.** The quote below from a WOM staff member explains the importance of such groups in supporting farmers' livelihoods and adaptation activities:

We promote savings groups because they empower farmers, especially women, by giving them the financial resources and support networks needed to invest in their farms and adapt to changing climate conditions. These groups provide a safety net by encouraging farmers to pool resources, making it easier for them to access cheaper loans and invest in climate-smart practices.

WOM staff member

Technology transfer

## **3.** A staff member explained:

Aquaculture requires reliable water sources, and in a semi-arid district like ours, consistent access to water is a major challenge. Our priority is to help farmers improve crop and livestock production, which are more in line with their needs and better suited to the district's local conditions and natural resources.

TDA staff member

Input supply

#### **4.** A staff member of TDA commented:

One of the challenges we face with subsidies is that they do not always reach the farmers who need them the most. Due to issues like favouritism, logistical barriers, and limited resources, more connected farmers often benefit, while the most vulnerable smallholders are left out.

TDA staff member

Institutional linkages

*Institution-to-institution linkages* 

**5.** A representative of WVG explained the institution's role in international market development as:

We aim to connect farmers in the Talensi district to international markets to increase their income and expose them to higher standards and practices, which drives the adoption of more sustainable and resilient farming methods. By linking them to global buyers, we help them become competitive and better equipped to withstand climate-related challenges.

WVG staff member

**6.** Explaining this trend, a staff member from the FTC remarked:

Each institution has its own priorities and targets to meet, and we often do not coordinate because of the different timelines and mandates. However, we recognise that working together would streamline our efforts and achieve greater impact.

FTC staff member

*Institutions-to-farmers linkages* 

## 7. A WVG staff member added:

We are driven by specific development goals, such as empowering vulnerable groups, promoting gender equality, and supporting marginalised communities. We often work closely with local communities to identify the most vulnerable populations, tailoring our interventions to address their unique needs and challenges directly.

# **8.** A TDA staff member reported:

As a public institution, we ensure our presence in every community, aiming to promote comprehensive development. However, reaching every farm household remains challenging due to logistical, funding and personnel constraints.

TDA staff member

# **Supplementary material 2**

Adoption and sustainability of institutional adaptation actions

## 1. The staff commented:

Honey is a highly sought-after product with established markets both locally and in larger towns. The demand for natural, organic honey and related products like beeswax has steadily grown, making beekeeping a viable and profitable adaptation action among farmers.

WVG staff member

#### **2.** A WOM staff member said:

Shea butter has a ready market locally and internationally, especially in the cosmetics and food industries. This market demand encourages farmers and women's groups to engage in sustainable shea tree management and butter production and processing.

WOM staff member

## **3.** A WVG staff member commented:

Interventions must include strategies to secure ongoing funding, such as building local savings groups, accessing microloans, or generating income through value-added activities. Such actions tend to be more relevant, accepted, and sustained without constant external support.

WVG staff member

## **Supplementary material 3**

Operational challenges of institutions

Resources

#### 1. A staff member from DoA stated:

We face significant challenges where other institutions offer farmers allowances at their training workshops. Our inability to provide such incentives skews community attendance and engagement, resulting in lower participation rates. Such practice severely impacts our ability to disseminate vital climate information.

DoA staff member

Planning

## **2.** A TDA staff member highlighted.....

While we recognise market/private and civic/civil society institutions' valuable contributions to climate adaptation in the district, integrating their adaptation plans into our formal planning processes is challenging due to differing operational timelines and priorities. They often initiate actions rapidly in response to immediate community needs, whereas government planning cycles are longer and require extensive bureaucratic approvals.

TDA staff member

**Transparency** 

**3.** For example, a DoA staff member noted the perceived inefficacies in their beneficiary selection processes:

Despite our efforts to facilitate a democratic beneficiary selection process to ensure inclusiveness and transparency, we are aware of ongoing concerns about nepotism and favouritism. We admit there are instances where our adherence to these democratic principles has not led to the intended outcomes to reach the most vulnerable farmer. We are actively looking for ways to improve these processes.

DoA staff member

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To reduce the overall length of the thesis, the literature cited in the empirical chapters—except for Chapter 5, which is already published—is not reproduced within those chapters but is included in the thesis bibliography.

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