Climate change, Indigenous knowledge and food security in northern Ghana

Thesis submitted for the Degree of

Doctor of Philosophy

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Thesis declaration

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Publications arising from this Thesis

Peer review journal articles

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Article submitted for publication

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Guodaar, L. and Bardsley, D.K. (2021). Social perceptions of climate change impacts on food security in northern Ghana: Do social networks matter in coping with household food insecurity? [Manuscript]

Perspective for a book

Guodaar, L. and Bardsley, D.K. Indigeneity in Africa: Implications for climate change adaptation. In Nursey-Bray et al. (Forthcoming). Old ways for new days: Indigenous survival and agency in climate changed times: Indigenous people and climate adaptation.

Abstract

It is well established in the literature that agricultural systems are highly vulnerable to climate change risks, particularly in the African Sahel. The risks posed by climate change are severely impacting upon food security and livelihoods of smallholder farmers in dryland communities in sub-Saharan Africa, including in Ghana, which is more regularly experiencing extreme climatic conditions. There has been a lot of work on Indigenous knowledge, yet, there is dearth of understanding of how Indigenous knowledge and technologies have evolved and utilised by farmers to adapt to the complexity of climate change risks or to promote food security at household and community scales. This research aims to partially address that gap by examining the value of Indigenous knowledge in northern Ghana to complement modern adaptation approaches for building resilience within local food systems in rural communities and regions.

The thesis examines how farming households and communities are utilising their Indigenous knowledge and technologies to adapt to climate change risks and promote food security in northern Ghana. To this end, this research applies a mixed-methods approach to explore how farmers in selected communities of three rural districts in northern Ghana apply Indigenous knowledge and technologies to improve food security. The integrated theoretical approach is used to frame the different epistemological and methodological perspectives for a comprehensive understanding of the research problem. Overall, a comprehensive review of key narratives was undertaken using surveys (299 household heads), expert interviews (24 agricultural extension agents and community leaders), focus group discussions (60 lead farmers) and observations to outline the social perceptions of climate change and food security risks, as well as adaptation opportunities at household and community scales.

Northern Ghanaian farmers perceive of multiple climatic stresses including increased temperatures, decreased rainfall, seasonal changes and extreme climate events, but those perceptions are spatially differentiated and contrast to meteorological evidence of rainfall trends. The multiple climate risks farmers experience locally disrupt cropping calendars, decrease productivity and impact upon food security in all its dimensions (availability, accessibility, utilisation and stability). Results highlight the importance of social networks in helping households

to cope with food insecurity. Indigenous adaptation practices vary at both spatial scales and the ways that local approaches to risk adaptation integrate with modern methods. Farming households are individually implementing tangible Indigenous strategies such as rainwater harvesting, relocation of farms to water sources, neem leaf extract and organic manure applications, while communities are collectively engaged in more intangible Indigenous practices including congregational prayers, rituals for rainmaking and taboos.

This research provides an important learning opportunity for policymakers and practitioners; government, non-governmental organisations and development partners to understand how multi-scalar adaptation interventions could be designed and implemented to help build community resilience and sustain livelihoods of Ghanaian farmers through the explicit recognition and utilisation of Indigenous knowledge. The results of this study suggest that Indigenous knowledge is neither static nor limited to a particular scale in rural Ghana, but rather, is evolving in fluid and complex ways to support adaptation processes to climatic risk. The recognition of such an evolution of Indigenous knowledge is important for theory and practice. Integration of knowledge systems provide an important theoretical framework to address climate change and food security risks in dryland farming communities in Ghana, and also for other regions where Indigenous knowledge systems remain strong and there is a lack of state or civil society capacity to provide substantial external adaptation support.

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CHAPTER 1: General Introduction and Problem Formulation

1.1 Introduction

Achieving food security in the context of climate change remains one of the major challenges for countries in the global South. Adaptation to climate change has become increasingly urgent for socio-ecological systems in sub-Saharan Africa (SSA) and the Sahel due to high levels of vulnerability of agriculture and associated livelihoods across the region (Batterbury and Mortimore, 2013; Epule et al., 2017; Leal Filho et al., 2018). The Intergovernmental Panel on Climate Change (IPCC) suggests that agricultural practices that include Indigenous and local knowledge can contribute to successful adaptation to climate change and food security risks (IPCC, 2019). Yet, there is insufficient understanding of the potential of Indigenous knowledge and technologies for climate change adaptation within policy in SSA, and particularly Ghana, the focus of this research. To that end, this thesis applies a blended conventional and publication approach to present research on how Indigenous knowledge and technologies are utilised by farming households and communities in northern Ghana to adapt to climate change risks and promote food security.

This first chapter introduces the discourse on climate change risks and the application of Indigenous knowledge and technologies to reduce vulnerability within socio-ecological systems. It then presents the problem under investigation and highlights the aim, research objectives and questions of the study in Ghana. The justification for the study is outlined by highlighting the main gaps in the literature on climate change, Indigenous knowledge and food security as related to the thesis aims. The chapter further presents the integral theory and its relevance in framing the methodology of the study. Finally, a systematic outline of the structure of the thesis is presented to introduce the reader to the mix of stand-alone and manuscript chapters.

1.2 Research background

The Earth's climate system has been changing over decades to millennia and more dramatic changes are expected to occur in the future (Dessler and Parson, 2019; Lemery et al., 2021; IPCC, 2018). Climate change is referred to as "the change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer" (IPCC, 2014: p5). Continuous changes in global climate due to both natural and anthropogenic forcings are described as inevitable and unequivocal in the 21st

Century (Chen et al., 2021). Global climate models (e.g. General Circulation Model [GCM]) project continuing future climate change, although specific projections are often couched with high levels of uncertainty. Within the modern historical period, the earth's climate system started experiencing gradual warming trends in the 20th Century (IPCC, 2014). However, the rates of global warming have intensified in the 21st Century (Osborn et al., 2021; World Meteorological Organization [WMO], 2018). It is recognised that the warming trends will not be evenly distributed, with much warming expected to be experienced on land, especially in arid and semi-arid areas associated with changes in rainfall and extreme events (IPCC, 2019). Biophysical and socio-ecological systems in dryland regions will be particularly highly exposed to the risks associated with the strong warming trend in the Earth's climate system.

It is projected that not only will future global warming intensify, but also global mean surface air temperatures will likely exceed 2^{o}C above pre-industrial temperatures. Even in the event of all parties to the Paris Agreement achieving their national emission targets, global temperatures will likely increase to 3^{o}C above pre-industrial levels (United Nation Environment Programme [UNEP], 2019). Countries in West Africa, and the Sahel in particular, are expected to experience increases in temperature extremes and number of hot days (IPCC, 2018; WMO, 2021). The continued warming of the earth's climate is leading to observed changes in precipitation across the globe (see Donnelly et al., 2017; Konapala et al., 2020; Mishra, 2019; Siddique et al., 2021). In SSA for instance, rainfall patterns have become increasingly erratic and unpredictable (Bayable et al., 2021; Lüdecke et al., 2021). Across the region of West Africa, a trend in decreasing mean rainfall is projected under stronger global warming scenarios (Klutse et al., 2018). Also, it is predicted that there will be more variable rainfall patterns and extreme events such as droughts, floods and heatwaves in the future (Abram et al., 2021; United States Environmental Protection Agency, 2016; Weber et al., 2018)

SSA is amongst the most vulnerable regions to climate change due to its high exposure to climate risks (Leal Filho et al., 2017; Niang et al., 2014; Owusu et al., 2021), but also the sensitivity of its production and livelihood systems. Even though the SSA countries' contribution to global warming is relatively minimal compared to the developed world, the region is likely to bear disproportionate impacts of climate change risk due to its relative exposure and sensitivity. It is suggested that agriculture will be the most vulnerable sector to climate change, especially in SSA due to the reliance of agricultural systems on particular climatic conditions (Pereira, 2017; Shukla et al., 2021; Zeleke et al., 2021). Even though climate change has the potential to increase agricultural productivity in some regions, it is projected that productivity in most SSA regions, and especially the Sahel, will decline (Gibon et al., 2018; IPCC, 2018), and this will be linked to substantial adaptive capacity constraints (Herslund et al., 2016). The low adaptive capacity of many developing countries in Africa is influenced by a plethora of factors such as extreme poverty, ongoing agro-infrastructural challenges, governance constraints and insufficient social safety nets (Chepkoech et al., 2020).

Climate change is affecting food security. Under global warming of more than 2^{o}C, the western Sahel of Africa is more likely to experience the strongest drying with associated severe food security risks, which could lead to more hardships and disruptions for Indigenous farmers and herders, particularly in rural communities (Batterbury, 1996; Parkes et al., 2018). Thus, smallholder dryland farmers and marginal rural areas will be the most vulnerable due to high sensitivity of their production system and adaptive capacity to respond to risks (Molotoks et al., 2021; Shukla et al., 2021). Erratic rainfall patterns are impacting agricultural productivity and livelihoods by disrupting ecological calendars, and traditional planting seasons, which describe specific periods of the year when conditions for cultivation of crops are favourable (Connolly-Boutin, and Smit, 2016; Leisner, 2020; Wing et al., 2021). Extreme climate events, particularly high temperatures, droughts and floods adversely impact agricultural activities, which in turn affect food supply, quality, safety and stability (Bhowmik et al., 2021; Cammarano et al., 2020; Gitz et al., 2016). For example, tropical cyclones and associated flooding in countries such as Zimbabwe, Malawi and Mozambique have displaced many people and entrapped larger populations into devastating food crises. The level of food insecurity in SSA has been exacerbated by the global COVID-19 pandemic, suggesting that a lot of supply chains are vulnerable to external shocks (Kansiime et al., 2021; Wolfson and Leung, 2020). Given the impacts of climate change on food security, many farming households and communities in SSA including Ghana are implementing short and long-term strategies to mitigate the associated risks.

Indigenous knowledge remains significantly important to manage climate risks in vulnerable regions (see Ford et al., 2020; Son et al., 2019). Indigenous communities in Africa have traditional understandings and approaches to demonstrating socio-ecological resilience through the utilisation of Indigenous knowledge systems to enhance the efficiency of managing agro-ecological resources to reduce vulnerability (Ajayi and Mafongoya, 2017; Asmamaw et al., 2020; Mapfumo et al., 2016; Theodory, 2021). The valuable cultural knowledge and skills which are passed on across generations for managing the physical environment irrespective of socio-political and spatial disadvantages of many marginalised dryland smallholder farmers generate both challenges and opportunities for adaptation (Makondo and Thomas, 2018). Thus, the knowledge and perspectives of Indigenous populations provide an important source of support for risk analysis and response mechanisms within otherwise resource-poor households (Funatsu et al., 2019).

However, the perspectives of Indigenous populations and the potentials of Indigenous knowledge are largely untapped in formal climate change adaptation planning, policy and research (Diver, 2017; Ford et al., 2016; IPCC, 2014; Nyantakyi-Frimpong, 2013). Climate change is anticipated to intensify the risks to Indigenous ecological systems with the potential for cascading impacts on local resource availability and livelihood activities (Connolly-Boutin and Smit, 2016; Makondo and Thomas, 2018). For example, climate change has accelerated biodiversity loss and impacted water resource management and livelihoods of Indigenous communities in the Mbozi and Mbinga districts in the southern highlands of Tanzania (Kangalawe, 2017). The threat to Indigenous livelihoods could considerably aggravate poverty levels of vulnerable groups in SSA society. Thus, integrating Indigenous knowledge and technologies into climate change adaptation planning could provide opportunities to generate innovative and holistic responses to climate change risks, and improve the livelihoods of people in vulnerable communities (Guto, 2020; Nkuba et al., 2020).

Indigenous knowledge has evolved and changed over time (Thompson et al., 2020). Having recognised the value of Indigenous knowledge in climate change adaptation in different African contexts (e.g. Derbile et al., 2016a; Mafongoya et al., 2017; Mokondo and Thomas, 2018; Theodory, 2021), a better understanding of the evolution of this important knowledge and associated technologies will be very useful not only for research but also for sustaining local diversity. Modernisation has been one of the important drivers of change over knowledge systems; influencing Indigenous cultures and approaches to deal with socio-ecological challenges within the physical environment (Klenk et al., 2017). The application of modern approaches for resolving risk is defined by the modes of knowledge and actions as well as reflexivity of socio-ecological systems (Bardsley and Knierim, 2020). Such reflexivity of modern responses will help generate requisite learning capacities geared towards the development of unique adaptation pathways to climate change risks (Davidson and Stedman, 2018). It is highly likely, therefore, that both modern approaches and Indigenous knowledge will be relevant to provide sustainable outcomes for managing ecological and environmental risks, especially in Ghana which is considered one of the SSA's vulnerable countries to climate change.

1.3 Problem formulation

Rain-fed agriculture is the main livelihood activity practised by many people in northern Ghana (Derbile et al., 2016b). Household populations in northern Ghana, especially in rural areas largely engage in either crop farming, livestock rearing or both for subsistence and commercial purposes (Figure 1.1). Those activities form about 75% of the livelihoods of many populations in the regions of northern Ghana (World Food Programme [WFP], 2012). However, the agricultural livelihoods of many smallholder farmers in northern Ghana are challenged by many factors such as poverty, agro-infrastructural challenges, customary land tenure systems, institutional constraints and insufficient social safety nets (Nyantakyi-Frimpong, 2020; Yaro, 2010). Additionally, climate change is increasingly intensifying the vulnerability of agricultural systems in northern Ghana due to resource constraints, which limit adaptive capacity (Abdul-Razak and Kruse, 2017; Owusu et al., 2021). The vulnerability of agriculture to climate change in northern Ghana is now considered as one of the major causes of food insecurity and malnutrition in the region (Darfour and Rosentrater, 2016; Wood et al., 2019). Chapter two of the thesis provides details of the impacts of climate change on agriculture and food security in northern Ghana.

Given the climatic uncertainties and impacts of climate change on food security, many households and communities in northern Ghana are already adapting to mitigate climate change risks using different variety of knowledge systems and technologies (see Apuri et al., 2018; Cobbinah and Anane, 2016; Lawson et al., 2020; Napogbong et al., 2021). Farming households and communities utilise Indigenous knowledge to conserve water for agriculture through taboos on forest conservation and rain harvesting (Boafo et al., 2016; Opare, 2018). Farmers in the region have relied on traditional ecological knowledge to develop ways of fighting against insect pests of food crops (Shaiba et al., 2019).

Figure 1.1: Map showing northern Ghana

Source: nationsonline.org

Many smallholder farmers in northern Ghana are also diversifying and cultivating multiple drought-resistant Indigenous crop varieties (Asante et al., 2021; Fagariba et al., 2018). Mixed cropping and farming are additional important traditional practices popularly employed by many Indigenous farmers for managing crops and lands to mitigate climate change risks in many communities in the Savanna regions (Antwi-Agyei and Nyantakyi-Frimpong, 2021; Alhassan et al., 2018). Several Indigenous storage technologies such as raising of barns and platforms are used by households to preserve crops, particularly grains against post-harvest losses in the region (Darfour and Rosentrater, 2016). In recent years, community support systems and social networks are utilised by local people as important social capital for reducing vulnerability to climate risks and disasters in northern Ghana (Antwi-Agyei and Nyantakyi-Frimpong, 2021; Dapilah et al., 2020). These traditional approaches are helping to create opportunities for food security amongst local populations, especially in rural areas, and yet knowledge on how these traditional practices could evolve or be supported remains under-developed.

Indigenous knowledge is less prioritised in climate change adaptation policies in Ghana. Climate change adaptation and agricultural policies and strategies of Ghana and associated research (e.g. Atanga, 2020; deGraft-Johnson et al., 2014; Sova et al., 2014) have advocated the singular need for more investments into conventional modern approaches as the sole pathway to agricultural transformation. For instance, the Agricultural Mechanisation Service Centers, National Fertiliser Subsidy Initiative and the Planting for Food and Jobs implemented by the government of Ghana involves the importation and allocation of tractors, fertilisers, pesticides and improved seeds to farmers to enhance agriculture in the country (Kansanga et al., 2018; Ministry of Food and Agriculture [MoFA], 2017). Of great concern, the traditional knowledge and associated technologies are gradually being eroded, in part due to the emphasis on scientific knowledge and approaches, but also due to a lack of investment into understanding how Indigenous knowledge could enhance modern agricultural development in Ghana, particularly in the north. The lack of attention towards Indigenous knowledge in adaptation plans, policies and research in Ghana and other parts of SSA could undermine good traditional practices. This is because people could lose faith in their local knowledge due to the narrow focus on scientific knowledge as the most effective way of responding to ecological and environmental change risks.

The value of Indigenous knowledge is being overlooked in Ghana, while many studies and policies around the world are showing the value of understanding and applying that knowledge for effective adaptation. Vulnerable communities are utilising Indigenous knowledge to complement modern approaches to address social and environmental risks (Cuaton and Su, 2020; Iloka, 2016; Mokondo and Thomas, 2018; Mugambiwa, 2018; Nalau et al., 2028; Wang et al., 2019). Integrating Indigenous knowledge with scientific knowledge in the context of climate change adaptation at different local spatial scales is particularly important because it provides an opportunity to reduce vulnerability of farmers to climatic risks and future climate uncertainties while sustaining livelihoods (Bacud, 2018; Derbile et al., 2019; Mokondo and Thomas, 2018). Also, the effective integration of Indigenous knowledge with different knowledge systems will create opportunities for sustainable livelihood and environmental management for many household populations, particularly in rural areas (Kumar et al., 2021; Theodory, 2021). Thus, the main aim of this research is to use northern Ghana as a case study to improve understanding and insights into the utilisation of Indigenous knowledge and technologies to achieve food security in the context of climate change. The rationale of the study informs the objectives and questions that this thesis seeks to achieve and address.

1.4 Research objectives and questions

1. Analyse the extent of climate change in the regions of northern Ghana over the last five decades (1965-2015) and identify how those trends and recent changes have been perceived by farmers.
2. Examine farmers' perceptions of climate change impacts on food security and how they are utilising social networks to cope with associated food risks and insecurities.
3. Examine existing Indigenous knowledge and technologies and their evolution in response to climate change risks at different local spatial scales.

To achieve the afore-mentioned objectives of the study, this research sought to find answers to the following underlining questions:

1. To what extent has the climate changed in the regions of northern Ghana over the last five decades (1965-2015), and how have the trends and recent changes been perceived by farming households?
2. How do farmers perceive the impacts of climate change on food security and its dimensions?
3. What roles do farmers' social networks play in mitigating food security risks under the context of climate change?
4. What are the existing Indigenous knowledge and technologies used to respond to climate change risks at different local spatial levels?
5. How have Indigenous knowledge and technologies evolved and changed over time in addressing climate change risks?

1.5 Justification of the study

1.5.1 Expanding knowledge and understanding on the cultural dimension of climate change adaptation at different local spatial levels

Northern Ghana has the potential to be overwhelmed with climate risks and disasters. The regions of northern Ghana are the most vulnerable to climate change in the country, in a broader region that is one of the most vulnerable on Earth. Northern Ghana has gone through ecological and social transitions in the past which have shaped the livelihood of local populations. The well-established cultural traditions of the people of Northern Ghana present both challenges and opportunities to the people in their adaptive capacities. Although there is a plethora of research on climate change adaptation in Ghana (Acheampong et al., 2014; Antwi-Agyei et al., 2015; Laube et al., 2012; Omari et al., 2018), there is still insufficient knowledge onthe cultural dimensions of adaptation (Adger et al., 2013; Corner et al., 2014; Millar, 1996), especially at differing local spatial levels. This study adds to the existing literature by exploring the cultural dynamics of indigenous knowledge adaptation in response to climate risks to generate resilience in food systems at different local spatial levels. Integrating perspectives from different spatial levels could help demystify the complexities of socio-ecological change to promote community resilience for sustainable development and societal transformation.

1.5.2 Limited knowledge on the evolution of Indigenous knowledge and technologies for climate change adaptation in SSA

Indigenous knowledge is evolving in a fluid and dynamic ways due to the complexity of climate change in the Sahel. Therefore, it is imperative to understand the complexities of climate change and ecological resource management processes in Indigenous communities to improve adaptation outcomes in Ghana, especially in the northern regions. Indigenous knowledge has evolved and changed in many societies across SSA, including Ghana. For instance, some Indigenous people and communities evolve with the changes of modern ways and methods of managing ecological resources while others stick to their conservative traditional practices to promote generational continuity of culture (Nakashima and Krupnik, 2018). However, scholarship on the evolution of SSA Indigenous socio-ecological knowledge in the scientific literature remains sparse and largely theoretical (e.g. Briggs and Moyo, 2012; Emeagwali and Shizha, 2016; Emeagwali, 2020). This research expands knowledge by empirically examining how Indigenous knowledge and technologies have dynamically evolved and changed over time in Indigenous households and communities using northern Ghana as a case study.

1.5.3 Limited attention on the potential of Indigenous knowledge in climate adaptation policy in Ghana

The importance of Indigenous knowledge is insufficiently recognised in climate adaptation policies in Africa and Ghana. Ghana's Climate Change Adaptation Policy, which provides a framework for strengthening household and community resilience pays limited attention to the potential and opportunities of Indigenous knowledge in mitigating climate change risks to promote sustainable growth and development in the country (Sova et al., 2014). The policy focuses almost solely on conventional modern scientific approaches involving application of fertilisers, pesticides and planting of improved seeds to help local farmers adapt to climate change. This modernisation approach adopted by the government of Ghana and its developing partners to increase national wealth through agro-exports will likely disadvantage smallholder farmers, who are mostly the poorest, with limited financial capacity to access modern farm inputs. The policy provides very little information about Indigenous knowledge and technologies or the opportunities they generate to improve food security under climate change. This gap makes it difficult to emphasise the importance of Indigenous knowledge for improving socio-ecological systems. The devaluation in policy could also contribute to a gradual erosion of Indigenous knowledge in already marginalised and vulnerable communities in Ghana, and elsewhere (Antwi-Agyei et al., 2014; Yaro, 2010). A better understanding of the potentials of Indigenous knowledge, and their policy implications for climate change adaptation is important if it is to have an ongoing role in reducing food insecurity, particularly in semi-arid northern Ghana.

1.6 Integral theory and relevance

The complexities of climate change require aggressive and holistic response strategies at all scales (O'Brien and Sygna, 2013). The Integral theory (IT) framework which utilises the all-quadrant-all level (AQAL) model is an innovative all-inclusive framework that allows for the analysis of broad perspectives to provide a comprehensive understanding of climate change risks and local adaptation options using different epistemological perspectives and methodological approaches (O'Brien and Hochachka, 2010; Wilber, 2005). Even though the IT model is critiqued for having the potential to generate conflicting perspectives from multiple individuals or groups (Paulson, 2008), it is widely acknowledged as an effective critical approach for understanding the social reality in diverse fields (e.g. ecological, environmental and social sciences), contexts and scales (Esbjörn-Hargens and Zimmerman, 2009).

The IT model revolves around individual and group perspectives at different levels, within the broader framework of interior and exterior dimensions of reality (Figure 1.2). These perspectives are employed to complement each other to help to learn how social systems show resilience at the individual and community levels within the context of socio-ecological change (Folke, 2006). Thus, IT draws attention to the roles of individual cognition and consciousness, collective values and belief systems, and scientific observations in managing socio-ecological resources (O'Brien, 2010).

The interior of the IT model explains the intangible domains such as knowledge, understanding, mindsets and motivations that are individually and collectively measured. On the other hand, the exterior portions explain the tangible domain such as climate, natural resources, or production levels that are scientifically measurable. These interior and exterior interactions are grounded in different methodological strands and disciplines that help in understanding and responding to socio-ecological and environmental change (Esbjörn-Hargens, 2006).

While the IT model recognises the "human dimension" of individuals and groups to understand socio-ecological system milieus, it also covers "behavioural and system dimensions" of individuals and groups to understand adaptation dynamics in response to socio-ecological change (O'Brien and Hochachka, 2010). The IT model was utilised in this study to frame viewpoints from farming households and communities about climate change impacts and adaptation opportunities. This approach was useful to the study because of its comprehensiveness in solving complex individual and collective challenges in society (Hochachka, 2005; McLaren and Kelleher, 2005).

Climate models have been utilised as one of the means of detecting climate change and variability trends and making future climate projections. Temperature and rainfall have been used as key indicators in assessing the extent of climate change across the globe. The degree of confidence in using climate models has been widely recognised and established. (New et al., 2006; Held et al., 2006; Easterling et al., 2000).

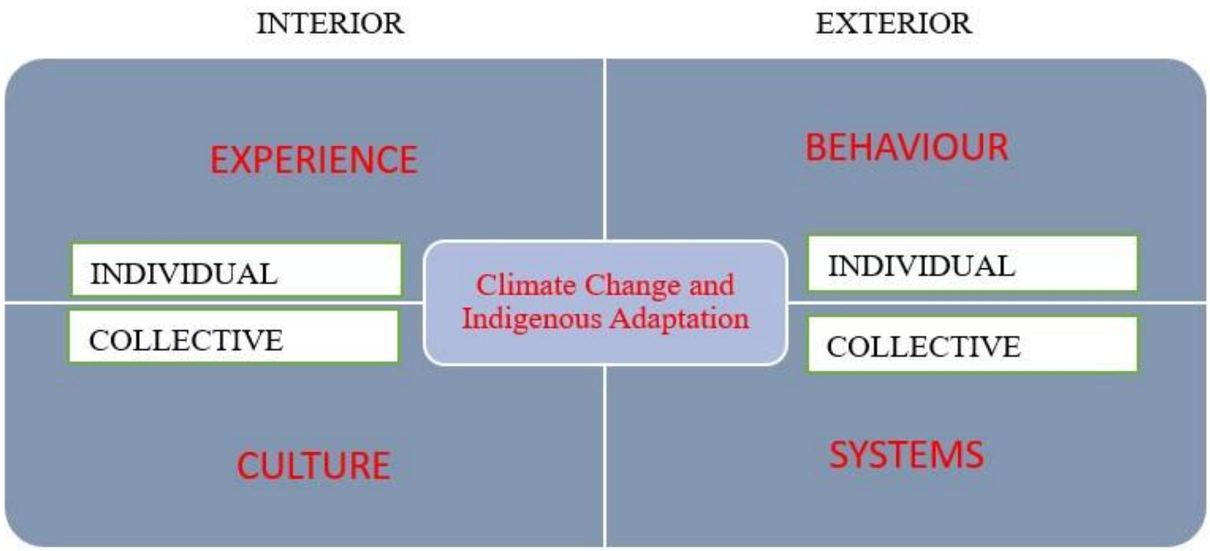

Figure 1.2: Integral theory of climate change adaptation

Source: Adapted from O'Brien and Hochachka (2010).

Even though the meteorological data provides scientific perspectives of historical climatic trends, they do not provide an exhaustive understanding of the complexities of climate change, especially at local scales and for specific local systems. Thus, an integration of local and scientific knowledge has the potential to help in providing a balance for a holistic understanding of the complexities of climate change.

Individual ways of dealing with complex socio-ecological changes are not mutually exclusive from that of the wider societal approaches which are collectively defined by the beliefs and value systems of society (O'Brien, 2010). Though individuals have the right to utilise and manage available local socio-ecological resources, they consciously and cautiously do so within the broader frameworks of collective conceptions and goals. Cultural geographical scholars are increasingly recognising the relevance of cultures, norms and beliefs in shaping our understanding of place and landscape in environmental discourses (Batterbury, 2008; Brace and Geoghegan, 2011). Societal norms, beliefs and practices were explored to develop understanding of conscious collective responses and actions of communities in sharing ideas to build resilience to mitigate climate change and food insecurity risks in dryland farming systems. Thus, integrating cultural ideas from households and communities provides an opportunity to develop deep understanding of the complexities of climate adaptation, which requires concerted and multidimensional approaches to enhance sustainable agriculture for food security in semi-arid regions.

1.7 Structure of the thesis

This thesis is divided into eight major chapters. Chapter one provides a general introduction and the central problem of the thesis. It also includes the research aim, objectives and questions as well as the justification and a theoretical framework to provide the basis for adoption of the mixed-method approach for the study. Following the introductory chapter, Chapter two reviews key literature on climate change and agriculture in Ghana and discusses the climate risks and vulnerabilities of northern Ghana and how those risks impact food security. The chapter presents a conceptual framework to develop an understanding of the vulnerability of socio-ecological systems to climate change and extreme events. The chapter also discusses the theories and practice of Indigenous knowledge and adaptation, and follows with a discussion of the importance of knowledge integration in climate change adaptation.

Chapter three presents a general research methodology of the study. It includes the philosophical underpinning of the study, which informs the mixed methods approach applied in the research. Also, important methodologies of the research methods utilised for the study are presented in the chapter. Chapter four is a paper under revision in the *Geoforum* journal, which critically reviews the complexity of Indigeneity in SSA and northern Ghana at continental and regional levels respectively. It emphasises migration as a driving force of Indigenous claims and broadly discusses the implications of the complexity of Indigeneity for natural resource management on the continent. Chapter five has been published in *Applied Geography*, and examines the integration of local perception and scientific evidence to comprehensively understand the complexity of climate change and variability. It highlights important factors that influence local perceptions of climate change risks. Chapter six is a manuscript ready for submission to a journal. The chapter focuses on how farmers perceive impacts of climate change on food security, and the important role of social networks in mitigating household food insecurity. Chapter seven is a published paper in *Climatic Change* and it emphasises the synergies and opportunities of Indigenous and scientific approaches as well as individual and community actions for climate change adaptation in dryland farming communities. The chapter also discusses the evolving capacity of Indigenous knowledge in climate change adaptation process in dryland farming systems. Chapter eight concludes the thesis with a general discussion and conclusion, which includes a synthesis of the research findings from the individual chapters and discusses the contributions of the study, theoretical and policy implications, limitations and suggestions for future research.

1.8 Conclusions

This chapter has provided the background and defined the problem of the study. It has outlined the main research objectives and questions the study intends to achieve and answer. The significance and justifications for conducting this research are presented with emphasis on the need for researching to improve understanding of the importance of Indigenous knowledge and the opportunities of its evolution with modern approaches to mitigate climate change risks. Also the chapter discussed the theoretical foundation of the study and its relevance in integrating different perspectives and methodologies to holistically address an environmental issue. Finally, the chapter has outlined the overall structure and organisation of the thesis.

1.9 References

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CHAPTER 2: Climate Change, Agriculture and Indigenous Adaptation

2.1 Introduction

This chapter reviews literature to develop understanding of the contextual issues of climate change, agriculture, food security and Indigenous adaptation. It begins by providing an overview of Ghana's agricultural systems and details how the sector contributes to the socio-economic development of the country. It then follows with a discussion of how agricultural systems in the country are exposed to climate risks, particularly in northern Ghana. The chapter also presents a conceptual framework to develop an understanding of the sensitivity and exposure of socio-ecological systems to climate change and associated risks. The risks and impacts of climate change on food security are also reviewed, especially in relation to crop production in the savannah regions. Theories and practices of Indigenous adaptation of households and communities are discussed in the context of sub-Saharan Africa (SSA) and Ghana. This is followed by a discussion of knowledge integration and the opportunities for improving livelihoods and food security in dryland farming systems. It is important to state that although the issues are manifest in SSA, the focus of this thesis is on the Ghanaian experience, hence the extensive discussions on Ghana in this chapter.

2.2 Agricultural systems in Ghana

Agriculture plays a leading role in the socio-economic development of Ghana (Darfour and Rosentrater, 2016). The production of crops and the rearing of livestock and fisheries are important agro-ecologcal systems that facilitate the growth of Ghana's economy (Ecker, 2018). The agricultural sector generally contributes about 20.2% of the economy's gross domestic product (GDP) (Ministry of Food and Agriculture [MoFA], 2015). However, crop production alone accounts for 75 percent of the total output of the sector, while the remaining 25 percent together is contributed by fishing, livestock and forestry sub-sectors (World Bank, 2018). Also, the sector provides three-quarters of the export earnings of the economy for socio-economic development (Breisinger et al., 2011). However, the average annual growth rate of the agricultural sector to GDP has been erratic (World Bank, 2018). The production of crops and livestock not only supports the transformation of Ghana's economy through improved GDP growth, but also provides the major source of economic opportunity for the population.

Most people in Ghana reside in marginal rural areas and depend directly or indirectly on the cultivation of crops and rearing of livestock as major sources of livelihood. The agricultural sector employs about 45% of the labour force in the country (World Bank, 2018). Particularly in rural areas, the sector employs 75.29% of unskilled workers (MoFA, 2017a). Farm labour, marketing and transportation are examples of job opportunities agriculture offer to many rural populations in the value chain process: from the farm to the market. Thus, agriculture is fundamental for the welfare of the vast majority of the rural poor and serves as an insurance for them even when they also exploit other economic opportunities. To this end, the agricultural sector in Ghana helps to reduce poverty among households with limited livelihood options, particularly those in the rural areas whose livelihoods largely depend on farming and livestock.

The abundance of arable land and farm labour in rural communities support agricultural production in Ghana (Darfour and Rosentrater, 2016). Of the 238,533km^2 total land area of Ghana, 57% are agricultural lands (Quaye et al., 2010). The soils of Ghana are highly weathered with predominantly light textured surface horizons covered largely with sandy loams and loams (Quaye et al., 2010). The rich soil nutrients of agricultural lands in many parts of Ghana support the cultivation of crops in the country. However, in northern Ghana the soils have poor water retention capacity making them prone to extreme runoff, which facilitates soil erosion and degrades agricultural lands (Nyantaky-Frimpong, 2020). The production of crops and rearing of livestock provide different sources of food and protein, which facilitate livelihood activities of people. These agricultural systems, particularly the sowing, growing and harvesting of crops in Ghana are influenced by several climatic indicators, particularly rainfall. However, during severe drought periods, water bodies such as rivers and lakes across the country provide important sources of water for irrigation. Such climatic and drainage systems support the cultivation of local staple crops such as maize, millet, plantain, rice, cassava, yam and vegetables, which improve crop diversity and food security for households (Bellon et al., 2020; Essegbey and MacCarthy, 2020).

Although agriculture is contributing to crop production in rural communities, the influence of land tenure arrangements and high levels of poverty, particularly in northern Ghana have restricted many farmers to engage in small-scale farming, with land holding of less than 1.5 ha (Lambrecht and Asare, 2016). This strongly affects income levels and consequently traps many Ghanaian farmers in the poverty cycle. Even, with the advent of modern Green Revolution in Africa, many agricultural activities in rural Ghanian communities remain largely traditional and rudimentary. For instance, agricultural inputs such as manure, compost and local irrigation technologies are used by many rural farming populations to improve crop production. In recent years, climate change is presenting a new challenge for the agricultural sector and associated systems by undermining food security and livelihoods in many rural communities, particularly in northern Ghana.

2.3 Climate change manifestations and risks in Ghana

Climate change continues to manifest in diverse ways in Ghana. Most of the communities in Ghana, and particularly within the northern regions, are experiencing more high temperatures, extreme rainfall regimes and other extreme events such as droughts, floods and wildfires in recent years (Afriyie et al., 2018; Atampugre et al., 2019; Bawakyillenuo et al., 2016; Owusu et al., 2019). Similar to other parts of the Sahel, annual average temperatures in Ghana have been increasing dramatically in most regions. For instance, according to Asare-Nuamah and Botchway (2019), temperature trends in Ghana between the periods of 1989 and 2015 have increased by about an average of $1.0^{o}C$ across the ecological zones of the country. Based on climate scenarios, temperature increases in Ghana, particularly in the north, are projected to exceed an average of $2.0^{o}C$ by 2080 (Klutse et al., 2020). The actual and projected increasing temperatures are likely to affect the sustainability of Indigenous crops (e.g. maize, millet and sorghum), essential for food security and livelihoods in the region.

According to Bessah et al. (2021), Ghana's annual rainfall trends have changed significantly in the 21^{st} century. Particularly in the Savannah agro-ecological zone, annual rainfall trends have reduced in recent decade (Baidu et al., 2017). It is projected that future rainfall patterns will alter further, with significant average reduction levels of 10.9% and 18.6% projected for 2050 and 2080 respectively in most parts of Ghana, and much of that reduction will be concentrated in northern Ghana (Boon and Ahenkan, 2011). The trends and future projections of rainfall will likely create uncertainties for food security and livelihood opportunities for rural agro-ecological systems. For instance, decreasing rainfall trends and variabilities have been one of the major causes of year-to-year fluctuations of food production among households in Ghana (Kyei-Mensah et al., 2019).

Droughts have been one of the major challenges to agricultural systems in Ghana (Atampugre et al. 2019; Yiran et al., 2016). A vulnerability assessment by Antwi-Agyei et al. (2012) revealed that the regions of northern Ghana are highly sensitive to drought conditions. It is projected that future drought events will be highly variable and uncertain (Food and Agricultural Organisation [FAO], 2017). Drought could pose catastrophic risks and consequences to household livelihood activities, particularly in areas of agricultural production on the margins for dryland arable systems (FAO, 2017; Tabari et al., 2014). For instance, evidence suggests that droughts have been one of the major causes of declining crop yields in many farming households and communities in northern Ghana (Leng and Hall, 2019; Mensah-Brako and Kotei, 2019). Droughts also affect livestock production through reduced forage availability and water scarcity which often lead to poor feed and high herd mortality (Twumasi and Jiang, 2021).

Flood events have intensified in recent years in Ghana (Balana et al., 2019). It is projected that the incidence of floods in Ghana will likely increase due to increased seasonal rainfall regimes in the 21st century (Bessah et al., 2021). Flood incidences in many parts of northern Ghana inundate farms and cause massive destruction of crops, and also creating localised food crises (Derbile et al., 2016). The occurrence of floods in Ghana could have implications for agricultural productivity and food security. For instance, excessive rainfall causes production losses of food crops such as millet, sorghum, maize, groundnut and rice (Derbile and Kasei, 2012). Notwithstanding the adverse impacts of droughts on agricultural systems, Balana et al. (2019) suggest that floods could increase residual soil moisture and deposit soil nutrients on floodplains providing opportunities for farming activities to be extended beyond the traditional growing season.

Wildfires affect ecosystems and livelihoods. Wildfire regimes have been threatening the Savanna ecosystem, particularly during periods of dry season (Kpienbaareh and Luginaah, 2019). The extent of wildfires in the Savanna has been suggested to create challenges for socio-ecological systems and biodiversity such as the forest ecosystem (Yaro and Tsikata, 2013). It is suggested that northern savanna areas in particular are more susceptible to wildfires due to high temperatures, prolong droughts and grassland vegetation cover (Amoako and Gambiza, 2019; Husseini et al., 2020). Couple with these influential factors, winds play a significant role in the spread and direction of wildfires (Kpienbaareh, 2016). For instance, in northern Ghana, harmattan winds facilitate the spread of wildfires, especially in dry seasons (Yaro and Tsikata, 2013). Such extreme wildfires are one of the major causes of deforestation, which destroy important traditional plant species and crops in most regions of northern Ghana (Amoako et al., 2018). This could potentially intensify the vulnerability of rural livelihoods and intensify food insecurity in northern Ghana.

2.4 Vulnerability conceptual framework

Vulnerability is often defined as the susceptibility of systems, individuals or entities to negative impacts of an event. This framing is reflective of past assessment reports of Intergovernmental Panel on Climate Change [IPCC]. For instance, in the fifth assessment report of IPCC (2014), vulnerability has been defined as the tendency to be adversely affected, which encompasses sensitivity to harm and lack of coping and adaptive capacities. In the context of this study, vulnerability is used as the state of susceptibility of socio-ecological systems to harm from exposure to stress connected with environmental, social, cultural, economic and ecological changes with fragile adaptive abilities (Berrouet et al., 2018). Socio-ecological systems are complex adaptive systems, that allow for the interaction between social and environmental factors and agents to facilitate change (Folke et al., 2016; Schlüter et al., 2019). Thus, this study uses the socio-ecological systems perspective and interpretation of vulnerability to understand how farming households and communities use their Indigenous knowledge and technologies to reduce their vulnerability to climate change risks and improve food production in the northern regions of Ghana.

The concept of vulnerability has evolved given the complexity of social and ecological changes in the biophysical environment. There is no consensus on how vulnerability is understood, interpreted or measured. Therefore, several approaches have been proposed by scholars and researchers to help develop understanding of the conceptualisation and interpretation of vulnerability. Two of such approaches of vulnerability, which are discussed in this thesis are identified by O'Brien et al. (2007) as outcome and contextual vulnerability (Figure 2.1). Outcome vulnerability is a linear approach for conceptualising vulnerability, which focuses on results of future climate change impacts on socio-ecological systems and the responsive processes of dealing with the pressures (O'Brien et al., 2007). Thus, this approach considers vulnerability to be the residual output after taking responsive measures to mitigate potential risks and impacts.

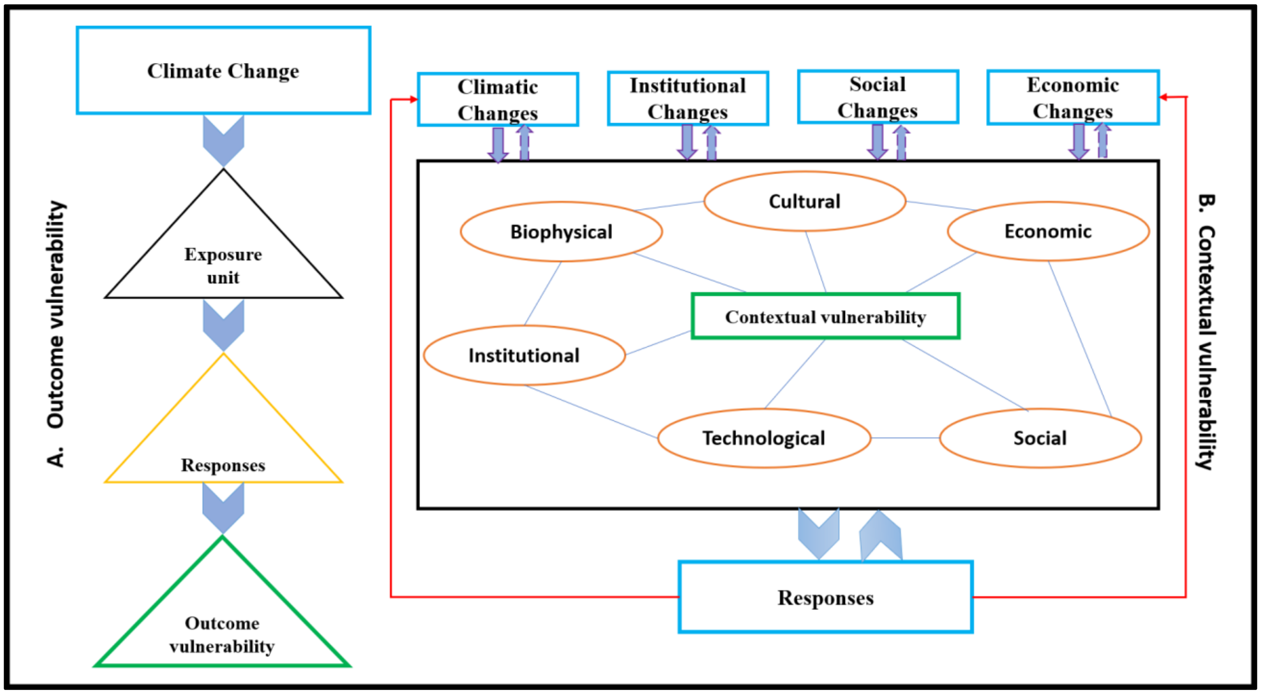

Figure 2.1: Framework of outcome and contextual vulnerability approaches

Source: Adapted from O'Brien et al. (2007)

This framing does not take into consideration the social aspect of vulnerability, which is crucially important for understanding complex social systems. It however, emphasises the biophysical dimension of risks, which should be addressed comprehensively within the contexts of social, economic and political conditions (Hopkins, 2015). This approach has its foundation rooted in the physical sciences, which utilises a positivist epistemological perspective to quantify biophysical vulnerability of systems (Okpara et al., 2016). The outcome vulnerability framing largely focuses on mitigation and technological options for adaptation to climate change risks (Räsänen et al., 2016).

Contextual vulnerability analysis, also termed "second generation" vulnerability analysis, challenges the dominance of the outcome approach and frames vulnerability within the broader scope of the "socio-ecological system", which assesses risks through the lens of cyclically interacting social and biophysical perspectives (Bennett et al., 2016). Contextual vulnerability is not only concerned with the processes of systems' vulnerability through human-environment interactions but also the context within which such socio-ecological relationships occur. This vulnerability approach emphasises "multiple stressors" including social, biophysical, technological, economic, institutional and structural (Naylor et al., 2020). Cultural factors are mostly ignored in the vulnerability assessments, yet they play an important role in defining the vulnerability of social systems. For instance, in Indigenous communities, the cultural traditions and values of people help them to understand the local environment and respond to potential risks. This approach explains that efforts to address current vulnerabilities and stressors will in turn solve future vulnerability challenges of socio-ecological systems (Hopkins, 2015). The contextual vulnerability is more associated the use of qualitative approaches in an interpretivist framework (see Török, 2018). However, Debortoli et al. (2018) and other researchers have attempted to frame this contextual vulnerability based on quantitative modelling techniques. In the context of environmental change, contextual vulnerability framing focusses on present impacts of climate change resulting from high levels of susceptibilities (Okpara et al., 2016), and the opportunities for social systems to reduce their vulnerability by modifying the contextual conditions for effective adaptation to climate risks (Atampugre, 2018). Notwithstanding the importance of the contextual vulnerability approach, some scholars have critiqued its effectiveness in addressing multiple stressors, particularly in relation to qualitative assessment of retrospective issues, with associated recall biases.

According to the IPCC (2014), the vulnerability of a system to climate change risks is reflective of the level of exposure and sensitivity of systems to risks, as well as the adaptive capacity to cope and recover from such risks (Figure 2.2). Exposure explains how socio-ecological systems and assets could be adversely affected by environmental changes (IPCC, 2014). Sensitivity, on the other hand, is conceptualised as the predisposition of socio-ecological systems to environmental risks (Birkmann et al., 2013). Adaptive capacity elucidates the level of adjustment of such systems to sustain and reduce stressors resulting from environmental change (IPCC, 2014). Within an institutional structure, adaptive capacity can be an important social capital including Indigenous knowledge utilised by stakeholders to tackle climatic pressures at local levels (Granderson, 2017). Impacts constitute the consequences or risks of climate change on socio-ecological systems as a function of exposure and sensitivity to changes (Lindner et al., 2010). The concepts of vulnerability, exposure, sensitivity, impacts and adaptive capacity are interrelated, dynamic and vary with wide application to climate change (Weis et al., 2016).

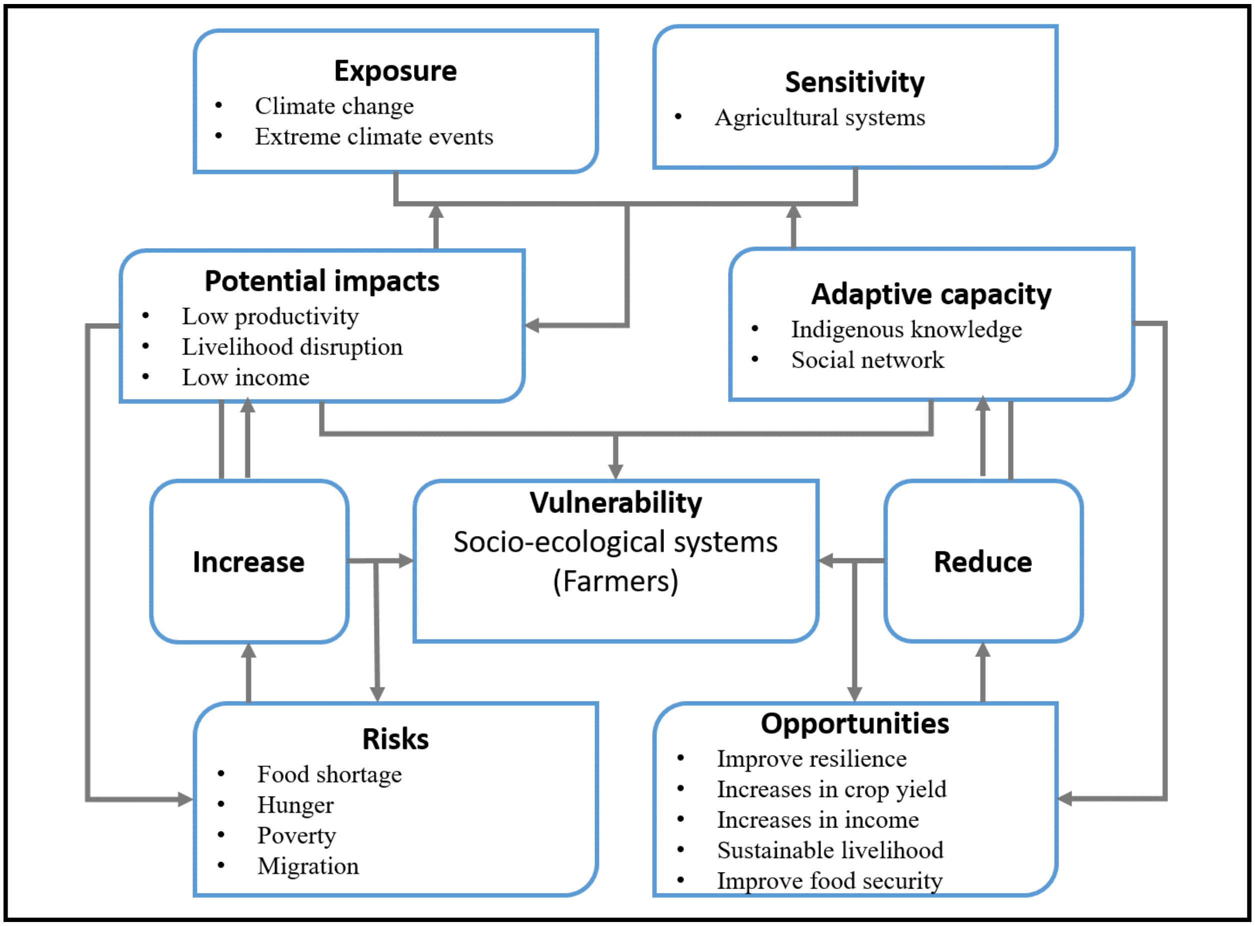

Figure 2.2: Framework of vulnerability components and their interactions

Source: Adapted from Gauthier et al. (2014)

It is important to emphasise that the exposition of these concepts is explicitly geared towards providing a relevant approach to broadly frame and shape the vulnerability of communities, particularly in the semi-arid regions of Ghana to climate change. The manifestations of climate change such as high temperatures, changes in rainfall patterns, reductions in rainfall and protracted droughts pose myriads of risks to the ecological systems. These systems become exposed to various risks and changes ranging from agriculture, economic, ecological and socio-cultural. The exposure and sensitivity of socio-ecological systems together pose significant livelihood and food security challenges to farmers in Indigenous communities (Mbuli et al., 2021). Given the impacts, rural Indigenous communities have been demonstrating reflexivity in their adaptation to climate change risks through Indigenous knowledge and technological applications. It is important to stress that across the northern regions, there is considerable interchange of Indigenous knowledge through marriage, movement, and longer distance migrations. However, it is worth stating that this thesis will emphasise on Indigenous adaptation at the farm level.

The Indigenous systems of adapting to climate change risks will provide an impetus to reduce the vulnerability of socio-ecological systems through a reduction in exposure and sensitivity to environmental changes (Derbile, 2013; Mugambiwa, 2018). The reduction in exposure and sensitivity of vulnerable communities in dryland regions such as northern Ghana will provide an opportunity to strengthen food security including accessibility, availability, stability and utilisation. The use of Indigenous knowledge and technologies by local farmers and communities serve as adaptive capacity in their own right and provide an opportunity to enhance individual and community resilience. Also, social networks provide important social capital for people in disadvantaged communities to strengthen their adaptive capacity for environmental resource management (see Witasari et al., 2006). Increases in adaptive capacity empower socio-ecological systems to become more resilient under extreme climatic stressors. Resilience in this research refers to the ability of individuals, communities, cultures and societies to adapt or transform into new development pathways in the context of dynamic changes (Folke, 2016). Also, improved adaptive capacity provides additional opportunities to improve productivity, livelihood income and food security. This thesis places much emphasis on food production to the household through an integration of approaches and knowledge systems. On the other hand, low adaptive capacity could increase vulnerability and generate more risks for socio-ecological systems. Increases in vulnerability adversely affect productivity leading to food shortage and hunger while intensifying poverty, which ultimately triggers migration and associated consequences (McMichael, 2014; Sadiddin et al., 2019; Smith and Floro, 2020).

2.5 Vulnerability of northern Ghana to climate change

The northern regions of Ghana are suggested to be the most vulnerable regions to climate change risks in the country (Owusu et al., 2021). This is attributed to the region's high exposure to climate risks, sensitivity of agricultural production systems, and low adaptive capacity influenced by factors such as poverty and illiteracy (Abdul-Razak and Kruse, 2017). The climatic system of northern Ghana is experiencing a warming trend (Asare-Nuamah and Botchway, 2019; Wossen and Berger, 2015). The warming trends in northern Ghana have created future uncertainties over the livelihoods of farming communities that depend heavily on weather and climate (Dickinson et al., 2017). It is projected that the warming trends in northern Ghana will intensify and generate more risks for farming households and the agricultural sector in general (Acheampong et al., 2014; Klutse et al., 2020). Also, extreme climatic events such as drought, floods, rainstorms and wildfires are intensifying in northern Ghana and increasing the vulnerability of farmers to livelihood disruptions (Atampugre et al., 2019). However, the levels of vulnerability are likely to vary across locations and different crop types. In north-western Ghana, for example, crops such as yams, groundsnuts and beans are highly vulnerable to multiple climatic risks compared with millet, guinea corn and maize (Derbile et al., 2021) (see Figure 2.3).

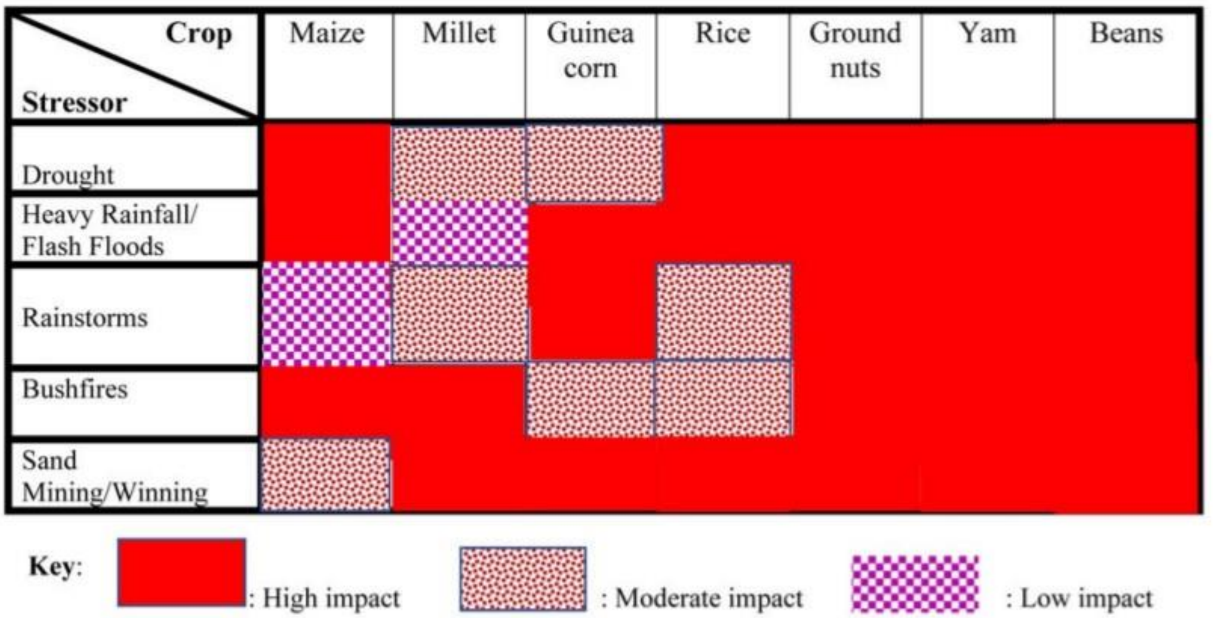

Figure 2.3: Vulnerability of crops to climate risks in north-western Ghana

Source: Derbile et al. (2021)

The dryland agricultural systems in northern Ghana are highly sensitive to climate change risks and impacts. The heavy reliance on rainfall and associated inherent variability is one of the key factors that are increasing the sensitivity of agricultural systems in northern Ghana to climatic risks and extreme events (Owusu et al., 2021). The exposure of northern Ghana and sensitivity of agricultural systems to climate change and associated risks have resulted in low crop output of smallholder farmers (Ayumah et al., 2020). Low agricultural productivity affects the livelihood and income of farmers in the savannah region and consequently inhibits their adaptive abilities to deal with climate change risks (Bawayelaazaa et al., 2016). Given the potential impact of climate change on agriculture, socio-ecological systems are building their adaptive capacities to increase resilience and mitigate vulnerability through Indigenous knowledge and social capital.

Access to agricultural infrastructure can enhance the adaptive capacities of farmers and communities in resolving climate risks. Such infrastructural accessibility could help improve the livelihoods of the rural poor and enhance household food security in Ghana. However, the lack of infrastructural development such as irrigation technologies for dry season agriculture and silos for crop preservation could accelerate the susceptibility of agricultural farmers to climate change. Consequently, the lack of agricultural infrastructure could undermine crop productivity while increasing post-harvest losses, with cascading impacts on livelihood income and food security in the country.

Institutional support systems have been identified as a means of building the resilience of rural agro-ecological systems in northern Ghana (Yaro et al., 2015; Williams et al., 2019). The provision of support systems such as finance, farm inputs and extension education by formal or informal institutions could provide farmers the opportunity to get access to the needed resources, knowledge and skills to better equip them to respond to climate risks. However, studies have suggested that communities in the regions of northern Ghana have low adaptive capacities due to poverty, remoteness, lack of favour from the government located in the south among others which increase their level of vulnerability to climate change (Abdul-Razak and Kruse, 2017; Alhassan et al., 2018). For example, smallholder farmers in the Northern Region of Ghana are generally suggested to have low adaptive capacity in key areas such as economic resources, awareness and training, and technology (Abdul-Razak and Kruse, 2017).

The economic and socio-cultural conditions of social and ecological systems could partly determine the adaptive capacity of a system (Adger, 2003). The lack of financial support and infrastructure (e.g. irrigation, storage facilities) limit farmers' adaptive abilities and make them more susceptible to climate risks (Antwi-Agyei et al., 2015). Also, the lack of climate information in providing early warning of extreme climate events could affect communities' adaptive abilities with the potential to increase their vulnerability when adverse climate conditions occur. Climate information is an important tool that helps farmers to prepare and make informed decisions on expected climate extremes such as floods and droughts (Boyd et al., 2013). Thus, effectively developing climate information system can provide opportunities for farmers and communities to enhance their abilities to adapt to expected climate change risks by reducing potential losses and damages (Antwi-Agyei et al., 2015).

The provision of knowledge and information through extension services could also influence farmers' adaptive capacity (Asare-Nuamah et al., 2019). Extension services involve communicative interventions given to farmers to help them update their knowledge and skills on best adaptive practices (Baloch and Thapa, 2018). Local people or professionals from different places are usually recruited as agents to provide training and disseminate information to groups of farmers on modern agricultural practices while assisting them to get assess to agricultural inputs to increase productivity and income (Anang et al., 2020). Such extension services largely provide opportunities for farmers to build their adaptive capacities. By building their adaptive capacities, these educational services could potentially help farmers to reduce their vulnerabilities and risks to climate change. Moreover, certain cultural beliefs and norms of communities may limit the adaptive capacities of people and communities and could increase their level of exposure to climate change risks.

2.6 Contextualising food security under climate change

Food insecurity is a national issue in Ghana due to socio-economic and environmental challenges (Ghana Statistical Service [GSS], 2017; Ministry of Food and Agriculture [MoFA], 2019). Several attempts have been made by successive governments to address food security risks in the country. For instance, in 2012, the MoFA outlined measures such as improved distribution system, enhanced storage system to reduce post-harvest losses and agricultural modernization through extension education to improve knowledge of farmers on effective agronomic practices (MoFA, 2012). In 2017, the government initiated the "Planting for Food and Jobs" programme to facilitate distribution of improved seeds and fertilisers at subsidised rates to boost agriculture and food security (MoFA, 2017). Even though these efforts have yielded some positive outcomes, yet statistics of people experiencing severe food insecurity are still inconceivable and more are expected to be done if Ghana can meet the United Nations Sustainable Development Goal (SDG) target of eradicating hunger.

According to statistics, Ghana has made some progress in stabilising food security, however, prevalence rates of food insecurity among individuals and households are above the expected target of the SDG. According to the GSS (2015), 47.3% of Ghanaians were food insecure between 1990 and 1992. However, between 2012 and 2015, the prevalence of food insecurity in Ghana significantly reduced to 5% (FAO, IFAD and WFP, 2015). It is projected that approximately 2 million people in Ghana are more vulnerable to become food insecure (WFP, 2014). The current status of food insecurity prevalence in the country is 4.8% indicating some positive strides in the efforts of addressing food security risks (GSS, 2017). Spatially, food insecurity is more experienced in northern Ghana where individuals and households normally experience severe food insecurity, especially at the beginning of the rainy season (Kleemann et al., 2017).

The WFP has reported that annually, 23.7% of populations in the northern regions of Ghana are food insecure (WFP, 2014). The problem of food insecurity persists in both rural and urban areas, however, many of the northern Ghanaian people highly vulnerable to the risks are located in rural areas due to economic challenges (Darfour and Rosentrater, 2016). Recent studies show that between 6.8% and 25.9% of rural households in northern Ghana are either moderately or severely food insecure (see Saaka et al., 2017), which manifest through dietary insufficiency, chronic nutritional deficiency illness such as anemia and stunted growth of children usually below five years (Agbadi et al., 2017). The people in northern Ghana usually find it difficult to get access to food but at different times and in different ways (WFP, 2012). For instance, people in the upper east region usually experience the longest food scarcity of 6 to 7 months while households in the upper west and northern regions record 5 months of food scarcity (Table 2.1).

Table 2.1: Food insecurity situation in northern Ghana

Crop	UPPER WEST		UPPER EAST		NORTHERN	
	Period of Shortage (Availability)		Period of Shortage (Availability)		Period of Shortage (Availability)	
	From	To	From	To	From	To
Yam	May	October	NA	NA	June	September
Rice	June	October	April	November	October	May

Groundnut	NA	NA	April	October	April	September
Soybean	April	September	NA	NA	April	November
Maize	June	October	April	October	June	September
Millet	April	September	January	July	June	November
Cowpea	June	October	March	October	May	October
Sorghum	June	October	February	August	June	November

Source: Adapted from Quaye (2008:12).

Poverty is one of the main causes of household food insecurity in Ghana, particularly in the northern region (Darfour and Rosentrater, 2016). According to the Brookings Ending Rural Hunger database, 51% of Ghanaians lack enough money to buy food (Mulanga, undated). Poverty has not only aggravated the level of food accessibility in northern Ghana but also on agricultural activities in general. For instance, because of poverty farm households are unable to access agricultural inputs such as fertilisers, pesticides and herbicides to improve productivity and sustain their livelihoods. They are also left with no option than to rely on rudimentary tools and equipment for farming, which largely results to low productivity. It is therefore suggested that when poverty is generally addressed in northern Ghana, food security will also improve (WFP, 2012).

Lack of infrastructural development in the agricultural sector also contributes to food insecurity in northern Ghana. Availability of food to rural households has been dependent on efficient and effective transportation systems. Good transportation networks provide an important role in the value chain of food systems. They help farmers to access farm inputs and markets at lower costs while improving productivity and profitability of crops (Bonsu, 2014). However, the deplorable nature of road networks in northern Ghana has been posing a serious challenge to marketing of agricultural produce and food availability for households (Morgan, 2019). The poor condition of roads is sometimes exacerbated by the intensities of droughts and flood events, which further affects the efficient transportation of foodstuffs and inputs between farms and communities. This could potentially increase post-harvest losses and food prices, which may ultimately impact upon food supply. Consequently, the contribution of the crop sub-sector to GDP will be diminished, with dire economic consequences on the national economy.

In recent years, climate change is presenting a new challenge to food security in Ghana and across the globe. Particularly in northern Ghana, the impacts of climate change and extreme events are intensifying food availability, accessibility, utilisation and stability in recent years (Wood et al., 2021). Climate change risks to rain-fed agriculture have been one of the major causes of much of the malnutrition and mortality in rural agro-ecological settings in the savannah areas (Nyantakyi-Frimpong, 2021). Erratic and declining rainfall in northern Ghana has adversely affected the quality and quantity of food crops and livestock production culminating in necessary livelihood challenges to the population who depend largely on agriculture (Bawayelaazaa et al., 2016). Additionally, prolonged droughts have been a major problem affecting many households to obtain crops such as millet, sorghum and rice, which are important staples in the regions of northern Ghana (Ayumah et al., 2020). Droughts affect water availability for agricultural activities and related livelihoods, which adversely impacts incomes and ability to access food, especially during inflation periods. Also, extreme droughts have been facilitating wildfire risks and disasters in many rural communities in the northern regions, which destroy farmlands and crops and intensify household food insecurity (Kpienbaareh and Luginaah, 2019). Such impacts are expected to create more developmental challenges to a wide range of marginalised communities that are strongly connected to their natural environments. In light of the challenges climate change presents to agricultural systems and food security, households and communities in the West African Sahel including Ghana are adapting to mitigate associated risks and improve livelihoods (Batterbury and Mortimore, 2013). Many households and communities do so by implementing actions involving the application of Indigenous knowledge.

2.7 Indigenous knowledge and adaptation: theory and practice

Indigenous knowledge is very difficult to clearly define (Lanzano, 2013; Agrawal, 2009). However, several scholars and countries use and develop the concept, but with several inherent problems and ambiguities. For instance, Orlove et al. (2010) define Indigenous knowledge as the embodiment of a place-based knowledge that is grounded in the culture of people who have settled in a particular place for a long time, with strong attachment to their physical environment. This definition is problematic and many of such have been problematized in chapter four of this thesis to develop understanding of the complexities of 'Indigeneity' at the continental and regional scales, which is important for climate change adaptation and natural resource management in Ghana and SSA.

Adaptation is viewed from different perspectives, particularly in the context of socio-ecological and environmental changes. According to IPCC (2014), adaptation refers to the adjustments of systems to moderate actual and expected climatic risks while exploring opportunities. Moser and Ekstrom (2010) explain adaptation as the long-term actions and decision-making processes utilised by individuals and societies to generate resilience in light of socio-ecological changes. Adaptation in the context of this study involves management practices and strategies utilised by farm-households and communities to mitigate climate change threats and take advantage of new opportunities to alleviate food insecurity. The adaptation strategies of socio-ecological systems could be anticipatory or reactive (Klein, 2003). According to Berrang-Ford et al. (2011), reactive adaptation actions are usually implemented in low-income countries, with the aims of avoiding, coping, or spreading risks while proactive adaptation actions are taken by high-income countries to plan, monitor and enhance learning or research. Also, socio-ecological systems' adaptation mechanisms could be in the short or long-term (Moser and Ekstrom, 2010) and vary spatially within their locale or be aimed more at supporting recovery from loss or damage (IPCC, 2014). Watts and Bohle (1993) describe the short-term coping measures as "adaptability" and the long-term strategies as "potentiality". The "adaptability" and "potentiality" evolve and change over time due to the dynamic nature of human society resulting from environmental changes (Smit and Wandel, 2006). Adaptation has also been argued to involve cultural practices that help societies to show resilience to overcome stress (Kodirekkala, 2018). Given the complexity of climatic risks, O'Brien and Hochachka (2010) have suggested the integration of adaptation at different spatial scales for effective outcomes.

In many parts of Africa and the Sahel, studies have indicated that households and local communities have developed sophisticated body of knowledge in mitigating agricultural system's vulnerability to climate change risks for sustainable rural development (Millar, 1996; Richards, 1979). Makondo and Thomas (2018) have suggested that many Indigenous farmers in Africa utilise their Indigenous knowledge to manage degraded farmlands while practicing traditional agroforestry in managing unproductive farmland. This in effect helps the farmers to increase food production and livelihood income. Ajayi and Mafongoya (2017) report that farmers in dryland farming systems in SSA are implementing Indigenous practices such as mixed cropping, minimum tillage and intercropping to promote higher yields and conserve the environment. In conserving water for agricultural production, Bapfakurera et al. (2020) state that farmers in the Musanze and

Nyabihu districts of north-western Rwanda are practising crop rotation, planting on ridges, using stone bunds, applying compost and constructing traditional dams or water retention ditches for irrigation. In the Sahel, agricultural producers in the Soudanian, Soudano-Sahelian and Sahelian agroclimatic zones of Burkina Faso are responding to climatic risks by applying organic matter and using furrows to improve agricultural systems (Alvar-Beltrán et al., 2020). Also, studies conducted by Gumo (2017) suggests that the Abanyore, Akamba, Maasai, Meru, and Kikuyu communities in Kenya are adapting to climate change extremes by worshipping and praying for rains during severe drought periods. Similar practices are also reported by Theodory (2021) among farmers in the Ngono River Basin of Tanzania. All these Indigenous knowledge applications help farmers to improve agricultural productivity and food security on the continent.

In the Savanna region of Ghana, Indigenous farmers are employing a variety of Indigenous innovations in response to climate change risks. According to Nyantakyi-Frimpong (2021), local farmers in northwest Ghana are utilising the *zaï* technique to facilitate rainwater harvesting, increase soil infiltration and improve crop production. Also, a study conducted by Antwi-Agyei and Nyantakyi-Frimpong (2021) shows that Indigenous northern Ghanaian farmers have been utilising Indigenous knowledge to adjust their planting calendar to mitigate impacts of unreliable rainfall on agricultural systems. Derbile et al. (2016) indicate that Indigenous farmers in the Northern region of Ghana have been cultivating multiple drought and flood resilient crops, which have been handed down to them from generation to generation to reduce their vulnerability to drought condition. According to the authors, the farmers reported that the practice of drought-resistant Indigenous crops such as *Naara* and *Zea* and seeds were inherited from their parents and grandparents. A similar study conducted in northern Ghana by Kuwornu et al. (2013) has also indicated the cultural practice of raising mounds and ridges for crop cultivation as an important adaptation strategy to provide support to crops in times of wind storm. Also, a study conducted by Alhassan et al. (2019) shows that many female farmers in the Northern region of Ghana have been practicing forms of mixed cropping that have been verbally passed on to them from generation to generation to deal with shocks relating to unpredictable rainfall fluctuations. However, how the Indigenous knowledge and technologies of the farmers have evolved and changed over time across different Indigenous communities have not been comprehensively addressed in the literature.

Social capital has been one of the ways by which socio-ecological systems, particularly Indigenous farmers and communities have been using to adapt to losses and damages of crop failures. A typical example is where rural communities in Savanna regions such as northern Ghana rely on communal support networks to build resilience to climate change (Dapilah et al., 2020). This support system provided by communities to each other helps to alleviate damages and losses associated with environmental and ecological risks. Thus, reducing climate change risks through cooperation provides an opportunity for indigenous farmers to enhance livelihoods, maintain diversity and ensure sustainability. This will be relevant in the thesis to understand how cooperation promotes sustainable agricultural systems and livelihoods of Indigenous farmers by mitigating losses and damages associated with climate change in local agro-ecological context.

2.8 Integration of Indigenous and scientific knowledge systems for climate change adaptation

Given that many opportunities arise to engage with other external sources of knowledge, many farmers only use Indigenous knowledge independently, partly because of conservative ideologies (Ebhuoma and Simatele, 2019). However, other farmers integrate their Indigenous knowledge with scientific approaches, which indicates that both knowledge systems should not be seen as mutually exclusive but complementary in generating opportunities for sustainable outcomes (Bohensky and Maru, 2011). According to Mokondo and Thomas (2018), many Indigenous people have been modifying their knowledge to accommodate other knowledge systems (scientific knowledge) to address the complexity of ecosystems due to changes in environmental conditions. Farmers usually complement their Indigenous knowledge with scientific approaches to increase food production for sustainable development. Thus, Indigenous knowledge is not simply static, but in most cases has been dynamically evolving over time in society's efforts to respond to social and ecological changes in the natural environment (Basdew et al., 2017; Bronen et al., 2020). This means that there can be traditional knowledge that is evolving within broader Indigenous knowledge systems. This is one of the complexities that this thesis will tease out in chapter seven, with particular reference to farmers' adaptation to climate change risks at different scales in northern Ghana.

The flexibility of Indigenous knowledge provides a range of opportunities to Indigenous societies, particularly in the Sahel to integrate new ideas and insights from other external sources that are relevant to mitigating environmental challenges in dryland farming systems (Batterbury, 1996). Many Indigenous people have been softening their strict traditional positions to accept modern technologies in coping and adapting to the effects of environmental changes in order to increase food production and reduce poverty among the people. It is therefore advocated that Indigenous and modern knowledge systems are integrated to benefit each other (Makondo and Thomas, 2018).

Globally, farmers are developing a good understanding of the significance of integrating local and modern technologies as a pathway for effective agricultural transformation. Theodory (2016) suggests that it is very difficult to identify knowledge that is utilised by Indigenous communities in this present era without external influence. For instance, in developing countries such as Nepal, farmers are combining their ecological knowledge and other knowledge systems effectively in addressing climate change risks (Manandhar et al., 2011). In SSA, many farmers are adopting both Indigenous and modern technologies as an effective complementary strategy to reduce their vulnerability and ensure sustainable agricultural development (Ajani et al., 2013). For instance, Indigenous communities in Kaijado County in Kenya are integrating Indigenous knowledge with information and communication technologies to mitigate impacts of climate change (Manei, 2013). This kind of integration can go a long way to solve land disputes and other related conflicts. Also, many farmers in most parts of SSA have been using scientific technologies (e.g. fertiliser, modern irrigation methods and agro-chemicals) together with other traditional systems to promote food security and reduce their poverty levels. Indigenous farmers in Nigeria use both organic manures and inorganic fertiliser as strategies to improve soil fertility for increased food production (Jaja and Barber, 2017). In north-western Ghana, farmers are integrating Indigenous and new external knowledge systems to diversify crops and conserve soil and water to improve crop production and sustain livelihood (Derbile et al., 2019).

Although the use of Indigenous knowledge can be criticised as being anti-development (Bardsley, 2006), the relevance and advocacy for 'knowledge integration' are recognised in recent Indigenous studies (Makondo and Thomas, 2018; Nyantakyi-Frimpong, 2013). Notwithstanding the criticisms, the complementarity of Indigenous knowledge and scientific approaches continue to generate opportunities for climate change adaptation in vulnerable communities such as those in northern Ghana. The integration of Indigenous knowledge with scientific knowledge can be targeted to promote the resilience of socio-ecological systems to withstand the pressures and stresses of climate change (Walker et al., 2006) and to remain flexible in dealing with socio-ecological change (Redman and Kinzig, 2003). Integrating scientific and Indigenous knowledge offers an opportunity to mitigate food insecurity for food production. Therefore, the main goal of this thesis is to examine how farmers are evolving their Indigenous knowledge in integrating with new modern approaches to adapt to climate change risks to improve food security in northern Ghana.

2.9 Concluding remarks

In this chapter, I discussed the contribution of Ghana's agricultural sector to supporting livelihoods. It is evident in this chapter that smallholder farming systems are more sensitive to climate change in the dryland areas of northern Ghana due to poverty. The multiple climatic stressors, particularly extreme events are altering agricultural opportunities leading to food insecurity in the region south of the Sahel. The chapter has also discussed that factors such as poverty and lack of formal institutional support systems, particularly at local and regional levels are affecting adaptive capacity and increasing vulnerability of dryland farming systems in northern Ghana. Conceptual frameworks to understand key vulnerability approaches, and interrelated components have been presented in the chapter. The chapter also contextualises the vulnerability of northern Ghana to climate change. It follows with discussions on theoretical and practical issues of Indigenous knowledge and adaptation as well as knowledge integration and the opportunities for enhancing livelihood and sustainable food security. This chapter has highlighted the complexities of Indigenous knowledge conceptualisations, with detailed discussion in chapter four. However, before the detail discussion on Indigeneity, the next chapter is devoted for a general overview of the philosophical and theoretical understandings of the research methods and methodologies used for the individual papers included in the thesis.

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CHAPTER 3: Research Methodology

3.1 Introduction

This chapter presents a general framework of research approach and methodologies utilised to conduct the research. As opined by Wiersma and Jurs (2005), methods and procedures of research are central to the entire research process, which requires considerable depth of explanation for a sound appreciation and justification of conclusions. While a research method provides detail explanation of techniques and procedures employed for data collection (Bryman, 2012), methodology on the other hand describes the theory of the methods, as well as the epistemological perspective through which the research is understood, designed and conducted (Walter, 2013). Therefore, this chapter provides a detail explanation of the philosophical underpinnings and methodological approaches of the research. A detailed explanation of the integration of different research methods (mixed-methods) that are employed to address the study objectives outlined in chapter one are also presented in the chapter. Finally, the chapter elaborates on the positionality, and ethical considerations required for the research.

3.2 Philosophical foundation of the study

In addressing a research problem, it is imperative to consider the epistemological perspective and position of the researcher (Stewart, 2004). Philosophical paradigms of epistemic (knowledge creation) systems across disciplines are very influential in determining the choice and application of particular research methods (Bryman, 2012). The two basic paradigms, which influence research approaches of a study are positivism and interpretivism or constructivism (Creswell, 2013).

Positivism suggests that reality exists independent of our knowledge of it and views the social world as something that is not constructed by us but rather revealed to us (Grix, 2004). Thus, positivists advance the argument that social reality is independent of researchers and can be made more meaningful by employing scientific methods through observation and experimentation (Krauss, 2005; Bryman, 2001). Positivism is built on the assumption that scientific judgments are objective, and that social research should be carried out in a manner that reflects objectivity through empirical results (Garner et al., 2009; Krauss, 2005). Positivism largely engenders the application of quantitative techniques and tools in data collection and analysis through questionnaire surveys, which have good reliability in explaining observable facts (Collins, 2010).

Interpretivism and constructivism on the other hand positions knowledge such that reality is subjective and humanistic in nature (Collins, 2010). Interpretivists view the world as inseparable from the objects who experience realities. Hence, they assume reality to be best explained and understood through people's own interpretations and value judgments instead of observable evidence. Interpretivism recognises the uniqueness of human beings in different research approaches to understand the social world (Walter, 2013). Thus, Interpretivists primarily advocate for the application of qualitative approaches to social research using methods and tools such as interviews, observations and focus group discussions (Collins, 2010).

There have been several arguments regarding the best philosophical paradigm to employ in social research. Easterby-Smith et al. (2012) argue that positivism is the best research paradigm to employ because of its objectivity in unraveling the truth about social reality. However, Bless and Higson-Smith (2000) hold a counter-argument that suggests that interpretivism is the best option for social research since social reality can only be truly interpreted through personal experiences of phenomena in the social environment. The two epistemological ideas within positivism and interpretivism paradigms can be integrated within the pragmatist or soft constructivist paradigm.

Pragmatism explains the idea that the social world can be interpreted in several different dimensions with different methodologies appropriate for the particular context of the research (Creswell, 2013). Pragmatists recognize that no single view can provide the 'best' understanding about reality, and practical integration of research methods (mixed methods) from the positivist and interpretivist are often required within the scope of a single study to provide a holistic understanding of a research problem. This philosophical orientation provides an opportunity to employ different research methods and tools such as surveys, interviews, focus group discussions and participant observations from the different research paradigms in a single study (Creswell, 2013). This epistemological perspective presents the opportunity for researchers to choose from the different techniques available and employ them to meet the intended needs and rationale of the study (Saunders et al., 2012). The implication is that the integration of the methods will provide practical support for each other to triangulate the knowledge generated to best address the research problem.

The overall thesis involves the integration of positivists and interpretivists epistemological perspectives to understand the ways farming households and communities are utilising Indigenous knowledge to help shape their adaptive capacities and create opportunities for sustainable food security under the circumstance of growing climate change risks. An interpretivist approach is applied to develop a narrative of the complexity of Indigenous knowledge conceptualisations at continental and regional scales. On the other hand, a positivist approach is employed to analyse regional meteorological data to determine the trends of climate change in three districts (Nandom, Savelugu and Bongo) of northern Ghana. Also, survey data on perceptions of Indigenous knowledge and practices of farming households and communities are quantified and qualified through questionnaires. The study further employs an interpretivist approach by establishing deeper personal perspectives and experiences of Indigenous farming households about their understanding of climate change and how Indigenous knowledge and social networks have been utilised to improve food security. Focus group discussions and in-depth interviews of key informants in the rural communities are utilised for the interpretivist perceptions analysis.

3.3 Mixed methods approach and justification

The debate around positivist or interpretivist approaches centers on which approach is most appropriate for researchers to use to understand realities in the social world (Walter, 2013). Mixed methods involve the integration of quantitative and qualitative approaches in data collection and analysis (Creswell and Creswell, 2018). Mixed method researchers focus on employing many approaches in single research to understand multiple realities of the social world (Creswell, 2013; Denzin, 2012). Using the mixed methods approach can provide a deeper understanding of the issues under investigation in their right perspectives than could possibly be obtained by exploiting one method alone. Thus, a mixed-method provides integrated results so that the weaknesses in one method can be compensated by the strength of the other method (Creswell and Creswell, 2018). This type of research approach is generally grounded in the pragmatist philosophy because it recognises the importance of practical integration of different approaches and methods to generate the best knowledge possible (Figure. 3.1).

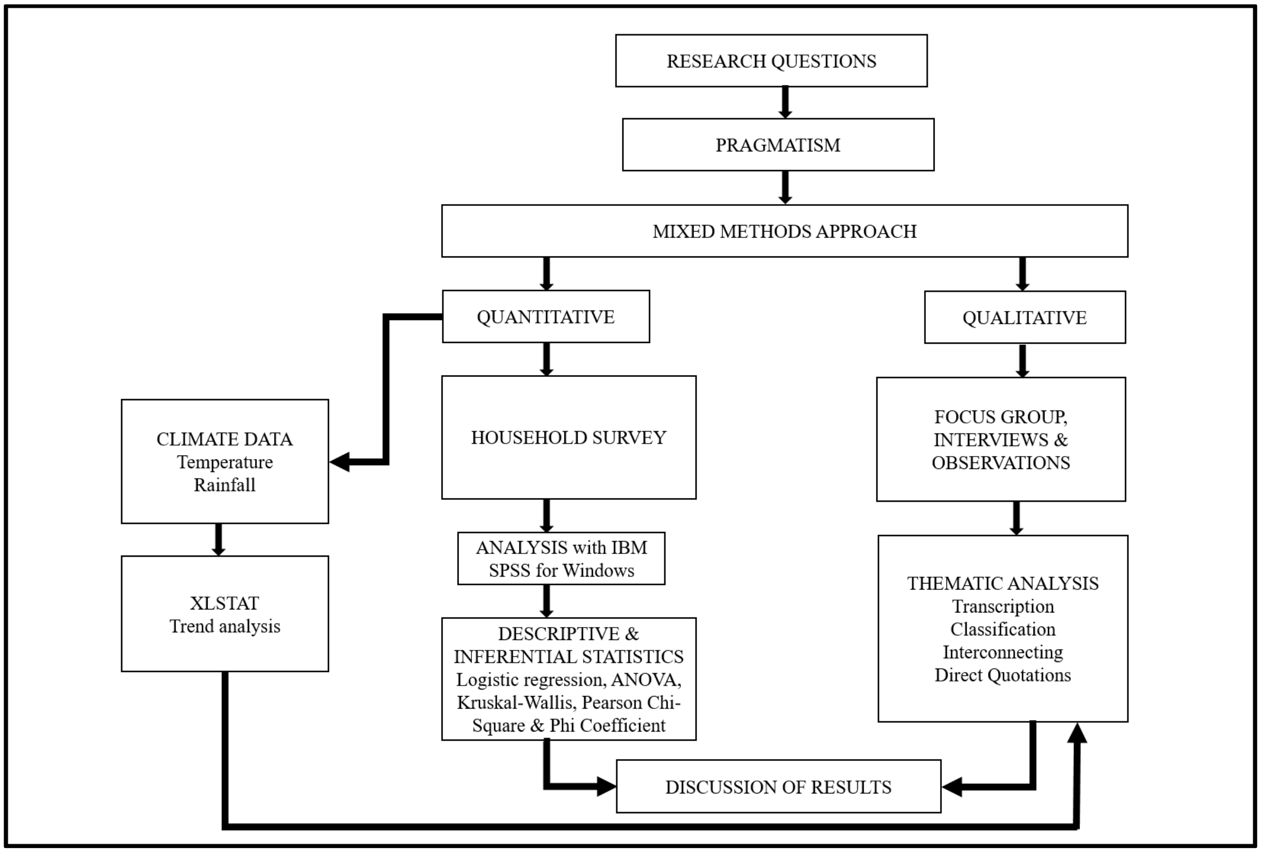

Figure 3.1: Schematic flow of research methods

Source: Author's construct, 2021

The mixed-method approach applied in this study provides a broader understanding of the complex human-environment interaction that exists between Indigenous populations and their local ecology. Integrating the subjective perspectives of participants helped in enhancing the validity, reliability and replication of the results (Bryman, 2012).

3.4 Research methods

The study employed an integration of surveys and several participatory methods, which are grounded in the integral theory discussed in chapter one. The integral theory provides a framework that blends different knowledge systems and approaches to holistically address a research problem. In this thesis, a survey was employed for quantitative data collection to identify specific issues and establish patterns of association and relationships between variables (Bryman, 2012). Surveys provides researchers the opportunity to estimate study characteristics for further detail analysis

(Creswell, 2013; Fowler, 2013). Despite the relatively expensive nature of surveys (Marshall and Rossman, 2002), they are widely used in social research because of efficiency and quick data collection (Bhattacherjee, 2012). Also, surveys ensure accurate measurements of study characteristics for generalizing (Marshall and Rossman, 2002). This study employed surveys to gather data about climate change and associated risks and impacts, food security status, social networks, and how Indigenous and modern knowledge systems are integrated and utilised for climate change adaptation. The surveys provided an important opportunity to gain a general insight about the complexity of the issues for specific detail analysis in the community-based focus group discussions.

A participatory method was particularly important for this study. Participatory methods are bottom-up approaches that are widely used in Indigenous studies to elicit information from rural populations to get a deeper understanding of their environmental conditions (Hofmeijer et al., 2013; Walter, 2013). They involve knowledge sharing between scientists and non-scientists (local people) in a collaborative manner (Ballard and Belsky, 2013). The participatory methods utilised in this study include focus group discussion, interviews and observations. The utilisation of these participatory methods is not only cost effective (Kingery et al., 2016), but also useful in providing depth to the quantitative findings (Creswell and Plano Clark, 2011).

Focus group discussions involving lead farmers were used to elicit detailed information that emerged from the surveys. A focus group involves a small group of people who possess unique characteristics to help engage in a focused discussion to gain an in-depth understanding on an issue of interest (Krueger and Casey, 2015). Focus group discussions enable researchers to collect rich data that are cumulative and elaborative and allows participants the flexibility to express their thoughts and ideas (Denzin and Lincoln, 2000). However, the use of focus group in social science research is not without critique. One of the main critiques is that results of focus group discussions cannot be generalized since one person may likely dominate the discussion (Flowerdew and Martin, 2005). In dealing with this challenge, Mubaya et al. (2013) argue for separate focus group discussions based on gender and ethnic differentiation. The utilisation of focus group in this study helped in providing an efficient way of getting a deeper understanding of issues from different perspectives.

Interviews were used to collect qualitative data from key informants in the study communities. An interview is a social encounter that allows participants to provide an account of their experiences, feelings and thoughts about an issue under discussion (Seale et al., 2004). It is recognised as an important research method in the Social Sciences that helps to understand individual or group perspectives of an issue (Denzin and Lincoln, 2000). The open-ended aspect of interviews reduces restrictions on the content and scope of respondents' answers (Creswell, 2007). In this thesis, interviews were utilised to generate specific indepth information from key-informants.

The study also utilises personal participant observation as part of the data collection process, which is fundamental to anthropology. Participant observation involves the process of interacting with research participants through observation and interviewing to understand the social world (Seale et al., 2004). Even though participant observation is argued to be biased and sometimes distract the focus of the researcher (Somekh and Lewin, 2005), it is regarded as an important method that provides researchers an opportunity to learn and understand the culture of the people by spending a considerable amount of time in the community (Marshall and Rossman, 2006). In this study, observations were made about Indigenous practices implemented by farmers at household and community levels (see Appendix A). The utilisation of the afore-mentioned participatory methods are useful in providing detail information to the quantitative findings (Creswell and Plano Clark, 2011). A qualitative validity of the study was achieved by spending a considerable amount of time in the field to get a deeper understanding of the issues through the different participatory approaches to build a credible narrative account (Creswell and Creswell, 2018).

It is important to mention here that because this thesis is a blended form, the specific design issues that were considered to address the research aim and associated objectives are not provided in this chapter. For example, the sampling procedures and data analysis processes are all not included in detail in this chapter, because they are outlined in the individual published and unpublished chapter papers included in the thesis (see chapters 4, 5, 6 and 7). This was done to avoid needless repetition, and also to show how particular methods led to specific data and analytical outcomes.

3.5 Positionality and ethical considerations

Researcher's positionality is vital in shaping social research (Adu-Ampong and Adams, 2020). Therefore, in conducting this participatory research, issues of appearance, dress code and approach to participants were critically considered, particularly given the northern Ghana context where there are different ethnicities across the regions. To that end, the research assistants were educated on how to approach participants. Those who were recruited for the survey were people who had lived in the study communities for decades with deep understanding of the culture of the ethnic groups. Apart from the Nandom district where the researcher is Indigenous and led the group discussions, the other focus group discussions in the Savelugu and Bongo districts were facilitated by research assistants who are Indigenous within their local communities. The background and cultural connections the researcher and his team of assistants had with the local people facilitated approachability and created a conducive atmosphere for friendly discussions and openness in responding to the research questions (Berger, 2015). Given the influence and authority of the traditional chiefs in the study communities, they were accorded the needed respect by performing the required traditions and customs, which included the pouring of libation as a form of prayer of acceptance into the community.

Since humans are at the center of this research, ethical clearance was sought from the University of Adelaide Human Research Ethics Committee (see Appendix C) before the surveys, interviews and focus group discussions with the respondents in the study communities (*Brutu, Danko, Nabogu, Kpalung, Bogorogo and Dua Nayire*). Ethical approval was obtained from the leadership of each community and the various heads of institutions to explain the rationale of the study for their consent. Also, permission was obtained from the respondents for their consent of participation or non-participation in the study. This was done through a detailed explanation about the focus of the research with the people. They were also given a considerable amount of time to consider their participation in the study. Respondents were given assurance of their confidentiality and anonymity regarding their names and responses they provide in the study. To ensure anonymity of participants for the survey, focus group and interviews, pseudonyms were used to represent their identities (e.g. a male participant, a female participant, an extension officer etc.), particularly in the key informant interviews and focus group discussions. Subsequently, each respondent was separately attended to with a questionnaire in order to give them the opportunity to respond candidly to the questions. In cases where photographs and recordings of respondents were needed, permission was sought from them with the assurance that their voices and pictures will be used in the study alone. The respondents were informed of their right to withdraw from the data collection process when they developed unexpected problems in the course of the study.

3.6 Concluding remarks

This chapter has discussed the research methodology of the study. The chapter has provided a discussion of the arguments between the positivists and interpretivist philosophical perspectives, and their importance in designing a research method. It also discusses the importance of integrating both philosophical ideas pragmatically to ensure that the strengths in one paradigm compensate the weaknesses in the other. The integration of positivist and interpretivist philosophical perspectives and the mixed-methods approach adopted here support the theoretical foundation of this study (i.e. the Integral Theory) discussed in chapter one. This chapter has discussed the positionality of the research and the ethical procedures that were duly followed in the data collection process. The rest of the thesis comprising the individual papers shows how the methods and tools selected for this study were applied.

Chapter four (Paper 1) presents the results and discussion of the complexities of conceptualising Indigeneity at continental and regional levels. This paper, which problematizes Indigeneity in SSA, with empirical evidence from Ghana provides an important theoretical foundation for developing understanding of the complexity of Indigenous knowledge, which is evolving in climate adaptation processes in Africa, and Ghana as discussed in chapter seven of this thesis. Chapter five (Paper 2) presents the results and discussion of the integration of local perceptions with scientific evidence to comprehensively address the complexity of climate change and associated risks in dryland farming systems in northern Ghana. Chapter six (Paper 3) focuses on a presentation of the results and discussion of how social perceptions of households and their networks impact upon food security in vulnerable northern Ghanaian communities. Chapter seven (Paper 4) presents results and discussion of Indigenous adaptation of farming households and communities to mitigate climate change risks in northern Ghana.

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CHAPTER 4: Problematizing Indigeneity in sub-Saharan Africa: Implications for Natural Resource Management

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Overall percentage (%)	80%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	07/10/2021

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);
ii. permission is granted for the candidate in include the publication in the thesis; and
iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

Name of Co-Author	Douglas K. Bardsley		
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Signature		Date	07/10/2021

Abstract

There is considerable evidence in the literature of the nature of Indigeneity in Africa, yet few studies explore the complexity of definitions of the concept at different spatial scales. This paper builds on existing scholarship by problematizing 'Indigeneity' at both regional and national scales through a critical analysis and synthesis of contemporary literature across sub-Saharan Africa, in association with a specific case study from northern Ghana. In generating the review, the concomitant implications for natural resource management and associated conflicts are analyzed. The paper argues that the definitions and conceptualizations of Indigeneity are heterogeneous with numerous ambiguities and complexities at regional and national scales, which has contemporary implications for both acute and prolonged issues of natural resource allocation and management. Claims of Indigeneity in relation to climate change-driven migration and settlement processes are facilitating support for resource access and utilization, but also generating a myriad of problems linked to overlapping and disputed claims. The ambiguity of claims of Indigeneity by vulnerable individuals and groups also has latent implications. Political misunderstandings or conflicts over natural resources are becoming more widespread across Africa during a period of environmental change. Understanding the complexity of Indigeneity at both regional and national scales will provide important opportunities to inform effective policy for the sustainable and equitable distribution and management of resources in sub-Saharan Africa.

4.1 Introduction

Indigeneity is one of the more contested and problematic social concepts, which has generated extensive debate among academics and policymakers (Berger, 2019; Guenther, 2006; Hope, 2017). Here, Indigeneity refers to "the socio-spatial processes and practices whereby Indigenous people and places are determined as distinct to dominant universals" (Radcliffe, 2015, 221). All over the world, claims of Indigeneity have become an important means to struggle for territory, natural resources or political support, thereby creating an issue that is becoming increasingly problematic globally, but particularly in Africa (Mandelman, 2014). Through self-identification, many minority groups in Africa have been claiming Indigenous status for places where they don't 'originally' belong, particularly to define a pre-colonial heritage with place (Pelican & Maruyama, 2015). Such claims can clarify access to resources, but also generate their own problems.

This paper aims to describe the complexity of the nature of Indigeneity in SSA, and Ghana in particular, by developing understanding of how the term is conceptualized at both regional and national scales. It problematizes Indigeneity by analyzing contemporary literature on how the concept has been interpreted by scholars. The discussion exemplifies the challenges of Indigenous ethnicities in SSA, with support from a case study from northern Ghana. In doing so, we ask the specific questions: how have the conceptions of Indigeneity influenced natural resource management conflicts, and what might be the future implications in the context of a changing climate? Research on Indigeneity is emerging in the literature, especially on how Indigenous people are asserting their rights to land and other natural resources (Barume, 2014; Home & Kabata, 2018), and managing local environments under rapid social and ecological change (Nursey-Bray et al., 2019; Nyong et al., 2007). However, there are still important questions regarding how Indigeneity is conceptualized at different scales to inform policy and practice across different societies and Indigenous groups in SSA (Bello-Bravo, 2019).

While Indigeneity is less contested in the Global North, it is more problematic and complex in the Global South, and particularly Africa where the diversity of ethnicities and ancestral heritage interact with complex migration histories to generate considerable status uncertainty (Pelican, 2009). The historical migration patterns of settlers and concomitant cultural assimilations, coupled with the challenges of ancestral home and territorial boundary identification, especially during the pre-colonial period, add to that complexity and make many claims of Indigenous status indefinite.

Given such cultural intricacies, African governments have advocated for the need to formally contextualize Indigeneity within policy frameworks (Pelican & Maruyama, 2015). Such a consideration has always been important because of claims for control over Indigenous lands and resources by migrant settlers, but is increasingly problematized by environmental change, which is both altering local resource conditions and facilitating increasing mobility of social groups (Gleditsch et al., 2007).

In developing countries, and once again particularly in SSA, transhumance has been used traditionally by Indigenous people, and especially pastoralists, as an important response mechanism to environmental and non-environmental stresses (Sletto, 2016; Thébaud & Batterbury, 2001). For instance, there has been a continuous trend since the 20th century where nomadic herdsmen in West Africa have moved from the Sahel to more humid Savanna and Forest zones for resource access and utilization under changing resource conditions (Tonah, 2002). Climate change and extreme events, particularly droughts, are exacerbating such use of human mobility to maximize opportunities for accessing natural resources (Batterbury & Warren, 2001; Farbotko et al., 2016). Such environmental responses are not only attributed to the high levels of vulnerability to climate change amongst Indigenous communities (Bardsley and Hugo, 2010; Intergovernmental Panel on Climate Change [IPCC], 2014), but also the failure of *in situ* response mechanisms in many societies.

Even though the movement of Indigenous people to different locations in search for opportunities helps to reduce vulnerability and enhance livelihood options (Simonelli, 2019), it generates tensions all over Africa due to increasing rivalries over natural resource access and management (Shizha, 2013). Tensions are associated with opportunities to claim Indigenous rights over resources or establish new claims in different ways. Such claims can provide migrant settlers with access or control over the management of natural resources within a geographic space, but in turn, may limit local opportunities for long-term residents or other established communities (Igoe, 2006). For example, such interactions between different peoples trying to exploit the same or neighbouring lands and resources have already led to heightened competition and conflict between migrant settlers and long-term residents in the African Sahel (Batterbury, 2010; Turner, 2004).

However, it is important to indicate that not all land use conflict in Africa is associated with Indigenous claims *per se*. For example, the Mossi people, who are recognized as Indigenous by the government of Burkina Faso, have been known to attack the Fulbe people not because of Indigenous claims of the latter group but due to direct competition over natural resources (Breusers et al., 1998). Moreover, there are historical land use conflicts between Indigenous groups in many places that are not related to Indigenous claims, including between the Ogiek and Maasai in the Mau Forest in Kenya (see Kameri-Mbote & Nyukuri, 2013); and the Hadza and Barabaig in the Lake Eyasi Basin of Tanzania (see Madsen, 2000).

Conflicts over natural resources are being exacerbated by climate change, which intensifies the call for clarity over Indigenous rights and resource claims. Indigeneity has lacked strict definitions or understandings across SSA, and as a result, the concept has been open to false or misleading claims on one hand or, on the other, has failed to uphold legitimate rights of Indigenous people in both the pre- and post-colonial periods (Nakashima et al., 2018). A lack of epistemological reflection on 'Indigeneity' has led to a dearth of conceptual clarification in the contemporary literature on SSA, or in fact in the policy arena (Lanzano, 2013; Pelican, 2009). While indigeneity is an evolving but complex concept, it needs now to be carefully clarified within particular defined criteria and/or socio-ecological and cultural contexts, so that the concept becomes meaningful for both Indigenous and non-Indigenous groups within and between African countries.

The paper describes the conceptual problematization of Indigeneity in SSA to provide an opportunity to inform policy that links Indigeneity to natural resource management. It maintains that there are opportunities generated by both Indigenous claims to resources and adaptation through the effective mobility of different groups, and especially in the context of climate change ([Remove for peer review]). For that reason, it is imperative that traditional authorities and governments generate policy to proactively avert conflict between Indigenous and non-Indigenous ethnic groups, and rather promote peaceful coexistence and sustainable development. In this sense, this paper is not intended to enthusiastically challenge the conclusions of existing studies, but rather is presented as a 'prologue' to inform discussion and discourse on future Indigenous-related resource management research and practice during a period of environmental change.

4.2 Research approach

The narrative review approach applied here involves a critical analysis and synthesis of the literature via a qualitative review of knowledge from scholarly academic sources including articles and books in Google Scholar and Web of Science Databases. The scope of the review largely focuses on the conceptualizations of Indigeneity amongst self-identified Indigenous ethnic groups within the countries of SSA, but also draws directly from recent empirical research undertaken with such groups in northern Ghana. The integration of local northern Ghanaian perceptions with academic knowledge of Indigeneity and its meanings provides an opportunity to frame the concept at two important scales in relation to natural resource management across SSA: regional and national. By presenting the research approach before the review, the regional narrative of the complexity of Indigeneity can be directly followed by the Ghanaian case-study. In such a manner, the available theoretical and applied evidence in the literature at a regional scale is exemplified through the perceptions of different Ghanaian Indigenous ethnic groups to generate a discussion of how local conceptualizations of Indigeneity influence attitudes and behaviours at the national scale.

The case-study research was undertaken through a series of 12 focus group discussions (FGDs) with Indigenous ethnic groups (Dagomba, Dagaaba and Grune/Frafra) in the Savelugu, Nandom and Bongo districts of northern Ghana (Figure 4.1). Indigenous male and female elders were engaged in discussions between September-December 2019 within public spaces in selected communities in the districts. The ethnic geographies of the districts are distinct, and the narratives emerging from the respondents' comments reflect this situation. The recruitment process focused on inviting Indigenous adults who have lived in the district for at least 50 years to the FGDs, as it was expected that such participants would be able to represent a deeper knowledge and understanding of the local histories of ethnicities and natural resource management. The study was advertised during community meetings, and those who were interested in participating and met the criteria were recruited, with a maximum of 10 respondents per meeting. A total of 60 participants volunteered for the FGDs, with a total of 20 participants (10 males and 10 females) from each of the three study sites (Fig. 4.1).

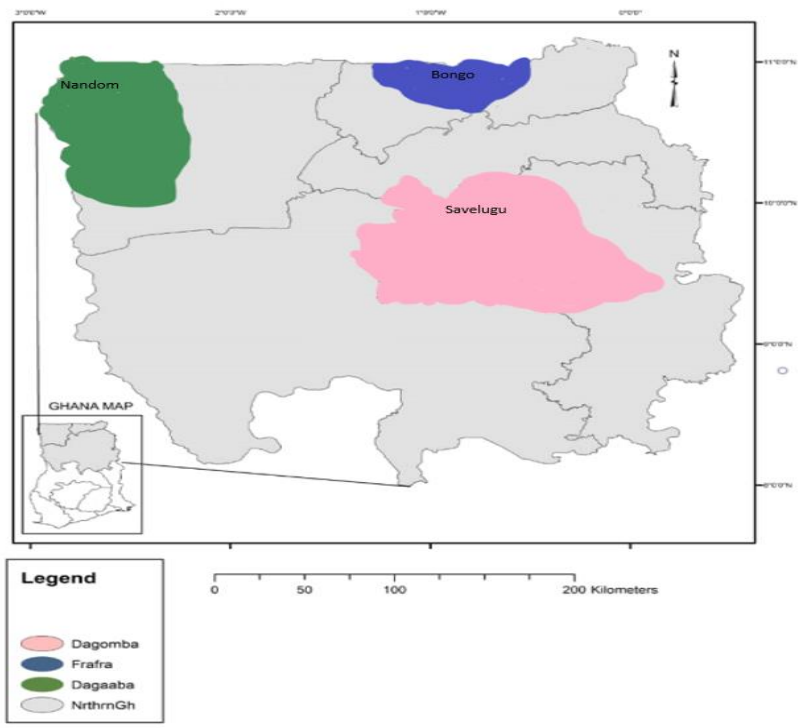

Figure 4.1: Map showing the locations where the three Indigenous groups are found in northern Ghana

Source: Author's production, 2018

The FGDs were conducted separately for male and female participants, with each discussion lasting between 60-90 minutes. They were conducted in an informal atmosphere to allow participants to express themselves freely, but were facilitated by the first author. The discussions were framed by a series of questions on the nature and conceptualization of Indigeneity within each particular ethnic group. Before the commencement of the research, ethics approval was obtained from the Australian Human Research Ethics Committee. The discussions were audio-recorded with prior permission obtained from participants. Participants were informed of the potential for anonymous referencing of their comments to support arguments and publication of quotes and concepts obtained during discussions. The FGDs were conducted in the local Indigenous languages/dialects of participants with the assistance of local professional translators of both genders. The recordings from the FGDs were transcribed verbatim and categorized for synthesis and interconnectivity to generate a case-study narrative on the nature of Indigeneity in northern Ghana. Those narratives are described in the results with the use of direct quotations from respondents.

4.3 Indigeneity across sub-Saharan Africa

There is little consensus on "what constitute(s) an Indigenous identity, how to measure it, and who truly has it" (Weaver, 2001, 240). Thus, providing a standard definition of who is Indigenous to satisfy different groups and societies has become a challenging and complex issue since the United Nation's Declaration on the Rights of Indigenous Peoples in September 2007 (Balaton-Chrimes, 2013). Notwithstanding, Daes (2008) has provided a general set of criteria for clarifying Indigeneity including occupancy and use of specific territory, cultural distinctiveness, self-identification and experience of marginalization, subjugation, dispossession, exclusion or discrimination. In the SSA region 'Indigeneity' is conceptualized and employed differently across countries and sub-regional contexts (Table 4.1).

Table 4.1: Selected definitions of Indigeneity across some sub-Sahara African countries

No	Meaning of Indigeneity	National Context	Regional Context	Author (s)/Years
1	A combination of cultural distinctiveness and marginalisation	Tanzania	East Africa	Igoe (2006); Mamo (2020); Matinda (2018)
2	Having the ability to establish an ancestral presence on Ugandan soil pre-dating the beginning of colonialism	Uganda	East Africa	Mamdani (2002)
3	Belonging to recognised tribal groups, and marginalised hunter-gatherers and pastoralists	Kenya	East Africa	Balaton-Chrimes (2013)
4	Group of people with distinct culture who are marginalised and dispossessed of lands	Sudan	Central Africa	Komey (2008)
5	Group of people recognised as the autochthones	Rwanda	Central Africa	Ndahinda (2011)
6	All citizens belonging to state recognised tribal groups	Nigeria	West Africa	Ojukwu and Onifade (2010)
7	Groups of people who are the immediate settlers	Cameroon	West Africa	Pelican and Maruyama (2015)
8	Every citizen and marginalised hunter-gatherers and pastoralists	Namibia	Southern Africa	Sapignoli and Hitchcock (2013)
9	All citizens of Botswana	Botswana	Southern Africa	Pelican and Maruyama (2015)
10	All citizens of Zimbabwe	Zimbabwe	Southern Africa	Mamo (2020)
11	All citizens having a sense of belonging in South Africa	South Africa	Southern Africa	Koot et al. (2019);

				Mamo (2020); Sapignoli and Hitchcock (2013)

How Indigeneity is employed is partly dependent on the concept's political utility to support the aims of different groups with different aims, depending on local or national circumstances (Andreasson, 2010). Given that complexity, the concept has seldom been used explicitly to guide policy in Africa (Shizha, 2010). This is perhaps because many African countries consider all their citizens as Indigenous and therefore disagree with the differentiation according to the UN Indigenous rights guidelines. Only a few African countries, such as the Central African Republic, have actually formalized the concept of Indigeneity in its constitution to guide policy. However, in recent times attempts have been made by countries to conceptualize and constitutionalize Indigeneity to make the concept useful in practice (Chanock, 2016; Holzinger et al., 2019), but even those attempts are adding to governance complexity. In fact, much of the discussion on Indigeneity in Africa is not based on the International Labour Organization Convention No. 69 on Indigenous and Tribal Peoples in Independent countries (1989), which no African country has signed and ratified, but rather the work of the Permanent Forum on Indigenous Issues and other parts of the United Nations system (Mamo, 2020; Toki, 2014). Many groups in Africa self-identify as 'Indigenous' to access lands and manage natural resources. Yet, it is important to note that even within the broader context of self-identification, not all Indigenous people or groups are recognized by governments. In just one example, the Twa of Rwanda who identify themselves as Indigenous are not recognized by the Rwandan government in relation to land rights (Ndahinda, 2011).

Cultural identity is an increasingly important indicator for measuring Indigenous identity in SSA countries. Indigeneity in the Tanzanian context reflects a combination of cultural distinctiveness and marginalization (Igoe, 2006; Mamo, 2020). Indigenous groups in Tanzania, such as the Maasai, Hadza and Dorobo are suggested to be vulnerable and suffer from political disempowerment and land-tenure insecurity (Matinda, 2018). Similarly, Komey (2008) suggests that 'Indigenous' in the context of Sudan connotes people who have distinct cultural attributes from the dominant national culture, and who are marginalized and dispossessed of lands by dominant invaders of state. However, conceptualizing Indigeneity around 'cultural distinctiveness' is operationally problematic, particularly in liberal multicultural and democratic societies with a range of unique and evolving cultural identities (Peter, 2007). For instance, people of Asian background in Tanzania generally possess distinct cultures, religions and languages, but are not considered Indigenous (Peter, 2007).

It is becoming increasingly insufficient to claim Indigeneity via the demonstration of distinct historical cultural characteristics. This explanation might suffice in countries such as Australia with a clear period of European colonization, but would generate a plethora of problems in the African context. That claim becomes more complex however, when a single period of residence of culturally distinct migrant settlers would need to be prioritized (Hodgson, 2009). Can a group claim to be Indigenous for settling in a particular locality for hundreds of years? For instance, in Namibia, white settlers have lived in the country for centuries, but may not be defined by themselves or others as Indigenous (Peter, 2007). Similarly, the white population in South Africa who have lived in the country are not formally considered Indigenous even though their culture differs from that of the larger society and they have been resident for multiple generations (Gildenhuys, 2005). In both cases, those white settlers migrated to southern Africa with their culture to ostensibly exploit resource opportunities during the colonial era, but cannot claim Indigeneity even though they have grown to be important groups in their country for centuries with unique cultures (Eyong, 2007). However, in another context, the Baggara Arab settlers claim Indigeneity in the Nuba Mountains of Sudan because they have settled there for over two hundred years (Komey, 2008). The eventual narrative has led to the expropriation of the Nuba region by the Baggara people. Thus, as Kuper (2003) states, the fact that one is resident in a place for a long time period does not automatically make him or her an Indigenous person, but has been used to warrant claims to Indigeneity.

Autochthony, which explains the originality of people has also been recognized as an important indicator of Indigeneity in many African countries (Côte, 2020). Pelican and Maruyama (2015) highlight that Indigeneity in Cameroon is associated with local groups of people who consider themselves as first-comers, or autochthones. However, precisely ascertaining whose ancestors first arrived at a place and the time of movement is characterized by a range of challenges and complexities due to factors such as migration, intermarriage and language assimilation (Kuper, 2003). For instance, the 'Karretjie People' in South Africa are direct descendants of the San/Bushmen who were the first inhabitants of the Great Karoo, but they are not recognized by the South African government or NGO agencies (De Jongh, 2012), and have become landless in the country (Koot & Büscher, 2019). Thus, due to the lack of evidence of territorial precedents in many African countries, particularly during the pre-colonial period, the concept of autochthony is increasingly problematic (Hodgson, 2009).

Even though autochthony seems to be attractive for providing some level of primal certainty and protection for migrant settlers, the claims of 'first comers' can be closely linked with conflict and violence (Bøås & Dunn, 2013). According to Arjun Appadurai (1999: 322) cited in Bøås and Dunn (2013), 'uncertainty about identification and violence can lead to actions, reactions, complicities and implications that multiply the pre-existing uncertainty about labels. Together, these forms of uncertainty call for the worst kind of certainty: dead certainty'. Thus, the very flexibility of the use of autochthony to claim Indigeneity in Africa could facilitate political violence, such as has been experienced around Mount Elgon in Kenya (Ceuppens & Geschiere, 2005; Geschiere, 2009).

Certain circumstances can lead to a group of people gaining or losing their Indigenous status. For instance, if dominant migrant settlers to a place occupy the land for years, can the dominant migrant group be considered the indigenes of that land? A typical example is what happened in the 17th century in Ghana when the Ashanti Indigenous group, through a coalition with the Kwaman people during the pre-colonial period, overpowered the Denkyira people and gained possession of their gold resources in the Ofin-Pra river basin (McCaskie, 2007). The insurgency of the Asante people over Denkyira pushed the latter group further south out of the basin to occupy their homeland around Jukwa in present-day Cape Coast in the Central region of Ghana (McCaskie, 2007). Thus, even though oral tradition has it that the Asante people were migrant settlers from ancient Mesopotamia to sub-Sahara Africa, their supremacy and dominance allowed them to occupy the Akan territories (McCaskie, 2003). On the other hand, there is a tendency for some migrant groups to claim Indigeneity to a place to which they have no original claim due to a lack of clear evidence of territorial precedents. For instance, Mbororo migrant settlers later became 'Indigenous' in Cameroon even though they were not considered as such by the local Grassfields societies (Pelican & Maruyama, 2015). Such territorial claims and counter-claims of Indigeneity can degenerate into conflict, especially if tenure over lands or access to resources influence opportunities for exploitation (Adebanwi, 2009).

In southern Africa, Indigeneity is conceptualized differently. According to Sapignoli and Hitchcock (2013), the government of the Republic of Namibia generally recognizes everyone originally of descent from Namibian lands as Indigenous, especially if they are also marginalized groups such as hunter-gatherers and pastoralists. Even though this definition may be partly valid in the context of Namibia, there are numerous Indigenous groups in SSA who are not marginalized (Niezen, 2003). For instance, in Ghana some self-identified Indigenous groups such as the Guans and Mole-Dagbani people have been successful in agribusiness and entrepreneurial activities, which have enhanced their economic status (Dzisi, 2008; Hatskevich et al., 2011). Importantly then, the concept of Indigeneity, which has in some definitions been equated with a level of marginality may need to evolve with the changing opportunities and positions of particular groups.

In the Apartheid period in South Africa, people claimed Indigeneity largely based on autochthony, with several forms of political, social and economic marginalization. However, in contemporary times, South African policy no longer recognizes 'original inhabitants' as Indigenous, but rather all citizens belonging to the country (Koot et al., 2019; Sapignoli & Hitchcock, 2013). Also, in Botswana, the government does not recognize any distinct ethnic or tribal group as Indigenous, but rather all citizens are considered Indigenous peoples (Mamo, 2020; Pelican & Maruyama, 2015). Similarly, even though in Zimbabwe the Tshwa and San self-identify themselves as Indigenous groups, the government recognizes all Zimbabweans as Indigenous in their own right (Mamo, 2020). The potential problem with this classification is that it permits other migrant groups or settlers who have acquired citizenship to be considered Indigenous. For instance, descendants of white populations in South Africa self-identify themselves as Indigenous because of their state of belonging to the country through birth or citizenship leading to ongoing arguments over resource control and utilization (Koot et al., 2019). Such broad classifications have also generated conflicts in countries such as Nigeria (Adebanwi, 2009) and Ghana (Kusimi et al., 2006), between migrant settlers and original inhabitants. Thus, even though a classification of all citizens as Indigenous could be seen to be inclusive and promoting of development, the downside is the possibility for the grouping to not provide sufficient recognition of original claimants, such as in those cases in West Africa.

While colonialism may not be necessarily important for claiming Indigeneity in other contexts (Thornberry, 2002), it has been widely considered by African countries. For example, in Uganda, to be Indigenous is to have the ability to establish an ancestral presence on Ugandan soil pre-dating the onset of European colonialism (Mamdani, 2002). However, defining Indigeneity within the context of colonialism is not only primordial, but potentially also politically restrictive (Maybury-Lewis, 2002). It could, for example, provide space for non-native ethnic migrant settlers prior to European colonization to be considered as Indigenous, while potentially declassifying some native out-migrant people as non-Indigenous. For instance, though the Peul and Tuareg people of Burkina Faso claim to have occupied their territory before colonization, they were not officially recognized as such by the state or other ethnic groups (Berger, 2019).

Beyond these examples of marginalization, self-ascription and non-dominance which usually define Indigeneity, 'tribal identity' also plays a critical role in defining the concept in SSA, particularly in East and West Africa. Even though temporal priority has not disappeared from the praxis of Indigeneity in Kenya, populations are officially recognized as Indigenous when they belong to one of the 42 tribes of Kenya defined since the country's inception (Balaton-Chrimes, 2013), including pastoralists such as the Turkana, Massai, Endorois and Borana, and hunter-gatherers such as the Ogiek, Sengwer, Yiaku, Waata and Awer (Mamo, 2020). A range of challenges and complexities are associated with this utilization of tribal origin. First, the problem arises whether it would be through the state, existing tribal groups, traditional authorities, self-identification or via the legal system that any tribe would be recognized as part of an official tribal group. For instance, the ruling of the African Commission on Human and People's Rights (ACHPR) that the Kenyan government violated the rights of the Endorois people exemplifies how people have used the law to assert their Indigenous rights beyond the classification of the state (Home & Kabata, 2018; Lynch, 2012).

Second, it is difficult, if not impossible, to clearly distinguish Indigenous from non-Indigenous groups within diverse ethnic cultural settings in many parts of Africa, where some minority tribal groups are assimilated to become part of a dominant tribal population through proficiency in language or other cultural practices. For example, until recently, the Mukogodo people of Kenya adopted the Maasai culture and language, and largely became part of the dominant cultural milieu, making it difficult to distinguish between the two tribal groups, especially if attempting to use historical criteria from the pre-colonial period (Carrier, 2011). Also, in West Africa, the Fulani are a tribal group who have persistently claimed Indigeneity in Yelwa, yet they are not recognized as such by the Tarok in northern Nigeria (Adebanwi, 2009). The Fulani are Muslim nomadic pastoralists who principally originated from the Sahelian regions of Nigeria and Niger (Thébaud & Batterbury, 2001). However, due to the nomadic movements of the Fulani in search of pastures and water for their livestock, they also occupied other Sahelian landscapes including within Senegal, Mali, Cameroon, Guinea, Ghana and Burkina Faso (Tonah, 2006). Thus, the question arises whether an assimilated migrant minority tribal group could be considered Indigenous. Again, either the acceptance or denial of such situations could potentially result in inter-tribal conflicts or xenophobic attacks if state actors fail to handle such issues with caution.

Using Indigeneity as a precondition for citizenship also appears problematic, as it could exacerbate levels of discrimination, either against certain ethnic groups who identify themselves as Indigenous based on the self-identification principle, or against recent settlers. For instance, until recently the Nubian people of Kenya, who have their origins in Egypt and Sudan, considered themselves Indigenous to Kibera, but were discriminated against by the state constraining their access to land and other entitlements that they had traditional rights over during the pre-colonial period (Adam, 2009; Balaton-Chrimes, 2017; Kenya National Commission of Human Rights, 2007). Therefore, resource rights that are tied to definitions of Indigeneity can lead to inherent exclusionary tendencies. Balaton-Chrimes (2013) states that as long as membership in a particular Indigenous tribe is the basis for citizenship, there will be the tendency for some existing populations and late settlers to be deprived of citizenship or other access, even when they are have become tightly connected to a place and would not be accepted in other jurisdictions as Indigenous.

The various definitions of Indigeneity reveal some clear differences even within sub-regional contexts in SSA. For instance, in southern Africa, while all citizens in Namibia, Zimbabwe and Botswana are considered Indigenous, not all citizens in South Africa such as the San or Khoe-San who are classified "Coloured" are considered Indigenous even though they wish to assert their self-identified rights of Indigeneity (Mamo, 2020). Also, in West Africa, while Nigerians confer Indigenous status on people who belong to state recognized tribal groups, the national political framework in Cameroon recognizes Indigenous people as local groups who consider themselves first-settlers on a particular land or location (Pelican & Maruyama, 2015). These differences and many others are important in demonstrating the complexity of Indigeneity between countries at the regional scale in SSA. It is in such a context of the complexity of definitions and the potential risks inherent to different conceptualizations that the case study was undertaken in northern Ghana to develop understandings of the implications of conceptual complexity at the national scale..

4.4 Case study: Indigeneity in northern Ghana

The case study was conducted in northern Ghana in West Africa. Northern Ghana is a largely semi-arid area on the southern fringe of the West African Sahel, characterized by high temperatures, low precipitation and extreme climatic events such as droughts, wildfires and floods (Guodaar et al., 2021). The abundance of agricultural land in the northern Ghanaian Savanna attracts people, particularly Fulani herders from the Sahara of Burkina Faso and Mali to settle (Rademacher-Schulz et al., 2014). The Dagaabas, Dagombas and Grunes are some of the major Indigenous groups in northern Ghana (Awedoba, 2006). These three ethnic groups are relatively large groups located in the Upper West, Northern and Upper East regions respectively (Figure 4.1) (Awedoba, 2006). They are Indigenous groups in their own right and none of them including other groups in Ghana have represented at international meetings on Indigenous peoples such as the Permanent Forum on Indigenous Issues (UNPFII) (Hodgson, 2009; Sapignoli, 2017). The groups are culturally diverse with different ancestral homelands and long histories that are largely distinct from one another. The traditional home of Dagombas and Grunes/Frafras are Dagbon and Bolgatanga respectively (Berinyum, 2006; Pellow, 2011). However, in the case of the Dagaabas, there have been controversies regarding their true traditional homeland due to hegemonic claims of superiority over Dagaaba land by various Dagaare speaking groups such as the Waalas, Briforas and Lobis (Yelpaala, 1983).

The three self-identified Indigenous ethnic groups in northern Ghana have some socio-cultural commonalities and also a range of differences (Awedoba, 2006). For instance, they are all farming groups who practice the patrilineal system of inheritance, and emerged from the broader Mole-Dagbani ethnic group that migrated to the savanna landscape in the fourteenth century (Awedoba, 2006; Kpieta & Bonye, 2012). The analysis revealed that the ethnic groups also have some common criteria for defining Indigeneity at the local level. For instance, among the Dagomba, Dagaaba and the Grunes, an Indigenous person is someone who has an ancestral linkage to the *Tendaanas*, or the original settlers of the land. Notwithstanding such similarities, there are several distinctly different ways by which the three Indigenous groups conceptualize Indigeneity (Table 4.2).

Table 4.2: A summary of Indigenous criteria among the three ethnic groups in northern Ghana

✓ (Yes) X (No)

No	Criteria for determining Indigeneity	Dagaaba	Dagomba	Gurune
1	Birth	X	✓	✓
2	Self-identification through longevity of stay in a place	X	✓	✓
3	Performance of traditional marital rites (bride price)	✓	X	✓
4	Patrilineal system of inheritance	X	✓	X
5	Original settlement	✓	✓	✓
6	Ancestral linkage to place	✓	✓	✓
7	Understanding the culture and traditions of a group	X	✓	X

From the perspective of the Dagomba Indigenous group, Indigeneity can be claimed when a person is born from a male parent who is deemed Indigenous to the Dagomba land. Given the patrilineal system of inheritance within the Dagomba group, having an original inhabitant biological father is sufficient for a person to claim Indigeneity. Whether one is born within or outside the Dagomba land doesn't necessarily matter when it comes to claiming that Indigenous status. In a FGD, a Dagomba male participant made the following remarks:

> We Dagombas inherit from our fathers' side, so it is only your father who can determine whether you are an Indigene or not. If your father accepts you as a biological son, you automatically gain the right to be called a Dagomba. So once your biological father is a Dagomba you are also a Dagomba by birth. However, if your father is a migrant settler, but your mother is a native, you don't qualify to be an Indigene even if you can speak the language. It doesn't mean that you will not

> be accepted here as our child, but the point is that when it comes to defining your true identity, you can't be considered a Dagomba.

However, a Dagomba female participant had a partially different view. She said that:

> Even though our culture sometimes limits women's opportunity to claim Indigeneity, I have always considered myself Indigenous in my own right. Once one of my parents is a long-term settler of this community, I am an Indigene of the land. It doesn't matter to me whether my father or mother is a long-term settler. The most important thing for Indigenous recognition is being able to trace one's root to the *Tendanas* who are the traditional overlords or landowners of Savelugu.

Interestingly, in the Dagomba culture, non-natives who are born on Dagomba land are given the right to self-identify as Indigenous provided that they have stayed in the community for a long period. However, such 'Indigenous' people without a patrilineal heritage do not have the right to perform certain cultural practices that are considered the preserve for fully Indigenous Dagombas. This indicates that there are some levels of Indigeneity within the Dagomba culture generated either by self-identification or conferral. A Dagomba male FGD participant stated:

> You cannot look at someone's face to indicate whether a person is Indigenous or not. But if a person is born and bred in this community and has stayed here for a long period, and knows the traditions and culture of the ethnic group very well, that person can classify himself/herself as Indigenous, but will not be generally classified as Indigenous by us, the original people. For instance, when it's time to perform certain rites, only those who are truly Indigenous are permitted to take part. Also, some migrant settlers are considered partially Indigenous when they marry from this community and continue to stay here. For instance, if a migrant settler marries an Indigenous woman from this village, the children become 'natives', but the husband is considered non-Indigenous.

Similarly, a Dagomba female FGD participant said that:

> It is not everyone who can be considered Indigenous. The Indigenous people we know in this community are those who have stayed here with us for centuries and understand our

> culture. There are old people in this community who know the history and everything about our community. They have married and given birth here, and they even speak the language more fluently than the landowners. Sometimes, we go to such people when we need some historical facts about a particular family or clan. Can we say that such people are not Indigenous? Even some migrant-settlers have been gazetted as members of the traditional council, and sometimes sub-chiefs of our communities.

This mode of claiming Indigeneity among the Dagombas is quite different from how the Dagaabas conceptualize the concept. In the Dagaaba culture, although having a native biological father is a necessary pre-condition, it is insufficient by itself to claim Indigenous status. The Dagaabas are of the view that one cannot use birth as a basis to claim Indigeneity if the important customary process of marriage that leads to child-bearing is ignored. Therefore, to the Dagaabas, a person can only claim Indigeneity within Dagara land when the father has customarily married and paid the bride-price, or dowry. In the Dagaaba culture, the payment of the bride-price is also the symbol of ownership of children, which gives them the right to claim Indigenous status on their father's land. Thus, if the bride-price is not paid, the opportunity to claim Indigeneity is very limited. However, the male child of an Indigenous father who has not paid the bride-price is given some level of Indigenous status because of the broader patrilineal system of inheritance. On the hand, a female child in the same situation is regarded as a non-Indigenous. A Dagaaba female participant noted that:

> If you are a male and your father marries from this village, but fails to perform the customary rites of your mother, you are considered an Indigene, once your father is an Indigenous person. However, if you are a female and your father fails to perform the customary rite for your mother you are not considered an Indigene because you will marry and go to your husband's house. Even if you don't marry, you are still not an Indigene because it is considered culturally inappropriate.

However, a Dagaaba male participant had a different view and said that:

> It is not always the case that males are given some Indigenous status when their fathers fail to perform the needed marital rites. In fact, if your father fails to perform the customary rights for your mother, you can't be classified an Indigene, just as women are

> not considered in that circumstance. You can only claim Indigeneity of your father's land when he has performed the necessary marital rites.

In the Grune tradition, the claim of Indigeneity appears to involve a blend of the cultural elements of the Dagomba and Dagaaba ethnic groups. To the Grunes, a person is considered Indigenous when a grandfather is a native of Grune land. Grunes also believe that grandfathers must perform the necessary customary rites by paying the bride-price before a person can claim Indigenous status. To them, a person is considered non-Indigenous even if he or she has a native father but a grandfather has not paid the bride-price. So, unlike the Dagaabas, the Grunes consider a female child as Indigenous even when the father has not paid the bride-price for the mother. The Grune male participants emphasized that:

> An Indigenous person is the one whose grandfathers or ancestors hail from the land by birth. You can settle in this community for over hundreds of years, if your grandfathers are not from this village, you cannot be classified as an Indigenous person. Since we inherit from our father's side, if your grandfather comes from this land, you will be granted that Indigenous status. In fact, your father must pay the bride price for your mother before you can claim to be Indigenous of this place. Also, if your mother is a native in this community and traditionally marries a migrant settler with all the requisite customary rites performed, all the children become Indigenous of their father's ethnic group. However, if your migrant father fails to perform the customary rites you are automatically considered an Indigenous person in this village until your father performs the needed traditional rites.

Also, a Grune female participant said that:

> Because of the patrilineal system of inheritance, children can claim Indigeneity of their father's land provided the traditional customary rites for the mother is performed. If it is not then, traditionally, a child cannot claim an Indigenous status of this place even though he or she can live in this village forever. So, the system of inheritance alone is not sufficient for a person to claim an Indigenous status of this place.

Like many other SSA countries, ethnic groups in northern Ghana are all using some level of autochthonous status, or first settlement rights, in association with ancestral links to a place as a means of confirming someone's Indigenous status (Jönsson, 2009). Indigenous northern Ghanaians are considered by the *Tendanas* to be the earlier people of the Savanna landscape before the colonial period (Phyfferoen, 2016). This mode of claiming Indigeneity during the pre-colonial period is still used by many ethnic groups in Ghana to determine one's Indigenous status. All other ethnic groups who join the autochthonous ethnic groups are considered migrant settlers or 'late comers' who must consult with the original settlers before they can settle on the land (Aleluma, 2002). While the Dagombas allocate some partial Indigenous recognition to such later settlers who have stayed in a particular place for a long period with their families, length of stay does not play a similar role for defining Indigeneity among the Dagaabas. For instance, during the FGDs, participants from each of the three ethnic groups reported a similar narrative that:

> Accepted migrant settlers with their families who have stayed here for so many years with understandings of the culture, including the language, cannot be considered an Indigene because they are 'late comers'. The reason is that such people cannot trace their ancestry to our grandfathers and great grandfathers. In our culture, such people are referred to as *Noora* (A Dagaaba male participant).

> Indigenous Dagomba people are those whose great grandparents originate from this community. In other words, the Indigenous people are those who can trace their ancestry to the Dagomba land. We have a family tree, and those who can trace their ancestral root to the family tree before the colonial period are considered Indigenous (A Dagomba female participant).

> An Indigenous person is someone whose grandfather, father and himself/herself can be traced to the history of this land. An adopted child is not considered an indigene because the identity of the biological father or grandfather is not known and cannot be traced to the ancestry of this community. A migrant settler who stays in this village for many years with family is not considered Indigenous of this village because they cannot trace their ancestry to this land (A Grune female participant).

How Indigenous ethnic groups in northern Ghana are conceptualizing Indigeneity suggests substantial complexities of Indigeneity exist. While there are basic common criteria under which a person can claim an Indigenous status in the northern region of Ghana, they are framed differently and operationalized uniquely within the cultural dynamics of their particular group. Unlike the broader context under which Indigeneity is understood and applied by international organizations such as the ILO or the UN, the fluidity of the concept at a national scale provides a flexible avenue for people to claim at least some level of Indigenous status locally. That flexibility suggests a freedom of interpretation and practice, but also has the potential to intensify future conflicts, considering the uncertain and ephemeral status of some claims and the likelihood that climatic change will drive further resource depletion across regional and national scales in the Sahel.

In northern Ghana, the opportunities given to migrant settlers to self-identify as Indigenous or for some individuals to be given partial Indigenous status due to the longevity of their residence, represent examples of people who have been able to migrate into places and establish themselves effectively within a framework of Indigenous rights of access. While a means of facilitating mobility in rural areas in the short-term, if migrant settlers were to claim full Indigenous status without good arrangements in place to guide their change in status, disagreements could emerge. Also, the challenges of women in claiming Indigenous status under the largely patrilineal system of inheritance is also seen to deprive them of rights within their ancestral homeland (Christensen, 2013). Since ‘non-Indigenous’ women are not permitted to perform certain cultural roles even if they have similar historical ties to place, their influence over decision-making diminishes on matters that affect them. Such marginalization of women in northern Ghana may not only limit their cultural relevance in society as the sourcing of resources becomes more difficult, but could potentially deprive them of important agricultural livelihood opportunities, especially if their rights to land tenure are questioned.

This case study may be representing a microcosm of a bigger problem across SSA, especially for women who often perform key roles in food production (Grabe et al., 2015). For instance, women provide much of the labour and perform other vital roles in subsistence agricultural production across the continent, yet their opportunity to control access to resources, and particularly land, within strict patrilineal systems often appears to be limited (Evans et al., 2015; Ogunlela &

Mukhtar, 2009). In fact, the definitions of Indigeneity across SSA, particularly in patrilineal societies may deny women important development opportunities tied to land (Davison, 2019). Broader complexities regarding classifications of Indigeneity add to the challenge of utilizing the concept as a mechanism for securing rights of access. To exemplify this point, the study examined the potential for conflict derived from human migration and natural resource access in SSA and Ghana in some further detail.

4.5 Indigeneity, migration and the potential for resource conflict

New movements of people to different landscapes have, at times, generated unhealthy competition for natural resources, which in turn has led to social instability in parts of SSA in the 21st century (Gleditsch et al., 2007). Conflicts in many African countries due to claims to the control over natural resources demonstrate a breadth of issues at a continental level. One relevant example is a conflict between the Indigenous Hausa-Fulani Muslim populations and the Christian migrant settlers in Nigeria (Omeje, 2007). In addition, there have been conflicts between nomadic pastoralists, and sedentary farming communities over issues of land and other resources in many other West African countries such as Senegal, Mali, Niger and Burkina Faso (Homer-Dixon, 2010; Thébaud & Batterbury, 2001; Tonah, 2002; Turner, 2004). Similarly, there has been reported incidents of conflicts between Indigenous farmers and Fulani migrant settlers in northern Ghana (Soeters et al., 2017; Tonah, 2002). During a FGD a Dagomba traditional leader recounted that: *Some years ago, there was a fight between some of the natives of the land and some Fulani migrants about land issues which resulted in people from both tribes losing their lives*. Some details on such conflicts were provided during the FGDs. For example, an Indigenous Dagomba participant reported that:

> Last year, I fought with a Fulani migrant who shares boundaries with me, in my farm. This man claims he bought the land from the chief several years ago, and has full right over the land. I cultivated on the disputed portion of land and he and his family destroyed the crops. That action of the man infuriated me, and I retaliated which resulted in a conflict. He reported me to the police and I was arrested. Later on, the traditional authorities intervened and resolved the matter. Even though the case is over,

> I am carefully monitoring activities on the land. If that man or his cohort makes any attempt again to claim ownership of that portion of land again, it will be bloody.

Also, a Grune participant said that:

> There was a time I had a serious confrontation with a Fulani man in this village. He took possession of land my grandfather gave me. I told him to stop going to the land, but he insisted that he acquired the land. So, one day when I met him on that land, we fought and wounded each other and it became a big problem.

The resource and physical conflicts are sometimes perpetrated by the destruction of crops by migrating pastoralists' cattle, which in turn threatens the livelihood of Indigenous farming communities (Miguel et al., 2004). For instance, in northern Ghana, it emerged that when migrant-settlers are in distress and migrate to settle on 'Indigenous' lands, they are usually accepted with conditionalities in respect of land claims and management of resources. A Grune male participant at Bongo said that:

> When the Fulanis come in peace, we also accept them in peace. If they are in distress and they find themselves on our land, we will accept them and coexist as a people. But if they later decide to entrench themselves on the land and begin to claim ownership of where they are occupying, we will resist with our blood. If we sit aloof and watch, our forefathers will never forgive us, and our children and grandchildren will become aliens of our lands.

Similarly, a Dagomba male participant indicated that:

> Migrant-settlers cannot take our leniency to be our weakness. If a migrant-settler allows his/her livestock to destroy my farmland, that person will be calling for war. I will not sit down and allow a Fulani person from Burkina Faso to take over my land, which provides me and my family our source of livelihood. Some people have found themselves in such similar situations where they have become slaves on their lands, and that cannot happen here as long as I continue to live.

Also, a Dagaaba male participant said that:

> We accept everyone who comes to settle on our land for a good reason. Usually what happens here is that when migrant-settlers come to our land, the *tendanas* or *tengansob,* who are the ‘first comers’ in the village, give them a place to settle with some conditions. They are usually asked to be responsible for their activities in order not to incur the wrath of the people. Once, they comply with the rules, they can stay as long as they want. However, if the migrant-settlers begin to usurp farmlands or dispossess us of our ancestral lands, that will not be tolerated. We will definitely drive them away so that we can protect the lands for our children.

In the northern Ghanaian example, all three ethnic groups recognize that while migrant-settlers are allowed into their Indigenous territories, the newcomers are required to stay away from specific Indigenous lands, and must respect the initial occupants’ rights. Also, it is clear that Indigenous people can only tolerate actions of migrant-settlers up to a certain acceptable threshold. Beyond certain local tipping points, further actions of deliberate control and management of natural resources are met with resistance leading to injury and loss of lives and property (Lindroth & Sinevaara-Niskanen, 2014).

There is some evidence to suggest that such conflict is becoming more common across SSA. Conflict between the Kouka farmers and Kreda pastoralists in the Moito area of Central Africa led to the loss of lives of over 80 people in 2003 (Barume, 2017). Also in 2013, conflict between the Rizeigat and Bani Hussein tribes for territorial control in the Dafur region of Sudan led to the loss of lives of over 800 people (Berman et al., 2017). It is possible also to suggest that natural resource conflicts could increase in the coming years based on future climate change projections that suggest a depletion of the local resource base across much of SSA, which in turn is likely to generate an increasingly urgent need for individuals and communities to explore beyond their immediate places to seek adaptation opportunities (Burke et al., 2009).

Given the range of examples of the complexity of Indigeneity at both regional and national levels, classifying and identifying who has rights and responsibilities of ownership of land is very important, particularly in relation to natural resource management in Indigenous societies. Indigenous rights over resources, whether they are enshrined in law or not, could provide a *sui generis* framework for defining access and responsibilities over places and systems. In the northern

Ghanaian case, the *sui generis* system might suggest that any migrant-settlers are subjected to, or at least referencing, the rules and restrictions which are embedded in the cultural traditions and customs of Indigenous groups (Kameri-Mbote, 2003).

4.6 Criteria for characterizing Indigeneity for natural resource management in Africa

The increasing claims of Indigeneity by groups in many African countries are also playing an important role in generating solutions to potential conflicts through the application of community-based natural resource management (CBNRM), which provide opportunities for claims over land or other resources. For instance, in Zimbabwe, CBNRM projects such as the Communal Areas Management Programme for Indigenous Resources (CAMPFIRE) have not led to *de jur*e land rights, but rather ensured that direct financial and biodiversity benefits are directed to local communities through the exploitation of local wildlife (Taylor, 2009; Toledo, 2001). In another example, in Botswana, the CBNRM programme works through registered community trusts to facilitate rights to manage and benefit from wildlife resources within the Trust's defined area, but does not provide tenure rights over the land itself (Cassidy, 2021). However, in other African examples, local people have been marginalized through CBNRM. In countries such as Cameroon, Malawi, Democratic Republic of Congo and Central African Republic there have been instances where the rights of Indigenous groups have been neglected by NGOs and government institutions as control is formalized over natural resources (DeGeorges & Reilly, 2009; Kamoto et al., 2013).

In these latter cases, it is clear that claims to resources based on Indigeneity and traditional rights across Africa at different scales have the potential to increase conflicts. A range of examples were discussed in this paper where claims overlap or are de-legitimized; where development and population growth increases demand on limited resources; or, where climate change alters the availability or access to natural resources. To generate effective policy to manage such conflicts, it will be necessary to acknowledge the complexity of claims across different spatial scales. For instance, Indigenous claims are often based on common cultural attributes manifest within the same or similar ethnic groups, but those cultural norms and values may evolve separately over time. For instance, the Pygmies and Mbororo in Cameroon have common cultural attributes, yet those people are different Indigenous groups (Pelican, 2009). Beyond the unique features of culture, there are also other sub-features such as marginalization that also partly define Indigenous groups. For instance, the Ogoni people of Nigeria, West Africa, like many other ethnic groups in Africa witnessed various forms of marginalization in the pre-colonial period (Osaghae, 1995). Also, Indigenous people could either be a minority or majority group within a given culture, especially where there is a diversity of ethnic groups.

While we accept the complexities of the definitions of Indigeneity and that the different approaches to classification are all valid, they may need to be accurately identified to empower *sui generis* rights to resources across the continent (Duffy, 2008). A *sui generis* system would describe the uniqueness and differences within and between groups, providing an opportunity for strengthening the status of Indigenous communities and their contributions to equitable and sustainable natural resource management (Ekpere, 2004). In many cases, *sui generis* rights can help to guide claims over the same resource by different ethnic groups by enabling a range of niche forms of exploitation (Duffy, 2008). Successful resolutions can be facilitated in situations of potential conflict, as deliberations on unique resource rights enable different groups to clearly identify their particular resource niche, which may be distinct in time, space, or process. Thus, natural resource management policies that facilitate *sui generis* rights of access could both preserve group differences and help facilitate productive and peaceful relations, especially in relation to resource access and utilization (Barrow & Rotman, 1997). In fact, unique forms of resource access are becoming more important during a reflexive period, where diversity across societies is increasingly prized (Castree, 2004). However, for unique claims to support sustainable resource management, people working in or moving into a place would need to acknowledge any extant entrant rights frameworks that are *sui generis* or equally distinctive at regional or national scales.

It will become increasingly important to develop an approach where Indigeneity is understood according to the particular ways that people self-identify themselves at national and sub-national levels (Canessa, 2007). A greater emphasis could be placed on framing Indigeneity within specific, local socio-ecological systems whereby a group of people or ethnic group with common historical, cultural and ancestral heritage exercise traditional and environmental rights over a defined geographic space. Such a definitional standpoint would also reflect global conventions on Indigenous rights, which have supported claims by many Indigenous people, especially during periods of social transformation (Hodgson, 2002). For instance, the ILO's Convention on

Indigenous and tribal people provides the opportunity for many people to claim Indigenous status through self-identification (Yupsanis, 2010). Also, the United Nations Declaration of the Rights of Indigenous People enables a framework that protects Indigenous people's rights and create opportunities for their existence in a place (Barelli, 2015). Yet, if such international organizations are going to oversee more sophisticated and/or formal mechanisms to represent Indigeneity, examples from Africa are suggesting underlining complexities need to be unpacked. International institutions will need to increasingly work with national and regional stakeholders to consolidate resource tenure arrangements and policies based on *sui generis* legal systems that allow for unique local diversity. That process would also provide opportunities for Indigenous groups to represent their rights and deliberate on conflicting claims to natural resource management, particularly under changing climatic conditions (Berkes, 1999). Opportunities to discuss the control and management of natural resources have the potential to enhance local resilience, but will also generate forums for dealing with the unpredictable social, economic, ecological and environmental challenges that lie ahead (Matarrita-Cascante & Trejos, 2013).

4.7 Conclusion

This paper contributes to the existing literature by arguing that the various ways in which the concept of Indigeneity is defined are complex, fragile and heterogeneous at regional and national scales. Clearly Indigeneity plays a vital role in supporting claims to land and other natural resources across SSA, and is thus supporting many rural livelihoods. However, the complexity of different interpretations of Indigeneity, and the rights associated with those conceptions, generates inherent problems at different spatial scales that make any particular definition difficult to be accepted broadly by all people within a society. It could be argued that current criteria for characterizing Indigeneity in many SSA countries are insufficient, and that conceptual vagueness generates difficulties to utilize Indigeneity to help to ensure just resource allocation and management. Contextualizing the concept of Indigeneity within clearly defined local criteria could provide an opportunity to meaningfully facilitate understanding on the circumstances under which the concept is defined to make it generally acceptable as a guiding mechanism to frame resource management.

The ambiguities associated with the definitions of Indigeneity have increased problematic claims for lands and natural resources in SSA. Such uncertain claims are already resulting in controversial implications from simple misunderstandings to violent conflicts. But climate change is generating new demands across Africa, and the potential loss of natural resource quality or quantity is highly likely to exacerbate conflict. Therefore, developing understanding of the complexity of Indigeneity at the regional and national levels will be increasingly relevant for developing policies that are contextually unique for sustainable development. Mechanisms that evolve co-management agreements between and across Indigenous groups and state actors could offer important pathways for mitigating resource conflicts and promoting sustainable outcomes in an era of environmental change.

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CHAPTER 5: Integrating Local Perceptions with Scientific Evidence to Understand Climate Change Variability in Northern Ghana: A Mixed-methods Approach

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Abstract

The integration of local perceptions and scientific evidence is important for developing comprehensive understandings of the complexities of climate change in sub-Saharan Africa (SSA). However, the literature on climate change and variability (CCV) trends for the region has largely focused on either local or scientific knowledge with less insight into their integration. Responding to this lacuna, a mixed-method approach with an integral theoretical lens was applied to understand farmers' perceptions of CCV in comparison with published meteorological data in northern Ghana. Results from the surveys, focus group discussions and interviews show that respondents perceive of increased temperatures, decreased rainfall, seasonal changes and extreme climate events, but those perceptions are spatially differentiated. Published average rainfall trends were found to be inconsistent with perceived reductions in rainfall. In contrast, perceived high temperatures were consistent with average meteorological data. Sophisticated understandings of both local and scientific knowledge systems inform decision-makers about the real lived experiences of CCV. Covariates such as location, place attachment, indigenous knowledge use and demographic characteristics of respondents influence perceptions of CCV. This study suggests that scientists and decision-makers should consider a blended approach that integrates local perceptions with scientific evidence in order to develop robust and sustainable adaptation policies.

5.1 Introduction

Global climate change and variability (CCV) is underway, and understanding people's perceptions of that change will be very important for effective adaptation planning and practice (Hasan & Kumar, 2019; Imran et al., 2018; Niang et al., 2014). Observed changes are escalating rapidly in the 21st century, and more dramatic manifestations and extremes are projected for the coming decades (Inter-governmental Panel on Climate Change [IPCC], 2014). With some variation, global surface air temperature trends have been increasing for over hundred years (Apuri et al., 2018). The observed warming trends and rising global surface temperatures have been attributed to increasing concentrations of atmospheric greenhouse gases, particularly carbon dioxide (IPCC, 2018). It is projected that future global warming will intensify with global mean surface air temperatures likely to continue to warm and exceed 2^{o}C above pre-industrial temperatures (IPCC, 2018). For instance, temperatures in many parts of sub-Saharan Africa (SSA) are expected to increase by an average of between 2.0 and 4.5^{o}C in the 21st century (Niang et al., 2014). CCV includes changes to precipitation and surface water regimes, but those changes are particularly uneven and unpredictable, leading to significant spatial and temporal variation across SSA (Arnell, 2004; Kotir, 2011; Serdeczny et al., 2017). Apart from temperature and rainfall, increasing seasonal variation and extreme events such as droughts, floods, rain storms, harmattan winds, and heatwaves are impacting many developing countries, and particularly SSA (Atampugre et al., 2019; Dapilah & Nielsen, 2019; Wetende et al., 2018).

The manifestation of CCV is threatening agricultural systems and human communities directly and indirectly, leading to new challenges for food security and constraints on sustainable development (IPCC, 2014; Wossen & Berger, 2015). The more dire projected consequences of CCV are regionally disproportionate. Global southern countries, and in SSA and the Sahel in particular, are suggested to be more exposed due to climatic patterns, and sensitive due to ongoing challenges with poverty, the reliance on agriculture and low levels of technology (Antwi-Agyei et al., 2017; Ayal & Filho, 2017; Shiferaw et al., 2014; Sissoko et al., 2011). Within the agricultural sector, Indigenous, smallholder farmers are regarded as both being particularly highly exposed and sensitive to CCV risks, which in turn will have major negative impacts on socio-ecological systems and livelihoods (Bardsley & Wiseman, 2012; Cohn et al., 2017; Gollin, 2014; Morton, 2007).

Particularly in the Sahel of northern Ghana, smallholder farmers are experiencing a double tragedy of agricultural vulnerability to long-term climatic trends and extreme climatic events (Derbile et al., 2016). The uncertainty inherent in rainfall regimes and extreme climate events are compromising food security, especially for rural communities in more marginal rural areas such as the Sahel drylands, where agriculture is the main livelihood activity (Moroda et al., 2018; Wossen & Berger, 2015). Severe droughts and high temperature and rainfall variabilities are particularly impacting upon agricultural systems in northern savanna region of Ghana, where dryland or rainfed agriculture dominates (Owusu et al., 2021). Low agricultural productivity, post-harvest losses and high levels of poverty are intensifying food insecurity in northern Ghana, with 20 to 37% of the population being moderately or severely food insecure and stunting rates in children under five years ranging between 14 to 33% (World Food Program [WFP] USA, 2021; WFP, 2012). The situation of food insecurity in northern Ghana is likely to become more precarious as global, regional and local climate change increase (Owusu et al., 2021), especially as rainfed cropping systems become increasingly untenable, and marginal communities transition into animal husbandry such as is already widespread in the semi-arid northern Sahel.

Considering the current and projected impacts of CCV on already vulnerable socio-ecological systems, researchers are arguing that comprehensive analyses are required to understand the complexity of impacts through an integration of knowledge from local perceptions and scientific observations (Alexander et al., 2011; Brown, 2002; Pelling, 2010; Shrestha et al., 2019). This will be important for a range of reasons, but vitally, knowledge integration assists farmers in developing countries to adapt to long-term trends in resource availability and build resilience against CCV risks such as extreme events, food insecurity and poverty, by ensuring that abstract and generalised information can be made directly relevant for their particular situations (Alkon & Agyeman, 2011; Folke et al., 2010). Moreover, the integration of knowledge can generate understanding from different perspectives through the enforced complementarity of varied epistemological standpoints (Dakurah, 2020). Especially in countries of SSA, where high-quality meteorological data are limited or unavailable for many people, local perceptions can be relied upon to assist understanding of the dynamic changes in local climate, especially in the context of local cultures and behaviours (Alexander et al., 2011; Roco et al., 2015).

According to Ado et al. (2019), local perceptions provide especially important baseline information for understanding local exposure to climate risks, which are essential for effective policy formulation and implementation to address the direct and indirect risks of CCV. Patt and Schröter (2008) argue that, climate change adaptation policies cannot be fully materialised unless the perspectives of beneficiaries of the policies are taken into account. Importantly however, Krishna Bahadur et al. (2020) argue that a reliance on subjective perception data alone could limit the reliability of information obtained due to local subjectivities and heuristic biases, hence, the need to integrate such data with objective scientific evidence. Yet, scholarship addressing the integration of differing knowledge systems, particularly local and scientific knowledges to CCV understandings remain limited in SSA (e.g. Ayanlade et al., 2017; Dakurah, 2020; De Longueville et al., 2020; Moyo et al., 2012; Simelton et al., 2013).

While most studies continue to focus on the scientific analysis of historical data of climate variables, particularly temperature and rainfall (e.g. Addisu et al., 2015; Asare-Nuamah & Botchway, 2019; MacKellar et al. 2014; Mengistu et al. 2014), researchers globally are contributing to the understanding of the complexity of local perceptions of CCV (e.g. Ajuang et al., 2016; Lee et al., 2015; Mamba, 2016; Owusu et al., 2019; Roco et al., 2015). For instance, Crona et al. (2013) compared public perceptions of climate change across different national contexts (Australia, Ecuador, Fiji, New Zealand, UK and US) and found that people shared common perceptions about climate change such as temperature and rainfall, especially those with higher education levels. Similarly, Limantol et al. (2016) examined farmers' perceptions of climate variability and change in the Vea catchment in Ghana and found that many farmers perceived declining intensity, duration and amounts of rainfall. However, such studies offer little insight into understanding the integration of local perceptions with meteorological evidence to address the complexity of climate change. In fact, the majority of recent studies that integrate local perceptions with scientific records (e.g. Amadou et al., 2015; Hasan & Kumar, 2019; Imran et al., 2018; Shrestha et al., 2019) provide limited understanding of how perceptions of climate change vary across different locations. Such spatial variations are important in geographic research to understand local human-environment relationships and regional imbalances (Wei, 2015).

Given the increasing understanding that effective adaptation depends on the integration of scientific and local knowledge systems (Dickinson et al., 2017; Kuivanen et al., 2016; Niles &

Mueller, 2016; Simelton et al., 2013), this study integrates farm-households' perceptions with historical scientific evidence to understand the complexity of CCV using quantitative and qualitative approaches in the semi-arid region of northern Ghana. By drawing evidence from three districts across different regions, the research addresses current knowledge gaps by firstly, examining how CCV is perceived by local farm-households; secondly, analysing the potential influence of location, demographic variables, place attachment and indigenous knowledge use on farm-households' perceptions of CCV; thirdly, analysing annual averages of long-term temperature and rainfall data (1969-2018) to corroborate local perceptions of climatic change; and fourthly, comparing farm-households' perceptions of CCV with available scientific evidence. By addressing these elements, the analysis contributes to the emerging field on the importance of the integration of farmers' perceptions with meteorological evidence to enhance understandings of CCV (Ayanlade et al., 2017; Asare-Nuamah & Botchway, 2019).

5.2 Study context

The research was conducted in Ghana, located in the Western part of Africa. (Figure 5.1). The total land area size of Ghana is about 239,460 kilometers square, with a water area of about 8520 kilometers square (Ghana Statistical Service [GSS], 2012). The total population of Ghana is estimated at 24 million, with an intercensal growth rate of 2.5% (GSS, 2012). About 80% of the economically active population in northern Ghana engage in rain-fed agriculture (Aniah et al., 2019). The study sites include the Nandom, Savelugu and Bongo districts in the Upper West, Upper East and Northern regions of northern Ghana respectively. The districts were selected because of evidence of high vulnerability to CCV risks within a semi-arid region that typifies the challenges of intensive smallholding agriculture and rurality within the Sahel (Antwi-Agyei et al., 2015; Atampugre et al., 2019; Lente, 2017).

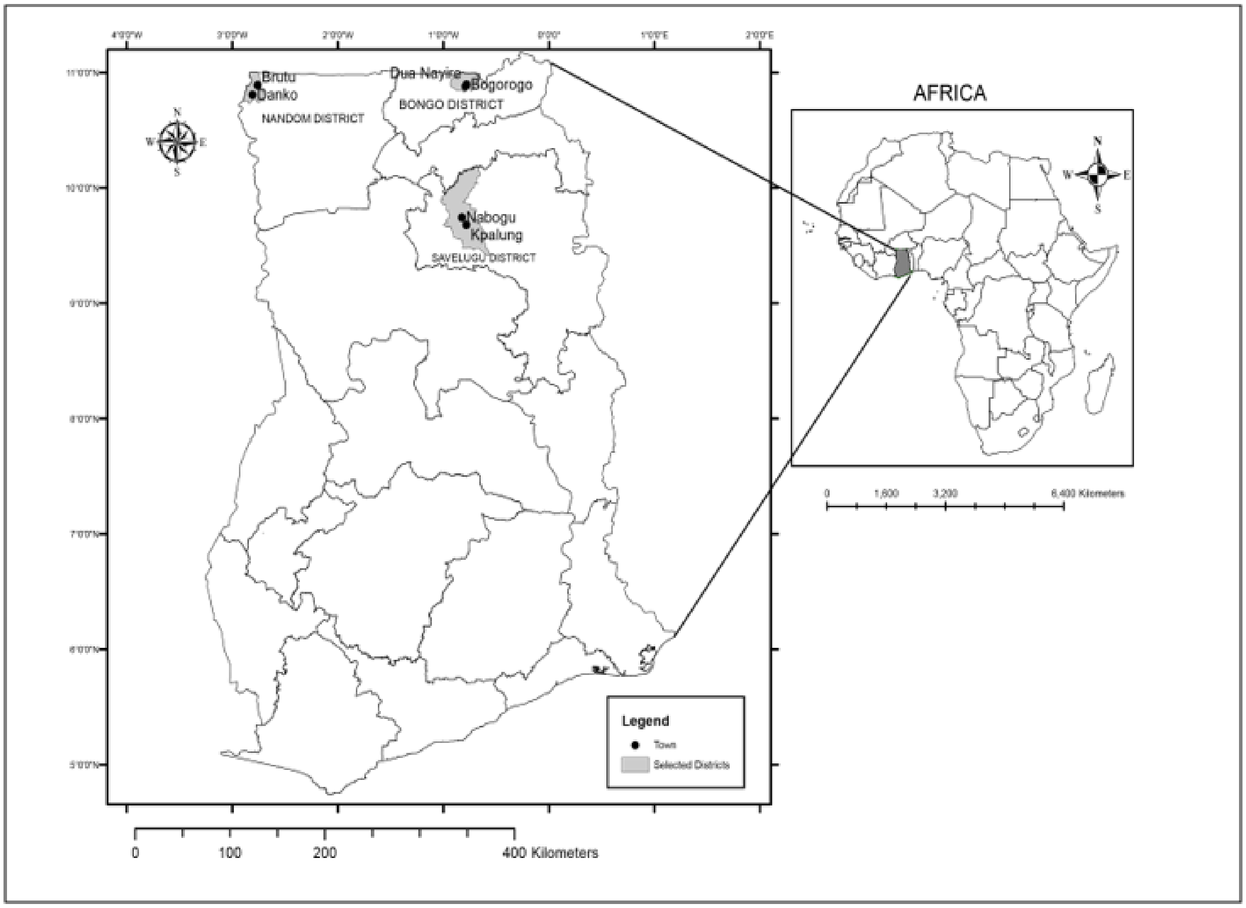

Figure 5.1: Location of the study sites in northern Ghana

Northern Ghana's climate is strongly influenced by trade winds and monsoon air masses originating from the Sahara Desert and the Atlantic Ocean respectively (Dickson et al., 1988). Rainfall distribution in northern Ghana is defined by the rainy and dry seasons with some spatial variation across districts. The rainy season largely begins in May and stretches to October while the dry season starts in November and ends in April (WFP, 2012). The rainfall regime in northern Ghana is monomodal which provides the opportunity for rainfed agriculture even though annual rainfall is low. The temperature distribution of monthly maximum temperatures averaged in the last five decades (1969-2018). Northern Ghana experiences higher temperatures in the dry season than in the rainy season with an average of 26.1^{o}C (Ahmed et al. 2016). Maximum temperatures peak in the dry season from November and April, with the lowest minimum temperatures in the rainy season (Asare-Nuamah & Botchway, 2019).

Major crops cultivated in northern Ghana include maize, millet, sorghum, rice, groundnuts, vegetables and shea nuts (WFP, 2012). Livestock husbandry is also an important livelihood activity, with many northern Ghanaian households integrating cattle, sheep, goat and poultry with crop farming. However, these agricultural systems have been under serious threat due to prolonged drought and other climate trends and extremes (Kuivanen et al., 2016). Therefore, addressing climate change risks, particularly droughts will be important for many agricultural farmers in northern Ghana.

5.3 Materials and methods

Primary data were collected using a mixed-methods approach. A sequential approach was employed, with a more exploratory quantitative phase taking place prior to a more detailed, qualitative explanatory phase (Creswell, 2013). The research methods employed were a household survey, focus group discussions (FGDs) and expert interviews. Integral theory draws knowledge from different subjective and objective perspectives to understand environmental issues (O'Brien, 2012). By analysing the resulting primary with scientific data through an integral theoretical lens, the opportunity was provided to generate deep understanding of the complexity of local and regional CCV from different epistemological perspectives (Creswell, 2013). The units of analyses were farm-household heads, lead farmers, agriculture extension agents and community leaders. Survey participants were systematically sampled while expert interviewees and FGD participants were purposively selected based on depth of knowledge of CCV and their associated local impacts. A total of 299 questionnaires were administered to farming-household heads (out of 1181 total households) in the study districts. Proportionally, 131 (out of 515 households), 81 (out of 321 households) and 87 (out of 345 households) participants at Bongo, Savelugu and Nandom districts respectively were involved in the study. The sample size (299) was obtained using the model:

$$n = N/1+N(\alpha^2) \qquad (1)$$

where 'n' is the sample size of the study, 'N' represents the total population and 'α' is the precision level which was set at 5%. Prior to the data collection, ethics approval (H-2019-058) was obtained from the Office of Research Ethics Compliance and Integrity at the University of Adelaide, Australia.

As well as socio-demographic household contextual information, participants were asked about their perceptions of temperature and rainfall changes, perception of seasonal climatic changes and extreme events. An earlier reconnaissance trip in the district helped to identify the important perception indicators for the study. A three-point Likert scale of "Disagree", "Neutral" and "Agree" was used to assess the level of agreement or disagreement of the perception variables (Likert, 1932). Prior to the actual survey, the questionnaires were pre-tested for internal consistency (Cronbach, 1984). The data were gathered within four (4) months (September-December, 2019) in the three selected districts in separate regions of northern Ghana. The survey interviews lasted between 45 and 60 minutes.

Subsequent to the survey, twelve separate focus groups involving a total of 60 participants and 24 expert interviews involving 12 agricultural extension officers and 12 community leaders, were undertaken. While English was occasionally used to interview participants who could speak and understand the language, the majority of data collection was conducted in local dialects (*Dagaare, Gurune and Dagbani*) with the help of local field assistance. The secondary data for the study is historical meteorological data obtained from district synoptic weather centers of the Ghana Meteorological Agency (GMet). The datasets included annual rainfall and temperature (maximum and minimum) data over the last five decades (1969-2018). Rainfall and temperature were used as key variables for CCV analysis because they are widely used as the key indicators undertaking CCV analysis (Abbam et al., 2018; Kabo-Bah et al., 2016). The two datasets (primary and secondary) were triangulated to build a deeper understanding of the complementarities of local perceptions and scientific evidence under CCV context.

The survey data were analysed quantitatively using IBM SPSS software package version 21 (Pallant, 2013). Descriptive tools such as frequency and percentage were employed to represent respondents' perceptions and of CCV. A Kruskal-Wallis test was applied to determine spatial variations in terms of responses. Also, a binary logistic model was utilised to ascertain the influence of respondents' demographics, place attachment and indigenous status on their perceptions about CCV. The logit model is expressed as:

$$\log\left(\frac{P}{1-P}\right) = \beta_0 + \beta_1 X_1 + \beta_1 X_2 + \beta_k X_{ik} \ldots \qquad (2)$$

Where i is the i^{th} observation; P_i indicates the predicted probability of perception coded as a dummy variable with 1' represented those who perceived CCV while '0' represented those who did not perceive such changes (1- P_i); β_0 represents the intercept term with β_1, β_2 and β_k indicating the coefficients of the explanatories (X_1, X_2 and X_k); and (P_i / 1- P_i) refers to the odds ratio. The explanatory variables were selected based on CCV and perception literature. Based on a critical analysis of the literature, factors such as age (e.g. Ayal & Filho, 2017), educational level (e.g. Lee et al., 2015), gender (Kisauzi et al., 2012), wealth status (Deressa et al., 2011), marital status (Habtemariam et al., 2016), indigenous knowledge use (e.g. Vedwan, 2006) and place attachment (e.g. Shrestha et al. 2019) are hypothesised to positively or negatively influence local perceptions of CCV in the different locations in the SSA, and beyond.

Qualitative data collected from the FGDs and expert interviews were analysed thematically (Braun & Clarke, 2013). The recorded voices were transcribed from respondents' local dialects (*Dagaare, Gurune and Dagomba*) to English with the help of local language transcription experts. Emerging themes were categorised and linked together to generate a structure to support the quantitative results using direct quotations.

The meteorological data (temperature and rainfall) were analysed to determine trends for the last five decades (1969-2018) using the Mann-Kendall (MK) test statistics with the aid of Addinsoft's XLSTAT software version 2020. The Mann-Kendall test is robust in detecting monotonic trends of non-normally distributed data (Chepkoech et al., 2018). Also, the non-parametric Sen's slope estimator was used to measure and indicate the magnitude and direction (positive or negative) of the trend. The significance of the trends was determined at 1% error margin and 99% confidence level. The quantitative meteorological data were triangulated with the quantitative results to allow for the comparison of local perceptions of climate to measured CCV.

5.4 Results

5.4.1 Respondents' socio-demographic profile

The socio-demographics of smallholder respondents from the three selected study districts were described (Table 5.1).

Table 5.1: Socio-demographics of respondents

Socio-demographics	Nandom N= 81	Savelugu N= 87	Bongo N= 131	Total N= 299
Gender				
Male	63(21.1)	77(25.8)	80(26.8)	220(73.6)
Female	18(6.0)	10(3.3)	51(17.1)	79(26.4)
Age				
18-24	8(2.7)	7(2.3)	5(1.7)	20(6.7)
25-35	13(4.3)	17(5.7)	28(9.4)	58(19.4)
36-45	22(7.4)	26(8.7)	29(9.7)	77(25.8)
46-55	20(6.7)	23(7.7)	18(6.0)	61(20.4)
56-65	9(3.0)	6(2.0)	39(13.0)	54(18.1)
>65	9(3.0)	8(2.7)	12(4.0)	29(9.7)
Education				
No education	34(11.4)	49(16.4)	80(26.8)	163(54.5)
Basic	30(10.0)	31(10.4)	35(11.7)	96(32.1)
Sec/Tech	11(3.7)	2(0.7)	9(3.0)	22(7.4)
Tertiary	6(2.0)	5(1.7)	7(2.3)	18(6.0)
Marital Status				
Single	14(4.7)	12(4.0)	6(2.0)	32(10.7)
Married	58(19.4)	74(24.7)	108(36.1)	240(80.3)
Divorce/Separated	5(1.7)	0(0.0)	4(1.3)	9(3.0)
Widowed	4(1.3)	1(0.3)	13(4.3)	18(6.0)
Income: Cedi (USD)				
<500 (<87)	16(5.4)	32(10.8)	41(13.8)	89(30.0)
500-1000 (87-174)	11(3.7)	38(12.8)	81(27.3)	130(43.8)
1001-1500 (174-300)	16(5.4)	4(1.3)	8(2.7)	28(9.4)
1501-2000 (300-346)	12(4.0)	4(1.3)	1(0.3)	17(5.6)
>2000 (>346)	26(8.8)	7(2.4)	0(0.0)	33(11.2)
Household Size				
1-3	20(6.7)	15(5.0)	19(6.4)	54(18.1)
4-7	32(10.7)	13(4.3)	60(20.1)	105(35.1)
8-11	19(6.4)	17(5.7)	44(14.7)	80(26.8)
>11	10(3.3)	42(14.0)	8(2.7)	60(20.1)
Size of farmland (ha)				
<2	43(14.4)	26(8.7)	86(28.8)	155(51.8)
2-3	22(7.4)	24(8.0)	42(14.0)	88(29.4)
4-5	16(5.4)	14(4.7)	3(1.0)	33(11.0)
6-7	0(0.0)	6(2.0)	0(0.0)	6(2.0)
>7	0(0.0)	17(5.7)	0(0.0)	17(5.7)

The majority of the respondents (73.6%) were males, which reflects the fact that the majority of household heads in northern Ghana are males (GSS, 2012). The age differentials of respondents show that a large proportion (65.6%) were within a middle, economically active age group of 25-

55 years, and the majority (80.3%) were married. Most (54.5%) of the smallholders had no formal education, which in itself could be an important barrier to both climate information access (e.g. from technical sources or mass media) and the adaptive capacities of farmers (Ndamani & Watanabe, 2016). The average income of a large proportion of respondents (43.8%) was between ¢500-1000 ($86 and $172), which is far below the national average annual per capita income of ¢5347 ($919) (GSS, 2014). Over 51.8% of the respondents had less than 2 hectares of farmland and a large proportion (35.1%) had a household size of 4 to 7 inhabitants. The area of small holdings was similar across the three districts, and could be attributed to the fragmentation of land in northern Ghana (Kuivanen et al., 2016). While large household sizes provide labour opportunities in the study area, they also suggest a large number of people dependent on household livelihoods from small holdings of land.

5.4.2 Perceptions of temperature changes

Almost all respondents perceived of temperature and rainfall changes (Table 4.2). Increased average maximum temperatures were perceived by majority of respondents (89%) in all the study districts (Table 2). Spatially, there was a statistically significant difference ($p < 0.05$) between respondents who perceived of increased temperatures in the districts of Nandom (91.3%), Savelugu (95.4%) and Bongo (83.2%). Nevertheless, 11% of the 299 total respondents disagreed with that perception. In relation to minimum temperatures, the majority of farm-households (80%) generally perceived of increased minimum temperatures with spatial distributions of 85.2%, 87.3% and 71.8% in the Nandom, Savelugu and Bongo districts respectively.

Many participants in the FGDs agreed that they had experienced increased temperatures over the last couple of decades. For instance, a 56-year male participant at Nandom had this to say:

> In the olden days, day and night temperatures were not as high as we are experiencing nowadays. We used to experience high temperatures in the dry season, but now we are in the rainy season and you cannot even imagine the heat (FGD, 2019).

A similar experience was reported by a 70-year female participant at Savelugu:

> "Day and night temperatures as well as temperatures in the rainy and dry seasons have intensified in recent years. In the day time, it is difficult to walk through the sun and in the night the rooms become very warm" (FGD, 2019).

A 69-year female participant at Bongo had a particular reflection on the heat, stating that:

> The rate of increasing temperatures has been very rapid. Now the sun rises with very high intensity. We now feel the scorching of the sun very early in the morning- a situation which was never the case in those days. Sometimes, it is very difficult to even describe the extreme nature of the temperature. The heat from the sun mostly continues for a longer period of time before it subsides (FGD, 2019).

5.4.3 Perceptions of rainfall changes

About 75.3% of respondents perceived that annual rainfall had decreased (Table 5.2), although again there were some statistically significant differences ($p < 0.05$) in respondents' responses across the study districts. For instance, a larger group of respondents in Savelugu (87.4%) perceived of decreased rainfall than those in Nandom (71.6%) and Bongo (69.4%).

Table 5.2: Perceptions of rainfall and temperature

Perception indicator	Nandom N= 81	Savelugu N= 87	Bongo N= 131	Total N= 299	p-value
Decreased rainfall					
Disagree	23(7.7)	11(3.6)	30(10.0)	64(21.3)	0.00**
Neutral	0(0.0)	0(0.0)	10(3.3)	10(3.3)	
Agree	58(19.4)	76(25.4)	91(30.5)	225(75.3)	
Increased maximum temperature					
Disagree	7(2.3)	4(1.3)	14(4.6)	25(8.2)	0.03**
Neutral	0(0.0)	0(0.0)	8(2.7)	8(2.7)	
Agree	74(24.7)	83(27.8)	109(36.5)	266(89)	
Increased minimum temperature					
Disagree	12(4.0)	11(3.7)	26(8.7)	49(16.4)	0.40
Neutral	0(0.0)	0(0.0)	11(3.4)	11(3.7)	
Agree	69(23.1)	76(25.5)	94(31.4)	239(80)	

** mean significant at 0.05

Similar observations regarding rainfall trends were made during the FGDs and expert interviews. For instance, a 55-year female participant at Nandom stated that:

> I have observed that the rains don’t fall like they used to, especially in the dry season. The amount of rainfall in the dry season has reduced considerably in recent years compared to 50 years ago. During the rainy season where regular rainfall is expected, it rains two or three days and stops for some time before it rains again. Sometimes, the rain stops for a whole month and suddenly falls torrentially on a particular day (FGD, 2019).

Similarly, a 50-year male participant at Bongo said that:

> Generally, rainfall amounts continuously to decrease, especially in the dry season. The rains are not falling as they used to 40 years ago when I was a kid. In recent years, it rains for a shorter duration and the amount is not that much as compared to the olden days (Interview, 2019).

However, an agricultural extension agent at Bongo was of the view that rainfall had intensified in recent years, especially during the rainy season. As observed by an agricultural agent in one of the communities

> I think the amounts of rainfall these days are not as much as twenty years ago. However, what I have observed over the years is that the intensity of the rainfall has intensified with more destructive effects, especially during the peak of the rainy season (September-October) (Interview, 2019).

5.4.4 Perceptions of seasonal climatic changes

The study further assessed perceptions of some specific seasonal changes in the study districts (Table 5.3). From the survey, 91.9% of the household heads generally agreed that the seasonal rainfall regime had become erratic. There was a significant difference ($p < 0.05$) in such perceptions across the study districts, as a larger proportion of respondents in Savelugu (96.6%) agreed that rainfall was becoming more erratic, followed by Bongo (94.7%) and Nandom (82.7%).

Table 5.3: Perceptions of seasonal climatic changes

Perception indicator	Nandom N= 81	Savelugu N= 87	Bongo N= 131	Total N= 299	p-value
Erratic rainfall					
Disagree	9(3.0)	3(1.0)	7(2.3)	19(6.3)	0.00**
Neutral	5(1.7)	0(0.0)	0(0.0)	5(1.7)	
Agree	67(22.4)	84(28.1)	124(41.4)	275(91.9)	
Late onset of rainy season					
Disagree	3(1.0)	5(1.7)	6(2.0)	14(4.7)	0.92
Neutral	4(1.3)	1(0.3)	1(0.3)	6(2.0)	
Agree	74(24.8)	81(27.1)	124(41.4)	279(93.3)	
Early ceasing of rainy season					
Disagree	4(1.3)	25(8.4)	23(7.7)	52(17.4)	0.00**
Neutral	6(2.0)	0(0.0)	5(1.7)	11(3.7)	
Agree	71(23.8)	62(20.8)	103(34.5)	236(79.1)	

** mean significant at 0.05

FGD and interview respondents had similar perceptions of erratic rainfall. For instance, a 74-year male participant at Savelugu observed that:

> The rainfall has been on and off in recent times. It used not to be the case in the prior three to four decades. The time we expect the rains to come for us to plant doesn't happen any longer. The rain doesn't come at the right time for us to plant. However, in the sixth or seventh month the rain will come very heavily such that the soil will be socked and if you plant the seed, germination becomes a problem (FGD, 2019).

Also, a large group of surveyed respondents (93.3%) perceived that there was a late onset of the rainy season, with similar findings in Bongo (94.6%), Savelugu (93.1%) and Nandom (91.4%). Coupled with the late arrival of the rains, a majority of respondents (79.1%) observed the more regular, early termination of the rainy season. This observation varied significantly ($p < 0.05$) across the study districts with a large group of respondents at Nandom (87.7%) perceiving an early termination of the rainy season, than Bongo (78.6%) and Savelugu (71.3%).

Particularly, there were growing concerns amongst respondents in FGDs and interviews about the late onset and early termination of rainfall. A 72-year female participant at Nandom stated that:

> The rainfall season starts late nowadays and ceases very early. In recent years there has been a shift of the rainy season from April to June and early ceasing from November to October. This has reduced the days of our planting season, making us alter the entire cropping calendar (FGD, 2019).

Similarly, a traditional community leader at Nandom in an interview in one of the villages indicated that:

> Our farmers, including myself, have had to change our cropping calendar and system in recent years. We are doing so because of the late start and early cessation of the rainy season. We now face uncertainties in predicting when to start planting our crops (Interview, 2019).

5.4.5 Perceptions of extreme climate events

Most respondents agreed that they were experiencing more extreme climate events in their districts (Table 5.4). A large majority of respondents (92.7%) perceived of more prolonged and/or severe droughts across the study districts, with similar perceptions in Bongo (90.8%), Nandom (93.8%) and Savelugu (94.2%).

Table 5.4: Perceptions of extreme climate events

Perception indicator	Nandom N= 81	Savelugu N= 87	Bongo N= 131	Total N= 299	p-value
Prolonged and severe droughts					
Disagree	0(0.0)	5(1.7)	5(1.7)	10(3.2)	0.48
Neutral	5(1.7)	0(0.0)	7(2.3)	12(4.0)	
Agree	57(19.1)	82(27.5)	119(39.8)	277(92.7)	
Frequent flood events					
Disagree	29(9.7)	4(1.3)	21(7.0)	54(18.0)	0.00**
Neutral	11(3.7)	6(2.0)	15(5.0)	32(10.7)	
Agree	41(13.7)	77(25.8)	95(31.8)	213(71.3)	
Frequent wildfires					
Disagree	7(2.4)	9(3.0)	13(4.4)	29(9.8)	0.97
Neutral	0(0.0)	0(0.0)	7(2.3)	7(2.3)	
Agree	74(24.7)	78(26.1)	111(37.2)	263(88.0)	
Severe rainstorms					
Disagree	14(4.7)	25(8.3)	13(4.3)	52(17.3)	0.00**
Neutral	13(4.3)	7(2.3)	15(5.0)	35(11.6)	
Agree	54(18.0)	55(18.4)	103(34.5)	212(70.9)	

Severe harmattan					
Disagree	15(5.0)	3(1.0)	9(3.0)	27(9.0)	0.04**
Neutral	2(0.7)	4(1.3)	18(6.0)	24(8.0)	
Agree	24(8.0)	80(26.8)	104(34.8)	248(83.0)	
Intensified heatwaves					
Disagree	19(6.3)	16(5.3)	60(20.0)	95(31.6)	0.00**
Neutral	0(0.0)	1(0.3)	23(7.7)	24(8.0)	
Agree	62(20.8)	70(23.4)	48(16.7)	180(60.3)	

** mean significant at 0.05

The general perception of droughts across the study districts could be explained by the manifestation and impacts of high temperatures and evapotranspiration and more variable rainfall, which increasingly characterises the regions of northern Ghana (Yaro & Tsikata, 2013). A 59-year male participant at Savelugu in one of the discussions indicated that:

> There has been long period of drought. The droughts we experience these days have intensified with high frequency and severity making it literally impossible for crop and livestock farmers to cope. In fact, the patterns of droughts have changed remarkably in the last 50 years. I have observed that the droughts are no longer occurring the time they used to occur. The *birigu sansali* (sowing droughts) have shifted forward while the *kpagla sansali* (flowering droughts) have shifted backwards. The early shedding of leaves of the *Sinsaba* and *kparega* trees indicate the extreme and severe nature of droughts in this community (FGD, 2019).

Frequent floods were perceived by a majority of respondents (71.3%), but that perception varied spatially, with significantly greater perceptions ($p < 0.05$) in Savelugu (88.8%) than Bongo (72.5%) and Nandom (50.6%). More frequent wildfires were perceived among a majority of respondents (88%) across the districts, with Nandom (91.3%), Savelugu (89.7%) and Bongo (84.7%).

These quantitative findings of extreme events were supported during discussions. For instance, at Savelugu a 79-year male participant said that:

> Floods are more frequent in the rainy season with severe impacts. Even though we used to experience floods in this community some years back, what we are experiencing now is an extreme case where the floods could engulf an entire

> building without seeing the roof. The situation becomes more severe when the Bagri Dam is opened upstream in Burkina Faso. During the peak of the rainy season in August, there are high incidences of floods in many communities in the district. The few and narrow drainage systems in the communities are unable to cope with the large amounts of the running water with its inherent high velocity making it more destructive (FGD, 2019).

Harmattan winds were found to be severe in all the study districts as well. Though a majority of respondents (83%) generally perceived severe harmattan winds in northern Ghana, the level of perception varied significantly ($p < 0.05$) across the districts, Savelugu (92%), Bongo (79.4%) and Nandom (79%). A 60-year female participant at Nandom noted that:

> The harmattan winds have become very severe in recent years with more dryness and dustiness. Before the year 1980s, the harmattan was normal and many children could even walk bare chested, but now children cannot do that because of the severity of the harmattan winds. The winds have become so severe that if you don't cover yourself well you may get pneumonia. Also, in those days, the harmattan winds were not strong as compared to what we are experiencing in recent years. I also think in recent years, the harmattan winds develop earlier than some years ago. Now, we sometimes experience the harmattan winds as early as October (FGD, 2019).

According to 60.3 percent of majority of respondents, heatwaves were intensifying in northern Ghana, with statistically significant ($p < 0.05$) variation across the study districts, Savelugu (80.5%) followed by Nandom (76.6%) and Bongo (36.7%). Globally, higher temperatures are suggested as one of the factors accounting for the extreme heatwaves experienced in many Sahelian countries of SSA (Barbier et al., 2017). Participants in the FGDs perceived similar developments, and at Bongo a 66-year female participant explained that:

> The heat that accompanies the harmattan winds is sometimes indescribable. The winds are so hot in the dry season when temperatures are very high. During this period, it becomes very difficult to go about our daily activities in the communities (FGD, 2019).

A large proportion of respondents (70.9%) perceived that severe rainstorms were coming more regularly in their locality, with similar responses in all the districts, Bongo (78.6%), Nandom (66.6%) and Savelugu (63.2%). Respondents were concerned about the impacts of rainstorm on their agricultural activities, including the loss of fertilisers after their application. A 66-year female participant at Savelugu reported that:

> I don't think I have ever experienced last night's rainstorm before, since I was born. It was very severe and devastating. Our crops were doing very well but the rainstorm destroyed them, especially the grains such as millet, sorghum and maize. You look at how the millet you see over there has been brought down by the rainstorm. Another sad thing is that sometimes you apply fertiliser and after a few hours it rains heavily and everything is washed away. This usually affects our crop yield (FGD, 2019).

Similarly, a 71-year male interviewee at Nandom had this to say:

> My brother, the recent rainstorm we experienced over the last three days was unprecedented. I thought that was going to be the end of the world. The rainstorm destroyed everything I cultivated including the maize, millet and sorghum (Interview, 2019).

5.4.6 Factors predicting perceptions of climate change variability

Major predictors of perceptions were examined using binary logistic regression analysis. Respondent perceptions of CCV were influenced by age, educational level, wealth status, place attachment and indigenous status (Table 5.5). Specifically, the results show that older household heads were more likely to perceive of CCV than younger respondents, perhaps because older respondents are more familiar and experienced in observing and understanding the manifestations of long-term changes in the local climate (Ayal & Filho, 2017). The coefficient for the educational level was also positive and statistically significant ($p < 0.05$) suggesting that respondents with high educational levels were more likely to perceive CCV.

Table 5.5: Results of binary logistic regression predicting perceptions of climate change and variability

Variable	Perception of climate change				
	Coefficients (β)	Standard error (SE)	Odds ratio Exp(B)	95 % Confidence Interval (CI)	Sig. (*p*)
Age	1.59	0.549	0.21	0.07 - 0.60	0.00**
Gender	-0.05	0.48	0.95	0.37 - 2.42	0.91
Income	0.08	0.150	1.08	0.80 – 1.45	0.15
Education level	2.02	0.520	0.13	0.05 - 0.37	0.00**
Marital status	-0.39	0.575	0.68	0.22 - 2.09	0.50
Wealth	1.45	0.622	0.23	0.07 - 0.79	0.02**
Place attachment	1.15	0.428	0.32	0.14 - 0.73	0.01**
Indigenous knowledge use	1.22	0.468	3.38	1.35 - 8.46	0.01**
Omnibus Test of Model Coefficients (P < 0.05)					
Cox and Snell R Square = .133					
Nagelkerke R Square = .259					
-2 Log likelihood = 173.066					

** mean significant at 0.05

Wealthier respondents were significantly ($p < 0.05$) more likely to perceive of CCV than their poorer counterparts. The study also found place attachment (defined by length of stay of a place) and Indigenous knowledge use of respondents both significantly ($p < 0.05$) influence their perceptions of CCV. Respondents who had greater place attachment and made greater use of their indigenous knowledge were more likely to perceive CCV, which are particularly important in informing their decisions to implement appropriate adaptation strategies to mitigate climate change and food security risks.

5.4.7 Meteorological analysis

Maximum and minimum temperature trends have been more pronounced than rainfall trends in northern Ghana over the last five decades (1969-2018) (Figures 5.2 and 5.3). The rates of change in maximum and minimum temperatures in all three districts are statistically significant (MK, $p < 0.001$).

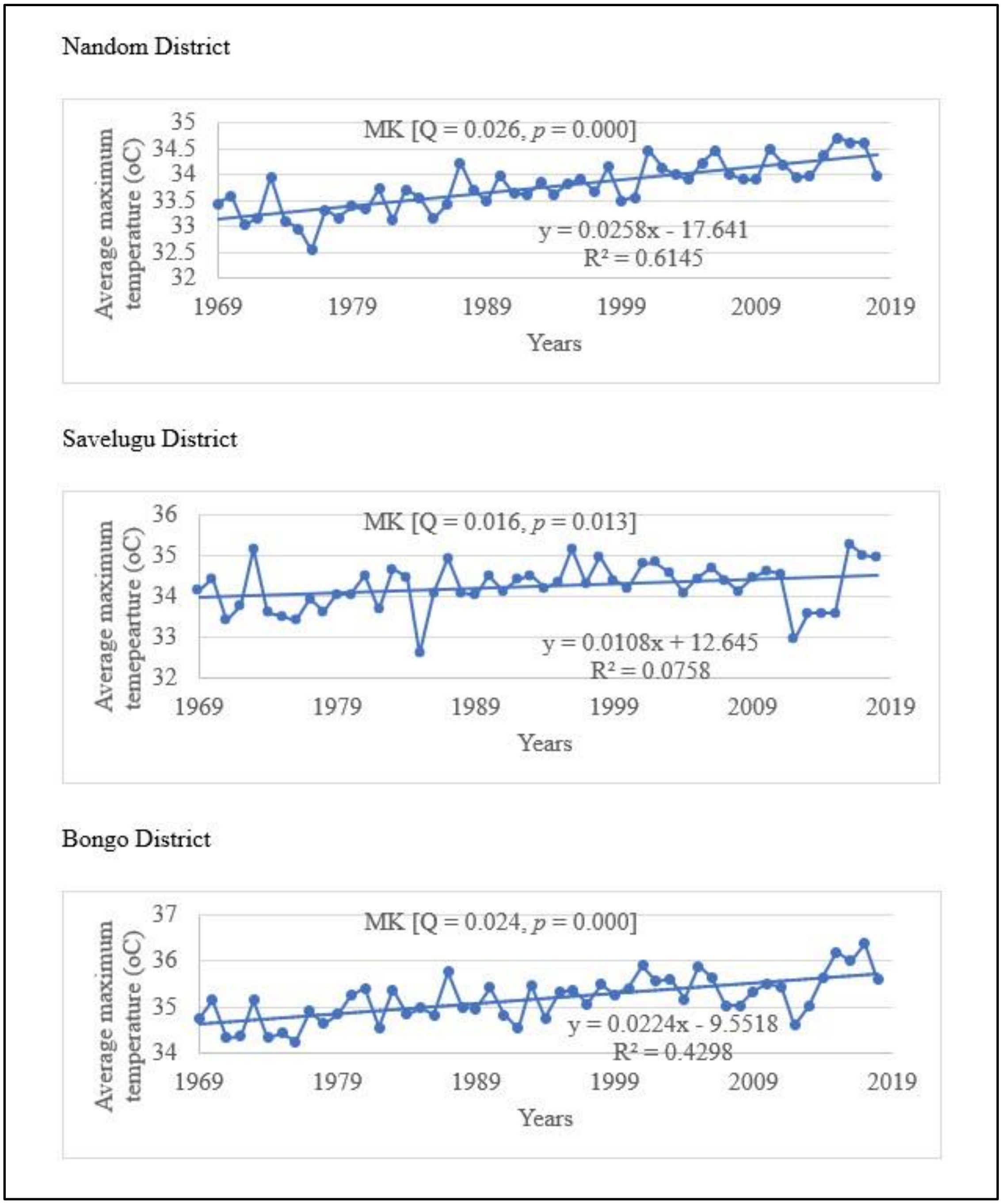

Figure 5.2: Graphs showing average annual maximum temperature trends (1969-2018)

Maximum and minimum temperatures increased in Nandom by 0.0258 ^{o}C/year and 0.0269 ^{o}C/year more than in Bongo (0.0224^{o}C/year; 0.0174 ^{o}C/year) and Savelugu (0.0108 ^{o}C/year; 0.0258 ^{o}C/year) respectively over the five decades. The magnitude of the minimum and maximum temperature trends in the three districts of Bongo (MK, Q = 0.018 ^{o}C, 0.024 ^{o}C), Nandom (MK, Q = 0.026 ^{o}C, 0.026 ^{o}C) and Savelugu (0.025 ^{o}C, 0.016 ^{o}C) respectively, show some slight variations.

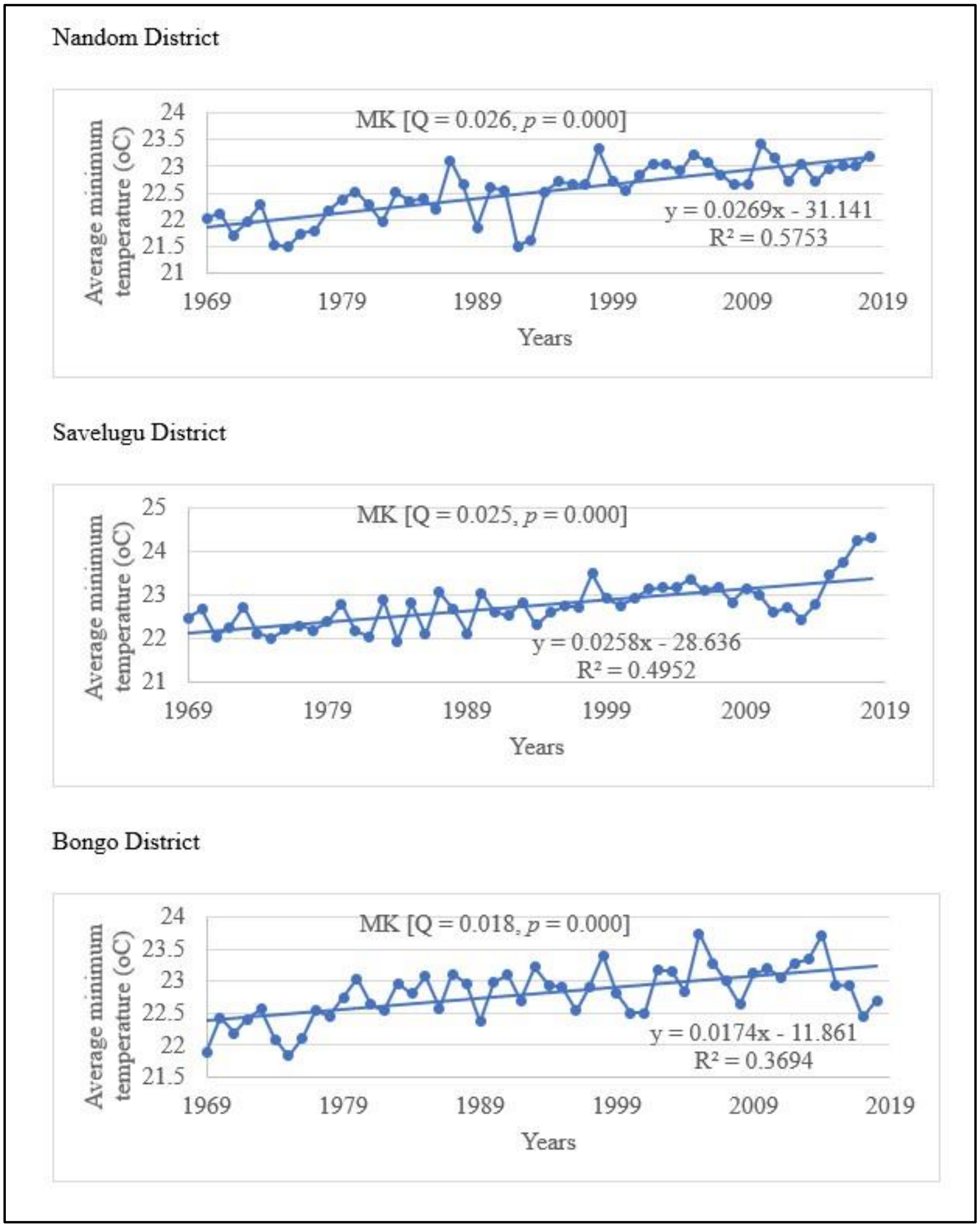

Figure 5.3: Graphs showing average annual minimum temperature trends (1969-2018)

The average annual rainfall values as shown in Figure 5.4 indicate a marginal decreasing trend for Savelugu (MK, Q = -0.054) at a rate of 0.0491mm/year, but increasing in the Bongo (MK, Q = 0.101) and Nandom (MK, Q = 0.061) districts at the rates of 0.0758mm/year and 0.0838mm/year respectively, with the rate of increase in rainfall in Bongo marginally more than Nandom district, although none of the changes are statistically significant: Bongo (MK, $p = 0.437$), Nandom (MK,

p = 0.536) and Savelugu (MK, p = 0.694). While annual rainfall volumes have not seen significant changes in the districts, variabilities are reported by respondents which have implications for agriculture and other related livelihoods.

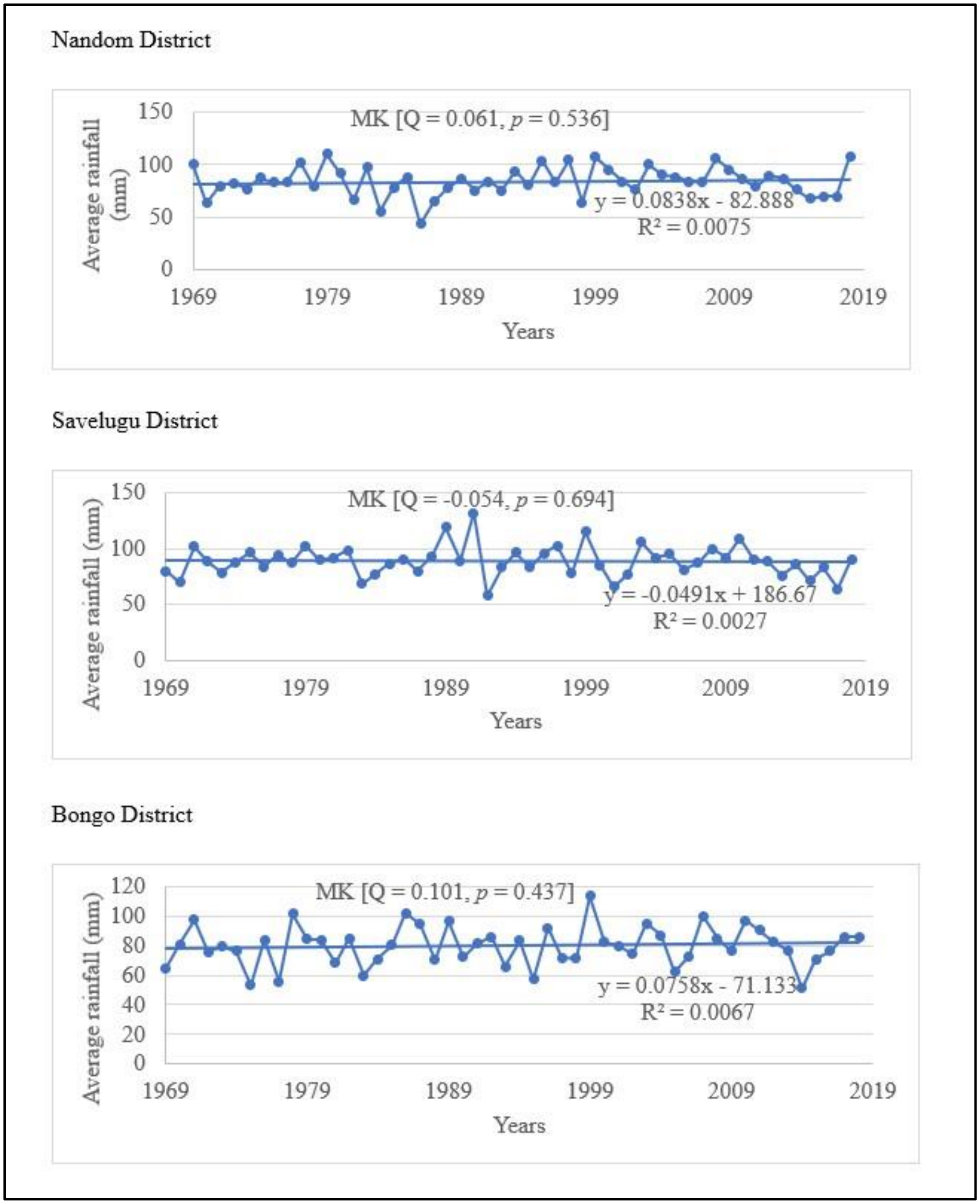

Figure 5.4: Graphs showing average annual rainfall trends (1969-2018)

5.4.8 Comparing perceptions with scientific evidence

As indicated earlier, a majority of respondents (75.3%) perceive of decreased annual rainfall in the study districts. Yet, the study found disparities between respondents' perceptions of decreased rainfall and meteorological evidence, which pointed to no significant variation in annual rainfall trends (MK, $p > 0.05$) in all districts. In contrast, respondents' perceptions of increased maximum and minimum temperatures were found to be generally consistent with the available meteorological evidence across the stations. The average annual minimum (80%) and maximum (89%) temperatures were perceived by a majority of survey respondents to be rising significantly suggesting warming conditions in the study districts. Similar perceptions were reported during the FGDs and interview sessions in all the study districts. This difference in accuracy of perception might suggest that local people are able to perceive temperature trends more accurately than rainfall trends. It might also indicate however, that while average annual rainfall trends are not showing significance, the increasing variability in the timing and extreme events may be skewing perceptions. In other words, it is the usefulness of the rainfall for agriculture, especially as evapotranspiration rates increase, which are of particular importance to local farmers and potentially influencing perceptions of long-term trends.

5.5 Discussion

This paper integrates local perceptions with scientific evidence to better understand the changes and trends of local climate to inform adaptation policy and actions across different locations in northern Ghana. In line with previous studies in northern Ghana and the broader regions of the Sahel, most respondents perceived that the districts under investigation have experienced changes in temperature and rainfall (e.g. Derresa et al., 2011; Dickinson et al., 2017; Mertz et al., 2009). The Sahel remains an important region for the exploration of the complexity of CCV given the high levels of exposure and sensitivity of the region to changes in key climate variables (Antwi-Agyei et al., 2017; Niang et al., 2014). Increases in local average temperatures and extreme events are being noticed by individuals, in association with personal experiences.

There are spatial variations in respondents' perceptions of increased temperatures across the study districts, which may be particularly important for understanding local spatial dynamics of socio-ecological systems and the willingness of farming communities to invest into adaptation.

Respondents at Savelugu perceive greater temperature change than at Nandom and Bongo, perhaps because the communities in Savelugu are farther from the Sahel and appear to be experiencing a particular change in temperatures. On the other hand, Nandom and Bongo, to the north-west and north-east respectively, have historically experienced average warmer temperatures and so appear to be less likely to be observing a warming trend (Dickinson et al., 2017; Lawson et al., 2020).

Respondents' recognition of climate change in northern Ghana is in contrast to some claims that farmers elsewhere in Africa are unaware of climate change (Ajuang et al., 2016). Such awareness and perceptions will be important for policymakers to fashion policies that will help farmers to better prepare and implement robust adaptive strategies to mitigate potential risks such as food insecurity and poverty (Mertz et al., 2009). Also, farmers' perceptions and local experiences of climate change could potentially engender their willingness to adapt or accept information about risks and adaptation, as well as increase their desire to invest in long-term adaptation goals (Wetende et al., 2018).

According to most respondents, rainfall patterns have become erratic with late onset and early termination of the rainy season. Again, however, the level of perception varied across the study locations. More respondents at Savelugu perceived changes to rainfall patterns than at Nandom and Bongo, perhaps because they are traditionally more accustomed to reliable, timely rainfall that has become more variable in recent years with the weakening of the African Monsoon in West Africa (Jarawura, 2014; Shanaham et al., 2009). On the other hand, Nandom and Bongo are farther to the north-west and north-east respectively, which historically have experienced more rainfall variability (Nkrumah et al., 2014). For instance, the Bongo district in particular has been experiencing significant rainfall variability in the past century probably due to regional spatio-temporal natural variabilities (Abbam et al., 2018). However, there was more early termination of rainfall during the rainy season at Nandom than at Savelugu and Bongo, perhaps because of the influence of the Sahelian climate (Lawson et al., 2020). Such changing rainfall patterns, as reported by respondents, are spatially heterogeneous that are leading to a truncation of growing seasons (Chepkoech et al., 2018). As Ayal and Filho (2017) also found in Ethiopia, agriculture and associated livelihoods are likely to be threatened by such seasonal changes, which in turn could intensify food insecurity, particularly in rural communities due to their limited adaptive capacities.

In accordance with previous studies in northern Ghana and SSA, respondents also perceived that extreme climate events, particularly droughts, floods, rainstorms, harmattan winds, heatwaves and wildfires are intensifying (e.g. Antwi-Agyei et al., 2017; Ayanlade et al., 2017; Dickinson et al., 2017). As with other climatic factors, respondents' perceptions of extreme climate events varied spatially, with again a higher percentage of respondents at Savelugu perceiving more extreme droughts, floods and harmattan winds perhaps because that place may be historically more resilient but have become highly vulnerable in recent years (Alhassan et al., 2019). Therefore, it is expected that places that were hitherto not experiencing more extreme climatic conditions will experience more of such events in future. However, respondents at Bongo perceived more rainstorms than at Nandom and Savelugu, perhaps because of high convective atmospheric dynamics in the north-east due to high temperatures, which produces more rainfall with thunderstorms during rainy season in the day time (Dietz et al., 2004). Such climate extremes not only amplify negative climate-carbon cycle feedbacks, but also lead to harvest reductions or failures which consequently threaten the livelihoods of agricultural producers and the food security of communities (Vogel et al., 2019). Reduced production quantity and quality due to climate extremes could cause declines of agricultural sales out of the region, leading to reduced incomes and increased food prices with potentially dire consequences for both subsistence and import-dependent communities.

Apart from location, several factors were found to influence respondents' perceptions of climate change and variability in northern Ghana. Respondents with high educational levels were more likely to perceive of CCV. This finding is not surprising since higher levels of education improve people's access and understanding of climate information which better prepares them to adopt appropriate measures to mitigate any potential risks (Lee et al., 2015). Wealthier respondents were highly perceptive of CCV. As Deressa et al. (2011) also found, wealthier respondents generally have greater abilities to access and make use of climate information, either because they are more educated or they have the financial capacity to procure assets (e.g. television and radio sets) and newspapers. Age was also found to determine respondents' perceptions. Age is directly linked with farming experience, and it is suggested that older respondents are influenced by their indigenous knowledge in their conception of CCV (Mamba, 2016). According to Ayal and Filho (2017) in Ethiopia older farmers are likely to detect climatic changes with a high level of accuracy than younger farmers.

Also, respondents who had strong attachment to their location were more likely to perceive CCV. This could partly be explained by the fact that people who are connected to a place through their daily interaction with the environment develop a deeper knowledge and understanding of their local ecological and climatic systems. Respondents who utilise their indigenous knowledge were more likely to perceive CCV. Relying on indigenous technologies provides opportunities to understand local ecological changes (Nyong et al., 2007). All these results suggest that perceptions of CCV are influenced by important socio-demographic and cultural factors, which could deepen understandings of climatic risk and future adaptive practices. Integrating such complex understandings of that knowledge will be important for scientists, policy formulators and actors such as community leaders, because it will offer them the opportunity to comprehensively understand CCV in order to improve adaptation policies and practices (Berke, 2014).

From the historical data, temperatures are seen to be rising over the last five decades in all the study districts. However, maximum and minimum temperatures were higher at Nandom than at Savelugu and Bongo. Location may again play a role here, because Nandom is to the far west of the country where warming conditions are severe anyway (Lawson et al., 2020). The results indicate that the climate in northern Ghana has significantly warmed since the second half of the 20th century with more expected high intensity of the warming in the 21st century. One of the possible reasons for the warming trends in northern Ghana is the increasing variability of the El-Nino Southern-Oscillation (ENSO) which strengthens the north-easterly winds and drives warm air from the Sahara over the Savanna (Baidu et al., 2017). The evidence supports temperature trends globally, and particularly in the Sahel where temperatures are suggested to increase rapidly in the 21st century (IPCC, 2014). Increased temperatures affect soil moisture content with implications for farming activities and livelihoods due to direct community dependence on rain-fed agriculture (Limantol et al., 2016). Even though research shows that warming could improve the yield of some crops such as cassava (Amikuzino & Donkoh 2012), the adverse impacts of high temperature on staples such as maize, sorghum, rice, millet, yam and vegetables which form a greater proportion of food consumed in Ghana will intensify food insecurity and aggravate poverty levels, especially in rural communities. It is evident that people are detecting temperature changes in their local environment with some level of accuracy.

In relation to rainfall, and even though Figure 5.4 appears to reveal some minor trends, the meteorological data suggests that there have been no significant changes. This suggests that annual rainfall volumes have been largely similar over the last five decades across the study districts, which supports other studies suggesting that average annual rainfall has been generally stable over the past couple of decades in Ghana (Asare-Nuamah & Botchway, 2019; Limantol et al., 2016). What the average annual data does not reveal however, is how the rainfall was experienced locally– whether in extreme events, concentrated in shorter periods, or as regular rainfall across the growing season. The changing seasonal rainfall regimes and increasing intra-annual rainfall variabilities in Ghana are partly influenced by rising sea surface temperatures in the Gulf of Guinea or the Equatorial Atlantic (Waylen & Owusu, 2014), and it is these changes in variability that appear to strongly influence local perceptions.

The convergence and divergence of meteorological data with respondents' perceptions are reported in previous studies elsewhere (e.g. Ayanlade et al., 2017; Hasan & Kumar et al., 2019; Imran et al., 2018; Shrestha et al., 2019). Discrepancies between meteorological data and respondents' perceptions of rainfall may be due to factors such as respondents' inability to document historically observed trends or the dominance of heuristics recent climate events, but may also be due to difficulties perceiving rainfall long-term patterns (Debela et al., 2015). While farmers who mainly engage in irrigation farming may not need to take an immediate interest in the dynamics of rainfall trends, dryland farmers who are directly dependent on rainfall may be more perceptive of short-term rainfall changes, and may develop particular sensitivities to altered rainfall patterns or conflate changes in variability with long-term average trends (Shrestha et al., 2019). As a result, while the significant increases in spatiotemporal precipitation variability could account for some of the differences in perceptions (Abbam et al., 2018), as the variability in rainfall patterns increases, it is likely to become more difficult for all farmers to accurately perceive of broader increases or decreases in average rainfall trends. Farmers will hold distinct perceptions of rainfall change and variability as increasing spatial and temporal rainfall variabilities at differing scales impact in a range of ways across local agricultural production systems and rural livelihoods.

Respondents perceived changes in the start and end of the rainy season, as well as the manifestations of other extreme climate events such as floods, rainstorms, wildfires and droughts. That increasing variability witnessed by farmers is particularly important for agriculture in areas such as northern Ghana (Amikuzino & Donkoh, 2012), because farmers must maximise the opportunity to efficiently utilise the available rainfall from within the rainy season to produce food – and that rainfall is no longer as predictable or reliable to support established rainfed cropping regimes. The resulting divergence between the local knowledge and scientific records emphasises the importance of knowledge integration for adaptation policy and planning in marginal rural agro-ecological settings.

To ensure successful implementation of climate change adaptation policies, the perspectives and experiences of local farmers who will be impacted by the policies have to be recognised in the adaptation decision-making process (Patt & Schröter, 2008). Higher levels of indigenous knowledge were also found to play an important role in helping farmers to understand their local ecology, which in turn improves their adaptive knowledge. A greater recognition by decision-makers of the importance of local perceptions tied to place and ways of understanding and acting has the potential to stimulate farmers' interest in participating in adaptation interventions and programmes for sustainable food production in SSA. In fact, a singular focus on average trends by science, might make decision-makers less interested in responding to rainfall change, but at the local level people are experiencing real problems with greater variability. Thus, the specific emphasis on the importance of local knowledge – in this case the importance of perceived rainfall variability over rainfall averages for local socio-ecosystems – can also inform interventions that may be able to account for shorter growing seasons or more extreme events.

5.6 Conclusion

This study contributes to understanding the convergences and discrepancies of farmers' climate perceptions and meteorological data using a mixed-methods approach in northern Ghana. The study revealed that respondents had perceived different manifestations of CCV and associated climatic extremes across the three locations. Decreased rainfall, increased temperature, late start and early cessation of the rainy season and extreme climate events such as droughts, floods, harmattan winds, wildfires and rainstorms were identified by respondents as the important local climatic changes they have been experiencing, with most changes being spatially differentiated across the study districts. Age, education, indigenous knowledge use, place attachment and wealth status are covariates that likely influence respondents' perceptions of CCV.

Importantly, while perceived declines in average rainfall were found to be incongruent with meteorological rainfall data, perceived and measured increases in temperatures were largely consistent. This study suggests that climate adaptation policies for marginal agricultural production areas in developing countries, such as the Sahel, should take into consideration both local and scientific knowledge of the spatial and temporal variations in temperature and rainfall trends. The disparities between perceptions and historical scientific evidence suggest that neither local perceptions nor scientific evidence alone is sufficient for adaptation planning and policy. Rather, adaptation policies should be informed by integrated climatic knowledge, where local perceptions are compared and contrasted with available scientific data to understand the intricacies and dynamics of the climatic changes in order to develop robust adaptation strategies. In this case, if the limited meteorological data is not complemented by local farmers' sophisticated understanding of increasing rainfall variability, adaptation policy would fail to generate resilient agricultural systems, or improve the livelihood of farmers in general. Thus, the intermittent assessment of farmers' perceptions of CCV through research will be helpful for tailoring adaptation planning and policy for particular locations. Simultaneously, efforts should be made to intensify education and training to enhance farmers' knowledge and awareness of CCV, particularly the drivers of those changes. Scientists, agricultural extension agents, community leaders and elderly farmers should be part of such knowledge generation and awareness creation campaigns in the communities, so that the local knowledge is brought together with scientific understanding through the processes of mutual learning.

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CHAPTER 6: Social Perceptions of Climate Change Impacts on Food Security in northern Ghana: Do Social Networks Matter in Coping with Household Food Insecurity?

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Abstract

The earth's climate system is changing rapidly and as it does, achieving food security is more challenging than ever in sub-Saharan Africa (SSA). There is substantial evidence in the literature of a number of theoretical and modelling understandings of the impacts of climate change on food security in SSA, yet local perceptions of the impacts across all dimensions of food security remain limited in many places, particularly how social networks help households to cope with food insecurity in resource-constrained dryland areas. The study draws insights from northern Ghana using a mixed-method approach to frame understanding of how farmers perceive of the impacts of climate change on food security, and the role social networks play in promoting food security. Farmers are perceiving impacts of climate change on food security including low crop productivity, disruption of distribution of crops, reductions in income and purchasing power, limited food supplies, and emerging food quality and safety challenges. Age, gender, education, household size and wealth status all associate to farmers' perceptions of the climatic impacts. In response to those impacts, farming households are utilising social networks to access financial support, technical training, farm inputs, inter-farming support, food sharing and cultural support to enhance food security. Those households with strong social networks are much less likely to perceive of high levels of food security risk. Rural farming households and communities would become more resilient and food secure if their perceptions are considered in agricultural policy decisions and effective social relationships are promoted and maintained.

6.1 Introduction

Agricultural innovation has been playing a fundamental role in promoting food security and creating wealth in many parts of the world. Yet, food insecurity remains a major global challenge in the 21st century, particularly in developing countries (Bahar et al., 2020; Davis et al., 2016; Pereira et al., 2020; Thornton et al., 2018). According to the Food and Agricultural Organisation (FAO) of the United Nations, there is food security when all people, at all times, have physical, social and economic access to sufficient, safe, and nutritious food that meets dietary needs and food preferences for active and healthy life (FAO, 2019). Food security encompasses availability (sufficient quantity and quality of food), accessibility (having resources to obtain sufficient food), utilisation (having safe and nutritious food to meet dietary needs) and stability (having access to sufficient and nutritious food at all times) (World Food Programme [WFP], 2012). To achieve the Sustainable Development Goal (SDG) target of eliminating hunger, there is the need to increase production and access to food, especially in sub-Saharan Africa (SSA) (Giller, 2020; Palazzo et al., 2017).

Nevertheless, a recent report by the FAO indicates downward food production trends in Africa, which suggests that the continent will struggle to meet the needs of the over 277 million severely food insecure people (FAO, 2019). The situation is particularly precarious in SSA, where the prevalence of undernourishment has increased from 17.6% in 2014 to 19.1% in 2019, more than twice the global average and the worst situation of any continent (FAO et al, 2020; Thiede and Strube, 2020). The recent COVID-19 pandemic has further aggravated food security risks in countries across the globe (Laborde et al., 2020; Niles et al., 2020). Congruent with this trend, many households and communities in Ghana, the focus of this paper, are food insecure with significant malnutrition challenges in marginal areas (Aurino et al., 2020; Saaka et al., 2017). Over 1.2 million Ghanaians are food insecure, and additionally 2 million people are considered highly vulnerable to food insecurity (Ministry of Food and Agriculture [MoFA], 2019). Particularly in northern Ghana, many households experience six months of deficiencies of local food staples including millet, sorghum, maize, rice and groundnut, and one-quarter of children under five are chronically malnourished (Frempong and Annim, 2017). The driving forces of food insecurity are diverse. Particularly in SSA, poverty, rapid population growth rates, conflicts and lack of good governance systems have historically been suggested as key factors impacting food security on the continent (Arndt et al., 2016; Ogunniyi et al., 2020). However, in recent decades, environmental change, particularly climate change is intensifying food insecurity in developing countries, particularly SSA due to increased risks to food availability and access (Campbell et al., 2016; Hall et al., 2017; Misselhorn, 2008; Ringler et al., 2010; Wheeler and Von Braun, 2013). In Ghana, climate change is disrupting agricultural systems and livelihoods leading to high production and post-harvest losses, which are compromising all dimensions of food security (Akudugu et al. 2012; WFP 2012).

Consequently, climate change and associated risks are compromising the achievements that aim to meet the United Nations targets of eradicating hunger and malnutrition by 2030 (Pérez et al., 2016; Tumushabe, 2018). Yet understandings of the complexity of climate change-food security nexus are fragmented, with the emphasis on modelling scenarios (e.g. Hall et al., 2017; Knox et al., 2012; Ringler et al., 2010) and theoretical reflections (e.g. Connolly-Boutin and Smit, 2016; Thompson et al., 2010; Ziewdie, 2014), but limited understanding of local perceptions within local socio-ecological systems (e.g. Akudugu et al., 2012; Armah et al., 2019; Hussain et al., 2016; Poudel et al., 2017). The dearth of knowledge of local perceptions of food security situations in SSA is important for developing appropriate adaptation interventions needed to sustainably enhance rural livelihoods and food security, particularly in the Sahel (Mertz et al., 2009).

Given the impacts of climate change on food security, discussions are ongoing over appropriate pathways for improving food security. Many researchers globally are advocating for the need to intensify agriculture and engage in diversification, conservation and/or climate-smart practices to improve food security (e.g. DeLonge et al., 2017; Garnett et al., 2013; Mbow et al., 2014; Mulwa and Visser 2020; Teklewold et al. 2019). In SSA, researchers have argued that improving agricultural extension, storage technology, food banks and spiritual prayers are important factors that can promote food security (Abdu-Raheem, 2013; Erhabor and Erhabor, 2016; Omotilewa et al., 2018). Particularly in Ghana, non-farm work, food sharing, seasonal migration and the empowerment of women are suggested as other key pathways for improving household food security (e.g. Fonjong and Gyapong 2021; Kuuire et al. 2013; Owusu et al. 2011; Van Der Geest 2010; Zereyesus et al. 2017).

Social network plays an important role in environmental risk management and natural resource governance (Alexander et al., 2015; Bodin and Crona, 2009). Network cohesion of social systems provides sustained collective action for enhancing food security (Lee et al., 2018; Martin et al., 2004; Nosratabadi et al., 2020). Yet, there remains a dearth of knowledge on the extent to which social networks influence food security and associated risk perceptions of households in dryland rural areas of SSA, particularly under the context of climate change (Dzanja et al., 2013; Thamaga-Chitja and Tamako, 2017). Social networks, in this context, relate to the relationships and connectivity between individuals and groups with shared interests for mutual benefits (Chaudhury et al., 2017). That knowledge gap is particularly important in developing a comprehensive understanding of how rural communities, which generally have poorly developed and ineffective formal institutions can utilise social capital to increase resilient local food systems (Lowitt et al., 2014). Therefore, this study argues that social networks will play a significant role in mitigating food insecurity in rural households and communities.

This study aims to partially address current social perception and network knowledge gaps by finding answers to the following research questions: (1) how do farmers perceive the impacts of climate change on food security and its dimensions? (2) Are there associations between farmers' perceptions of climate change impacts and their sociodemographic characteristics? and (3) how do social networks help farming households to cope with food insecurity? Understanding how climate change and social networks affect food security from a local perspective in Ghana could provide important opportunities for policy considerations to better support rural farming systems to build local resilience in food production and help ensure sustainable livelihoods.

6.2 Methods

6.2.1 Study area

This study was conducted in Ghana located in the south of West Africa. The study covered communities within three districts, namely Nandom, Savelugu and Bongo which are situated in the northern savanna agroecological zone of Ghana to the south of the Sahel (Fig. 6.1). An average of 77.7% of the population in northern Ghana live in rural areas, which is considerably more than the national average of 49% (WFP, 2012). Agriculture is an important livelihood source for many households in the three districts of northern Ghana.

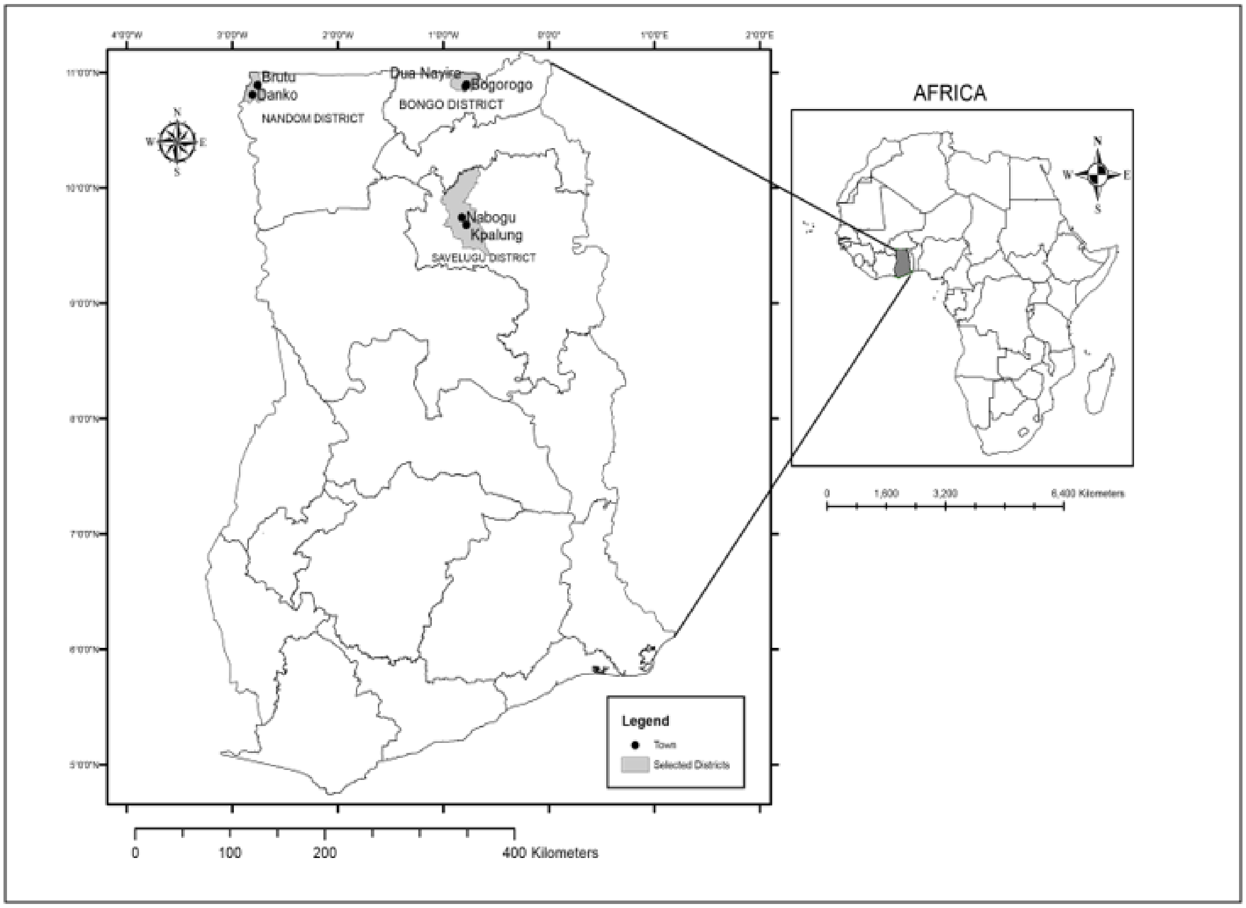

Figure 6.1: Location of the study sites in northern Ghana

Specifically, 98% of the population in the Nandom district, 97% in Savelugu and 96% in Bongo are engaged in rain-fed crop production for their household livelihoods (Ghana Statistical Service [GSS], 2012). Farming activities in all the selected districts are predominantly rainfed and small-scale, with over 67% of farmers cultivating on less than five acres of farm land (WFP, 2012). The soil type is generally coarse-textured, commonly with limited organic matter due to frequent burning, which makes it susceptible to high levels of leaching and run-off during heavy rainfall (Wossen and Berger, 2015). A large quantity of food crops produced in Ghana comes from the northern sector. However, food insecurity and undernourishment are higher than in the southern sector because of extreme poverty and difficult climatic conditions for production (Yaro and Hesselberg, 2010). The study regions have high illiteracy rates, infant mortality and high population densities (GSS, 2012).

There are two major seasons in northern Ghana, namely the wet and dry seasons. The rainy season begins in May and peaks in August, with a mean annual amount of 1030mm over the last 30 years across northern Ghana (Ahmed et al., 2016). The dry season runs from November to April, and it is characterised by the harmattan winds which blow from the Sahara Desert to the north (WFP, 2012). The relative closeness of northern Ghana to the Sahara Desert makes the region more vulnerable to climate change and extreme climate events, which consequently affects agricultural productivity (Akudugu et al., 2012). During the dry season, temperatures are very high with an average maximum of 29.2–32.4°C across the year, facilitating high evapotranspiration and severe droughts (Ahmed et al., 2016).

6.2.2 Data collection and analysis

This study applied a mixed-methods approach to systematically gather quantitative and qualitative data between September and December, 2019 (Creswell and Creswell, 2018). Integrating quantitative and qualitative methods was important in this case, because they ensure complementarity by allowing the limitations from each method to be compensated for by comparing findings from different perspectives (Heale and Forbes, 2013). The study conducted a household survey and focus group discussions in six purposively selected communities (*Brutu and Danko* in Nandom district, *Kpalung and Nabogu* in Savelugu district *and Dua Nayire and Bogorogo* in Bongo district) to collect important quantitative and qualitative data to address the research questions. The study sites were selected because of their relatively homogenous environmental characteristics and high vulnerability to food insecurity.

The face-to-face survey was conducted to determine how farming household heads perceive of climate change impacts on food security. A three-point Likert scale of “Agree”, “Neutral” and “Disagree” was used in the questionnaire to assess farmers’ level of agreement or disagreement of the perception variables (Likert, 1932), which were generated from critical literature reviews (e.g. Akudugu and Alhassan, 2012; Armah et al., 2019; Codjoe and Owusu, 2011; Connolly-Boutin and Smit, 2016). Apart from location, the study examined the associations between farmers’ sociodemographic characteristics (e.g. age, gender, education, household size and wealth status) and their perceptions of climate change impacts on food security components (availability, accessibility, utilisation and stability).

Farming households and lead farmers were also asked to describe their social networking and how that influences household food security. Before the actual survey, a pilot study was conducted at Kpong-Tamale to pre-test the questionnaire for validity and reliability. The pilot survey offered us the opportunity to rephrase some of the questions that were not well understood by farmers and to ensure the acquisition of required data. A total of 299 farming household heads were randomly selected from a total farming household population of 1181 within the six communities in the three target districts. The total sample was obtained based on the mathematical formula proposed by Yamane (1967) which is expressed as $n = N/1+N(\alpha^2)$, where ‘n’ is sample size, ‘N’ is total population and ‘α’ is the error margin at 5%. Proportionally, 131 household heads were sampled from 515 households, 81 from 321 households and 87 from 345 households across the communities in Bongo, Savelugu and Nandom districts respectively. The survey interview lasted between 45 and 60 minutes.

To support understanding, focus group discussions were also organised in all the six communities in the study districts to obtain detailed qualitative information from lead farmers. Ten participants (5 males and 5 females) were invited for further discussions from each of the six communities. In all, a total of 12 focus group discussions were conducted involving a total of 60 participants. Participants of focus group discussions were recruited purposively from different socio-economic backgrounds through an invitation to lead farmers with appreciable farm experience and knowledge of issues, and who declared their willingness to take part during the survey. The focus group discussions were conducted in the local dialects in each location; Nandom (*Dagaare*), Savelugu (*Dagbani*) and Bongo (*Gurune*) with the help of local field assistants, and each discussion lasted between 60-90 minutes. The discussions focused on the implications of climate change on food security and how social network systems influence food security. Participants’ responses were recorded on audiotape after verbally seeking their consent. In addition, some extension agents were interviewed on how government support systems are made available to farming communities to support their agricultural activities for food security. All ethical procedures were followed based on approval (H-2019-058) obtained from the Office of Research Ethics Compliance and Integrity at the University of Adelaide.

The survey data were analysed with the help of IBM SPSS Statistics for Windows version 21 (Field, 2013). Frequencies and percentages were used to represent respondents’ perceptions of climate change impacts on food security and the roles of social networks for food security. Cross-tabulations and nonparametric Kruskal-Wallis statistical tests were utilised to determine the significant difference of farmers' perceptions of climate change impacts on food security across the study locations (McKight and Najab, 2010). Pearson's chi-square test of independence was used to determine significant associations between farmers' sociodemographic characteristics and their perceptions of climate change impacts on food security (Sharpe, 2015). A standardized Phi coefficient was used to show the direction and level of association between the covariates and outcome variables measured (Wearden, 2010). Also, a logistic regression model was applied to determine if household social networks significantly decrease the odds of food security risks. The dependent variable in the model is a dichotomous measure of food security versus food insecurity. The explanatory variables were selected based on food security literature (e.g. Lee et al., 2018; Martin et al., 2004). The estimation form of the model is expressed as:

$$\log\left(\frac{P}{1-P}\right) = \beta_0 + \beta_1 X_1 + \beta_1 X_2 + \beta_k X_{ik} \ldots$$

Where *i* is the i^{th} observation; P_i indicates the predicted probability of perception coded as a dummy variable with 1' represented those who perceived food security risk while '0' represented those who did not perceive such risk (1- P_i); β_0 indicates the intercept term with β_1, β_2 and β_k representing the coefficients of the explanatory variables (X_1, X_2 and X_k); and (P_i / 1- P_i) represents the odds ratio.

The qualitative data from the focus group discussions and interviews were thematically analysed after the data had been transcribed from the local dialects (*Dagaare, Dagomba and Grune*) to English by local language transcription experts. We categorised the emerging themes from the focus group discussions and identified associated key narratives to generate a structure supported by quantitative results using direct quotations.

6.3 Results

6.3.1 Household characteristics based on food security status

This study analysed characteristics of farming households based on the level of food security (Table 6.1). Out of the 299 household respondents, 83.9% claimed they were food insecure. A slightly greater proportion of female respondents (87.3%) stated that they were food insecure than male respondents (82.7%), which conforms with the general idea of high vulnerability of females to food insecurity in SSA (Sekhampu, 2013). A much larger proportion of respondents (89%) with no formal education were significantly food insecure compared with respondents (21.7%) with formal education. Respondents who are married (85.8%) appear to be more food insecure than single respondents (75.5%), possibly because they had more dependents in their households. Across the ethnic groups, a larger proportion of Gurunes (92.2%) were significantly more food insecure than the Dagaabas (86.7%) and Dagombas (67.1%), which may be due to the higher vulnerability of agricultural systems in the Upper East region to extreme climate events, particularly droughts (Antwi-Agyei et al., 2012).

Table 6.1: Household characteristics based on food security status in northern Ghana

Variable	N	Percentage (%) of		(*p*-value)
		Food secure	Food insecure	
All households	299	16.1	83.9	
Gender				
Male	220	17.3	82.7	0.338
Female	79	12.7	87.3	
Age				
<60	158	16.5	83.5	0.841
≥60	141	15.6	84.4	
Educational level				
Formal education	143	78.3	21.7	0.011**
No formal education	156	10.9	89.1	
Marital status				
Married	246	14.2	85.8	0.064
Single	53	24.5	75.5	
Ethnicity				
Dagaaba	81	13.3	86.7	0.000**
Dagomba	87	32.9	67.1	
Gurune	131	7.8	92.2	

** represents significant level at 0.05

6.3.2 Perceived climate change impacts on food security

Rural farming households in northern Ghana perceive that climate change is having important impacts on food security (Table 6.2). Previous research has shown that farmers in the study districts perceive multiple climate change risks such as high temperatures, erratic rainfall patterns and extreme climate events such as prolong severe droughts, severe flood events and severe wildfires (Guodaar et al., 2021). Those impacts are translating into less secure food security situations in northern Ghana.

Table 6.2: Perceptions of climate change impacts on food security

Perception indicator	Study Locations			Total n = 299	*p*-value[a]
	Nandom n = 81(%)	Savelugu n = 87 (%)	Bongo n = 131 (%)		
Decrease in crop yield					
Disagree	26(32.1)	17(19.5)	6(4.6)	49(16.4)	0.000**
Neutral	0(0.00)	0(0.00)	0(0.00)	0(0.00)	
Agree	55(67.9)	70(80.5)	125(95.4)	250(83.6)	
Disruption of distribution of crop					
Disagree	5(6.2)	9(10.3)	20(15.2)	34(11.4)	1.307
Neutral	4(4.9)	0(0.00)	1(0.8)	5(1.6)	
Agree	72(88.9)	78(89.7)	110(84.0)	260(87.0)	
Reduction in income and purchasing power for food					
Disagree	3(3.7)	18(20.7)	44(33.6)	65(21.7)	0.000**
Neutral	2(2.5)	5(5.7)	3(2.3)	10(3.3)	
Agree	76(93.8)	64(73.6)	84(64.1)	224(74.9)	
Low food supply					
Disagree	21(26.0)	4(4.6)	15(11.5)	40(13.4)	0.001**
Neutral	4(4.9)	1(1.1)	8(6.1)	134.3)	
Agree	56(69.1)	82(94.3)	108(82.4)	246(82.3)	
Instability of food supply					
Disagree	23(28.4)	5(5.7)	15(11.5)	43(14.4)	0.001**
Neutral	1(1.2)	0(0.0)	7(5.3)	8(2.7)	
Agree	57(70.4)	82(94.3)	109(83.2)	248(82.9)	
Reduction of food quality					
Disagree	22(27.2)	24(27.6)	9(6.9)	55(18.4)	0.063
Neutral	0(0.0)	8(9.2)	7(5.3)	15(5.0)	
Agree	59(72.8)	59(67.8)	101(77.1)	219(73.2)	
Food safety problems					
Disagree	21(25.9)	6(6.9)	21(16.0)	48(16.0)	0.000**
Neutral	11(13.6)	1(1.1)	5(3.8))	17(5.7)	
Agree	49(60.5)	80(92.0)	105(80.2)	234(78.3)	

[a] Indicates *p*-values of Kruskal-Wallis test ** represents significant level at 0.05

A large group of surveyed respondents (250 or 83.6%) of the 299 total respondents perceived that climate change has adversely affected their crop yield, which has made it difficult for them to produce sufficient food for the household. A female participant at Bongo said that: '…*When the* *heat is too much it affects my crop. And fall armyworms* (*Spodoptera frugiperda*) *and wolmowo destroy the crops*. *My livestock also grow lean because they don't get enough water to drink. The rivers around usually get dried up and I sometimes have to take my livestock to farther places to find water and pasture for them'.* However, the perceptions varied significantly across the study locations (Table 2), with a larger proportion of respondents at Bongo (95.4%) perceiving climate change impacts on crop yields than those at Nandom (67.9%) and Savelugu (80.5%), perhaps due to a higher vulnerability to droughts and other extreme climate events in the Bongo district (Antwi-Agyei et al., 2012).

A large proportion of respondents (260 or 87.0%) perceived that climate change and extreme climate events disrupt crop distribution from farms to markets and are increasing post-harvest losses. For instance, a male participant at Bongo said that: '*When it rains heavily, it is always difficult to get vehicles to transport my crops to the market. The drivers usually charge high fares because of the bad road. Sometimes, I leave the crop on the farm to rot when I don't have money to pay for transport*. *Last two years my tomatoes got rotten on the farm because I couldn't get transport. Because of that, I didn't get any income*'. Although a similar proportion of farmers at Savelugu (89.7%) perceived of such impacts as Nandom (88.9%) and Savelugu (84%), severe frequent floods in the northern region due to the annual opening of the Bagri and Kampainga spillway may be causing more issues for local farmers (Amenuveve, 2010).

A large proportion of respondents (224 or 74.9%) perceived that the impacts of climate change have affected their income levels. Many respondents mentioned that low incomes made it difficult for them to access sufficient nutritious food. A male participant at Nandom indicated that: '*My crops have not been doing well in the past three farming seasons …. I have not been earning income to buy food from the market to add to the little I harvest. My young adults sometimes travel to the city, and when they don't bring money home, I find it difficult to eat*'. The proportion of respondents who perceived income reductions due to climate change varied significantly across Nandom (93.8%), Savelugu (73.6%) and Bongo (64.1%) districts (Table 6.2). The higher percentage of respondents at Nandom who perceived that impact more than the other districts might be explained particularly by the high levels of poverty in communities in North-western Ghana (Cooke et al., 2016).

A majority of respondents (246 or 82.3%) perceived that climate change has impacted upon food supply systems for households. Respondents mentioned that their transportation system is affected by extreme climate events, which in turn disrupts their agricultural trade but also affects supply. Direct impact of rainstorm during market days was reported by farmers as a limitation to their access to food at the market, especially during the peak of the rainy season. A female participant at Nandom said that: '*When it rains*, *I always find it difficult to get food from the market. During July/August, it sometimes rains continuously for days and sellers don't go to the market. …'.* Here again, the perception of respondents varied significantly across the study locations (Table 6.2). A larger proportion of respondents at Savelugu (94.3%) were perceptive of the impacts of climate change on access to food than those at Nandom (69.1%) and Bongo (82.4%). This spatial variation across the locations may perhaps be explained by the heavy rainstorms and associated flood events in the northern region, which are known to affect transportation and food market businesses (Amenuveve, 2010; Musah et al., 2013).

A large proportion of respondents (248 or 82.9%) also perceived that climate change has impacted the stability of food supplies. Most of the respondents indicated that rising food prices and income fluctuations affect their accessibility to food crops from the market to supplement the household production for regular food needs and that peaked during the lean season. However, respondents' perceptions varied significantly across the study districts (Table 6.2). More respondents at Savelugu (94.3%) perceived that climate change was altering the stability of food supplies than those at Nandom (70.4%) and Bongo (83.2%), again perhaps because of the floods during the rainy season, which destroy farmlands and crops leading to high food prices. A male participant at Savelugu stated that: '…*Because the rain sometimes fails to come at the right time, it is not all the time that I get food to eat before the next farming season begins. If my child sends me money to buy food, I eat all the time, but if he doesn't, I struggle to eat because food prices are always high in the beginning of the farming season*'.

A majority of respondents (219 or 73.2%) perceived that climate change has considerable impacts on the quality of food crops produced and consumed. Farmers mentioned that climate trends and extreme events affect the nutrition value of food crops which in turn affects their well-being. For instance, a male participant at Nandom indicated that: '*Too much heat affects the taste and sweetness of yam* (Dioscoreaceae) *crops. Also, windstorms sometimes force us to harvest* *unmatured crops such as maize for a low price because of the quality of the seeds*'. Farmers' perceptions of this risk were very consistent across the study districts of Nandom (72.8%), Savelugu (77.1%) and Bongo (73.2%).

Food safety was also identified by many farmers as being impacted by climate change, with 234 respondents (78.3%) perceiving that climate change has made this issue more important. Respondents mentioned that they have been using more agrochemicals because of climate change, which affect the quality and safety of crops produced. For instance, a female participant at Bongo said that: '*…. So I apply pesticides to the crops. The pesticides help me to control the spread of crop pests and diseases. But, to be safe, I cook the crop well before eating*'. Farmers responses again varied significantly (Table 2) with Nandom respondents (60.5%) perceiving less of an issue than Savelugu (92%) and Bongo (80.2%), perhaps because increased pests and diseases of vegetable crops was leading to high applications of agrochemicals at Savelugu (Dari et al., 2016).

Results of the surveys and focus group discussions demonstrate the variable extents to which farmers in northern Ghana are disproportionally experiencing the multidimensional impacts of climate change on food security across locations. The next section examines how farmers' sociodemographic characteristics correlate with their perceptions of climate change impacts on food security.

6.3.3 Association between farmers' sociodemographic characteristics and perceptions of climate change impacts on food security dimensions

Age, gender, education, household size and wealth status are all correlating or influential factors in association with farmers' perceptions of climate change impacts on food security (Table 6.3). Age has a very strong correlation (Phi = 0.54) with perceptions of climate change impacts on food availability. Older respondents, particularly those above 60 years were found to be significantly more likely to perceive the impacts of climate change on availability of food. Also, the gender of respondents has a significant correlation with climate change impacts, with female respondents more likely to perceive the impacts of climate change on food availability (Phi = -0.332), food accessibility (Phi = -0.416) and food stability (Phi = -0.284) than male respondents.

Table 6.3: Associations between demographic characteristics and perceived impacts of climate change on food security components

Variable	Availability		Accessibility		Stability		Utilisation	
	χ^2 (Phi)	Sig.(*p*)	χ^2 (Phi)	Sig.(*p*)	χ^2 (Phi)	Sig.(*p*)	χ^2 (Phi)	Sig.(*p*)
Age	62.936 (0.544)	0.000**	5.715 (0.138)	0.222	4.760 (0.126)	0.313	6.893 (0.152)	0.142
Gender	52.545 (-0.332)	0.000**	34.348 (-0.416)	0.002**	24.187 (-0.284)	0.000**	7.753 (0.161)	0.101
Education level	8.439 (0.168)	0.077	5.361 (0.134)	0.252	7.360 (0.157)	0.118	12.345 (0.203)	0.025**
Household size	12.737 (0.206)	0.013**	7.313 (0.156)	0.120	7.399 (0.157)	0.116	4.063 (0.117)	0.398
Wealth status	23.003 (-0.329)	0.028**	14.333 (-0.219)	0.037**	22.728 (-0.276)	0.004**	21.105 (-0.266)	0.007**

**, significant at 0.05; Correlation: > 0.25 – Very Strong; > 0.15 – Strong; > 0.10 – Medium; > 0.05 – Weak; > 0 – No or Very Weak

Education affects the mode of thinking and knowledge on issues. Specifically, respondents with a high level of education are more likely (Phi = 0.203) to perceive climate change impacts on food utilisation. There was also a correlation between household size and household head's perceptions of climate change impacts on food security. Respondents with larger households directly were more likely to perceive climate change impacts on food availability (Table 3). The wealth status of farmers also has a significant relationship with perceptions of climate change impacts on food security unsurprisingly perhaps, respondents who are poorer are more likely to be perceptive of climate change impacts on food availability (Phi = +0.329), food accessibility (Phi = +0.219), food stability (Phi = +0.276) and food utilisation (Phi = +0.266).

The analysis shows that sociodemographic characteristics of farmers are important factors that can shape people's understanding of how climate change impacts food security in northern Ghanaian rural communities. These factors require important consideration for adaptation planning and policy to ensure sustainable food security. In the next section, the study examines how social networks of farming households contribute to food security in rural communities of northern Ghana.

6.3.4 The role of social networks in moderating food insecurity

This study analysed farming households' social connections with other individuals and groups, and the associated implications for household food security in rural communities. The results show that farming households in northern Ghana have highly established social networks with people and groups at individual, family and community levels, which help households cope with or adapt to the risk of food insecurity (Table 6.4).

Table 6.4: Farmer households' social network in northern Ghana

Social network	Study Locations			Total	*p*-value[a]
	Nandom n = 81(%)	Savelugu n = 87 (%)	Bongo n = 131 (%)	n = 299	
Family groups	75 (92.6)	69 (79.3)	113 (86.3)	257 (86.0)	0.05**
Friends	73 (90.1)	79 (90.8)	117 (89.3)	269 (90.0)	0.10
Religious societies	49 (60.5)	76 (87.4)	84 (64.1)	209 (69.9)	0.01**
Agricultural co-operative societies	54 (66.7)	62 (71.3)	88 (67.2)	204 (68.2)	0.06
Community groups	67 (82.7)	65 (74.7)	102 (77.9)	234 (78.3)	0.07

[a] Indicates *p*-values of Kruskal-Wallis test ** represents significant level at 0.05

A large proportion of respondents (209 or 69.9%) indicated that they had social connections with religious groups. However, respondents' who associated themselves with religious societies varied significantly across the study districts, Nandom (60.5%), Savelugu (87.4%) and Bongo (64.1%). That spatial variation perhaps is due to that fact that many households in Savelugu are historically aligned with Islamic religion and have strong attachment to the principles of Islam as a pre- and postcolonial means of generating or sustaining identities of cooperation and mutual support (Alibasic, 2007). Most of the respondents mentioned that they were connected with two or more groups in their religious denominations, which enabled them to access diverse benefits to improve food security. For instance, a male participant at Nandom said that: '*I have never regretted ever since I joined the Choir and Knights of St. John. When I run out of food and need financial assistance, they help me. Apart from the physical support, we usually pray against bad farming seasons for group members*…'.

A majority of respondents (234 or 78.3%) mentioned that they had social connections with community groups, particularly those that are focused on trading and business such as food selling, *pito* (local beer) brewing, *koose* (local buffloaf) frying and marketing. Most of the respondents across the study districts, Nandom (82.7%), Savelugu (74.7%) and Bongo (77.9%) indicated that they joined community groups with the aim of obtaining technical and financial assistance so that they can increase crop yield and improve incomes, which in turn will enable support their access to food. Many participants during the focus group discussions described how their social networks with community have enhanced their food security status.

A male participant at Savelugu said that:

> Five years ago, my maize farm was destroyed by wildfire, and I found it difficult to feed my children when the little food I had was finished. So, I told my group members and they organised themselves and supported me with some food to support my family (FGD, 2019).

A female participant at Bongo also said that:

> …, sometimes our group leaders organise us and ask some extension officers to come and talk to us about new ways of farming... This year we invited some extension officers to our meetings, and they educated us on when and how to apply fertiliser to get more yield (FGD, 2019).

Many respondents (257 or 86.0%) indicated that they are connected as family groups, such as clans. The proportion of respondents who were connected as family groups varied significantly across the districts with more respondents (92.6%) at Nandom having clan connections more (e.g. *Kusiele*, *Bekuone* and *Koseble*) than at Savelugu (79.3%) and Bongo (86.3%), perhaps because of the cultural diversity and attachment of dagaabas to traditional customs and clan systems perpetuated during the pre-colonial period in the Nandom traditional area (Kuuder et al., 2012). Most of the respondents mentioned that the clan relationships enable them to maintain cultural identities through informal food sharing and other support systems, which traditionally help them to reduce food security risks. A male participant at Nandom said that:

Kusieles love ourselves and support each other in times of difficulties. As farmers, we usually support each other during the planting and harvesting of crops. Some *Kusieles* are extension officers and they sometimes organise us and educate us on some of the ways that we can do to adapt to the changing climate…

Also, a female participant at Nandom said that:

> … I did not have money to buy fertiliser for my crops, but some members of the *Bekuone* clan assisted me with some fertiliser, which helped my crops to grow well with high productivity (FGD, 2019).

At Bongo, a participant also said that:

> Our clan leaders pray for a good farming season for members. When our elders pour libation, they ask the ancestors to protect us from disasters… The prayers and the community have been helping us to survive during the lean season when it is usually difficult to get food (FGD, 2019).

A male participant at Sevelugu also had this to say:

> In my clan, what we usually do is that, when a family member and his household are in food crisis, a child is adopted from the family to reduce the family burden. … Now, two of my children are staying with my clan members and I am managing with the little food I have... (FGD, 2019).

Agricultural co-operative society was another source of farming household social network across all districts. Many respondents (204 or 68.2%) mentioned that they have memberships with agricultural co-operative groups such as vegetable, poultry and yam farmers association to enable them to obtain subsidised farm inputs such as fertilisers and improved seeds for generating higher crop yield. It was noticeable that many respondents in all the study districts were concerned about the levels of bureaucratic support and access to government support, with some heightening corrupt practices of some officers and agents. A male participant at Nandom stated that:

> The government give us fertiliser and we pay half of the price. It is helping me a lot, but last year when the fertilisers came, my group could not get some because of shortage. A friend told me if I pay extra money, I can get some from the office... (FGD, 2019).

However, a male participant at Nandom said that:

> I am in a group that always finds it difficult to get the subsidised fertiliser. The officers always ask us to apply the fertiliser for more yield, but now the land has

> become used to it that if I don’t apply the fertiliser, I don’t get high yield… For some time now we don’t have an extension officer at Danko, which makes it difficult for us to get the fertiliser on time... (FGD, 2019).

At Savelugu, a female participant said that:

> The fertilisers are supposed to help our farming activities, but some officers sell the fertilisers to their family members and friends. Also, those who have money buy a lot of the fertilisers and by the time we the poor can get money to buy, they will tell us they are finished… (FGD, 2019).

At Bongo, a male participant said that:

> During the planting and harvesting period, we come together as a group and help ourselves so that each household can get adequate food. Because we are a group, we get some of the fertilisers from government. The inputs help us to get more food for our families (FGD, 2019).

However, a male participant at Bongo disagreed and said that:

> How many groups get the government support? Our group has received support once, because some officers are farmers and they have the money to buy a greater part of fertiliser for their crops… (FGD, 2019).

An agricultural extension agent noted that:

> The government has been subsidising ferlisiser for our farmers. Unfortunately, when the farmers come and the fertilisers are finished, they usually think that we are selling to family members. Our District Director is strict, and always ensures that the right thing is done, so that farmers can get the farm inputs. But the truth is that, sometimes the fertilisers are not enough for our farmers (Interview, 2019).

A large proportion of respondents (269 or 90.0%) indicated that they had developed strong social ties with friends, which in turn helps them to reduce food insecurity. While many respondents developed friendship at individual levels, they indicated that such personal relationships led them to develop more other connections with people within and outside the community. Many people emphasised that such friendship networks help them in their farming activities through financial support and food remittance. A male participant at Savelugu said that:

> I have a very good relationship with my friend. He always supports me when I run out of food in my home. He also educates me on how to apply fertiliser and agrochemicals. When it is time for weeding and harvest, he and his family come to help me. When he is also in trouble, he contacts me for help. For instance, three years ago my friend's farm was destroyed by floods and I supported him with a bag of millet and groundnut (FGD, 2019).

The survey and focus group discussion results show that farming households have developed strong social networks with individuals and groups that are helping them to access direct and indirect support systems to mitigate their food security risks at the household level.

6.3.5 The influence of social networks on perceptions of food security risks

The regression model tests whether more social networks significantly decrease the odds of food security risk. The results show that household heads who have more social ties with family groups or clans are significantly ($p < 0.05$) less likely to perceive food security risk (Table 6.5). Respondents with more social connections with agricultural co-operative societies significantly ($p < 0.05$) decreased the odds of perceived food security challenges. Household heads with more social networks with community groups are significantly ($p < 0.05$) less likely to perceive high risk of food security. In this model, social connectivity with friends and religious societies did not significantly reduce the odds of food security risk. The analysis shows that some household social networks with individuals and/or groups are significantly associated with perceptions of food security or insecurity.

Table 6.5: Logistic regression model predicting odds of social network and food security risk

Variable	Perception of food security risk				
	Coefficients (β)	Standard error (SE)	Odds ratio Exp(B)	95 % Confidence Interval (CI)	*p*-value
Family groups	-1.47	0.23	0.23	0.15 – 0.36	.000**
Friends	1.20	0.42	3.30	1.44 – 7.59	.061

Religious societies	1.08	0.56	0.34	0.11 – 1.02	.054
Agricultural co-operative societies	-1.03	0.43	2.80	1.21 – 6.50	.016**
Community groups	-1.74	0.35	0.18	0.09 – 0.35	.000**

** represents significant level at 0.05

6.4 Discussion

Smallholder farmers in northern Ghana perceive multidimentional impacts of climate change on food security and all its components of availability, accessibility, utilisation and stability. Farmers perceive that climate change impacts directly on crop and livestock production, but more respondents perceived of those impacts at Bongo than at Nandom and Savelugu, perhaps because Bongo is more exposed and sensitive to extreme climate events (Antwi-Agyei et al. 2012). The finding is consistent with similar findings in other parts of SSA (e.g. Armah et al., 2011; Codjoe and Owusu, 2011; Ringler et al., 2010), which suggest that climate change is impacting livelihoods and food availability of farming households and communities in dryland and semi-arid landscapes. Such impacts are having implications for achieving the targets of eliminating hunger and poverty, particularly in SSA (Giller, 2020; Thompson et al., 2010). Thus, it is important to develop effective strategies that can enhance the resilience of agricultural systems and generate opportunities for sustainable food production in SSA.

According to northern Ghanaian farmers, climate change impacts upon households' access to preferred foods due to factors such as low incomes, bad road networks, functionality of food markets and associated price increases. Respondents at Nandom perceived greater impacts of climate change on food accessibility than at Savelugu and Bongo, perhaps because of higher household poverty levels at Nandom (GSS, 2018). Farmers have few alternative sources of income and insufficient purchasing power so their alternative access to sufficient quality foods beyond what they produce themselves is limited. Thus, in these rural communities where many poor people depend on local foods from periodic markets, high food prices are compromising opportunities for household food security. As climate risks increase, associated food insecurities could also intensify forced migration in northern Ghana (Hesselberg and Yaro, 2006).

Farmers in northern Ghana perceive that climate change is impacting food safety at various stages of the food chain, from primary production to consumption. Respondents at Nandom were less concerned about food safety issues probably because farmers in the Upper West region have been traditionally accustomed to agroecological innovations and practices, which are more organic and relatively less harmful (Nyantakyi-Frimpong, 2020). On the other hand, the over application of agrochemicals by farmers, particularly in Savelugu could reach a tipping point where such practices may adversely affect the opportunities of the agricultural systems and intensify food insecurity. Facilitating extension education on such modern practices will be particularly important in reducing any potential unintended outcomes for food safety and security.

Respondents' sociodemographic characteristics were found to have some association with their perceptions of climate change impacts on food security. Older respondents perceived climate change impacts on food availability, perhaps because of their high vulnerability to food insecurity. The elderly are more at risk to functional impairment, which affects their workability, efficiency and productivity in crop production (Li and Sicular, 2013). Such factors potentially increase their risk to food insecurity and associated nutritional challenges. Similarly in Nigeria, Titus and Adetokunbo (2007) found that older farmers between the ages of 61 and 70 years are more vulnerable to food insecurity due to lack of financial support. Given the rapid climatic changes in recent years, it is expected that older minorities will become more vulnerability to food security risks in the coming years, particularly in SSA, which suggest the need for government, non-governmental organisations and traditional authorities to develop effective local social support systems to improve food availability and accessibility of the elderly.

The gender characteristic of respondents was also found to be associated with their perceptions of climate change impacts on food security. Females perceived climate change impacts on food availability, accessibility and stability more than males, perhaps because women are more vulnerable to climate change and food insecurity than males in northern Ghana (Adzawla and Baumüller, 2021). This finding is similar to the findings of Sekhampu (2013) in South Africa that more females experience high levels of food insecurity than males, which influences their modes of thinking and actions. In fact, in developing countries particularly SSA, gender inequality is intensifying household food insecurity on the continent (Kassie et al., 2014). Despite the general idea that women play significant roles in agriculture, exogenous forces such as access to land, economic resources and structural social and political changes could limit their opportunities to develop resilience in food systems, which may increase their vulnerability to livelihood and food security risks. This research suggest that it is imperative to address gender inequality in SSA by empowering women in agriculture to enable them to generate the needed economic opportunities for improved household food security. Also, it is important to increase women's access to agricultural lands, credit facilities, climate information and extension services to enhance their resilience to mitigate climate change risks and achieve nutritional security and dietary diversity (Asadullah and Kambhampati, 2021).

Education was found to influence respondents' perceptions of climate change impacts on food security. Farmers who had higher educational levels were less likely to experience the impacts of climate change on food utilisation. This could perhaps be partly explained by the fact that educated farmers are likely more conscious and knowledgeable of climate change and associated implications on food quality, and hence are more likely to perceive adverse effects of such changes on the nutrition of food crops produced. As Grimaccia and Naccarato (2019) also found, two-thirds of people with a lower level of education are more at risk to at least one of the components of food security than their higher-educated counterparts.

Also, respondents who had large household sizes were more likely to perceive the impacts of climate change on food availability. Household size directly influences fragility to risks. Respondents who have large family sizes are more at risk of food insecurity presumably because large household size imposes pressure on household food production, particularly under severe climatic changes. The influence of household size is not consistent with the literature, which generally shows that large family sizes have positive impacts on household labour force and high crop productivity (Abdulai and CroelRees, 2001).

The wealth status of respondents reduced their perception of climate change impacts on food security. Wealthier respondents were less likely to perceive the impacts of climate change on food availability, accessibility, utilisation and stability suggesting that they have the financial capacity to purchase agricultural inputs to increase crop yield, generate more income to enhance their food security. The effect of wealth is consistent with what is observed in the literature, i.e. that low-income farmers are more worried and highly perceptive about the impacts of climate change (Chingala et al., 2017; IPCC, 2014). These findings provide useful insights for policymakers to consider the influences of household sociodemographic characteristics in climate change risk assessment and management for sustainable livelihoods and food security.

The study also found that respondents across the study communities in northern Ghana are utilising their social networks to obtain diverse supports such as financial, training, access to farm inputs, inter-farming, food remittance and cultural to enable them to mitigate food insecurity. Respondents' social networks were spatially differentiated with more respondents at Savelugu developing social connections with religious groups than at Nandom and Bongo perhaps because of the historical attachment of households to Islam and associated principles of fanatism (Alibasic, 2007).

The provision of financial, farming and technical support through social connections help build the social capacity of households to manage climate change and food security risks (Abdul-Razak and Kruse, 2017; Martin et al., 2004). Social networks provide vulnerable individuals the opportunity to access human or material resources to increase resilience and improve agricultural activities and food sufficiency (Nostratabadi et al., 2020). For instance, inter-farming reduces farm labour cost, particularly during cultivation and harvesting, which largely increases productivity indirectly. Also, the cultural practice of adopting family members, particularly children through social connectivity helps resource constraint households to lessen their burden of food and financial risks. Such social connectedness will be particularly important for socio-ecological systems in dryland rural agricultural regions to manage environmental risks to improve livelihood incomes, which will in turn enhance access to food (Carr, 2020; Fafchamps, 2006; Pretty and Ward, 2001).

The logistic regression results show that social networks, particularly with family groups, co-operative societies and community groups decrease the odds of households' perception of food security risk in northern Ghana. The findings suggest that social networks are associated with whether a household has adequate food for dietary requirement. Therefore, this study suggests that building social networks are particularly important in reducing food insecurity among households in rural communities. Regardless of confounding factors such as household incomes, education and employment, social networks could be an important 'public good' for households in marginal resource-constrained communities (Martin et al., 2004). While social networks could be important for mitigating food security risks, their promotion should not be assumed as a substitute for economic investment in marginal communities, but rather a complement for pro-poor programmes to improve socio-economic status and well-being of rural households. Therefore, this study suggests that policymakers, local government institutions and traditional authorities strengthen social networks between households to mitigate food insecurity in disadvantaged communities.

6.5 Conclusion

This study set out to examine farmers' perceptions of the impacts of climate change on food security, and the role social networks play in reducing food insecurity in northern Ghana. The study found that farmers had perceived climate change as decreasing crop yield, disrupting crop distribution, reducing income and purchasing power, decreasing and destabilising food supply, reducing food quality and creating food safety challenges. The results suggest that farmers are experiencing diverse impacts of climate change on all aspects of food security across rural communities necessitating the need to consider local perceptions in agricultural policy decisions and building their adaptive capacities to mitigate climate change risks. However, the study found that the perceived impacts of climate change on food security varied across the study locations suggesting the necessity for policymakers and agricultural development practitioners to consider spatial differentiation in understanding location-specific climate risks and food security issues for effective interventions in rural communities.

Age, gender, education, household size and wealth status are important variables that influence perceptions of climate change impacts on food security and all its dimensions. The results suggest the need to consider household sociodemographic characteristics in climate change impact assessment and policies to build the resilience of farmers against climate change risks in semi-arid rural communities. Particularly, agricultural policies need to address the aging and migration of the labour force of growers to ensure sustainable food production at local levels.

Smallholder farmers in northern Ghana are using their social networks through both individuals and groups to develop better understandings of climate change risks and methods to promote food security. Our findings suggest that social relationships are particularly important for building farmers' adaptive capacity to mitigate climate change risks through knowledge sharing and the flow of information about agricultural innovations to sustainably improve food security. Also, social networks of households are significantly associated with decreased odds of food security risk, which suggest the need to develop the right conditions for social relationships of households in rural communities. Broadly, policymakers in SSA should consider social networks in association with agricultural systems as an important component of the social capital to assist in the mitigation of food insecurity.

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CHAPTER 7: Indigenous Adaptation to Climate Change Risks in northern Ghana

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Abstract

There is growing evidence of a range of theoretical and applied Indigenous climate change adaptation strategies, yet analyses of African examples are generally focused at single local spatial scales, with limited description of how they have evolved over time. Drawing from research across three districts in northern Ghana, this study employs a mixed-methods approach and an interpretivist framework to develop understanding of how farmers are implementing Indigenous adaptation strategies in response to climate change risks at both household and community scales. Farmers are perceiving multiple climate risks such as increased temperatures, erratic rainfall and prolonged droughts, and those risks are disrupting cropping calendars and decreasing productivity. In response to those impacts, farming households are utilising Indigenous knowledge to individually implement diverse strategies such as rainwater harvesting, relocation of farms to water sources, neem leaf extract and organic manure applications, while communities are collectively engaging in congregational prayers, rituals for rainmaking, taboos, investment in local irrigation systems and tree planting. Farmers' adaptation strategies are evolving over time, as many people are integrating Indigenous practices with modern knowledge and technologies to facilitate improvements in irrigation, organic manure application, planting drought-resistant crops, agroforestry and crop diversification. Decision-makers in local, regional and national government institutions could work to design multi-scalar adaptation interventions that support the integration of Indigenous and modern knowledge to address the complexity of climate change risks across different scales to promote sustainable livelihoods.

7.1 Introduction

Agriculture plays multiple roles in society. It is the driving force of economic growth in many developing countries, and over 70% of the very poor in rural areas depend partly or completely on the sector for their livelihoods (Food and Agricultural Organisation [FAO] 2016; United Nations [UN] 2008). In sub-Saharan Africa (SSA), agriculture is fundamental for food security and provides employment opportunities for many people. In Ghana, for example, agriculture contributes one-fifth of the national gross domestic product (GDP) and employs close to half of the country’s labour force (World Bank 2018), and there is significant potential for future agricultural development to reduce poverty in many rural communities (FAO 2016). However, rainfed smallholder agriculture is highly vulnerable to shocks, especially as many systems rely upon sufficient, timely rainfall that is becoming increasingly unpredictable in many places, including Ghana (Intergovernmental Panel on Climate Change [IPCC] 2014; Nyantakyi-Frimpong and Bezner-Kerr 2015).

The Ghanaian Climate Change Policy indicates that the country is vulnerable to multiple climatic stressors including increasing temperatures, greater rainfall variability, extreme climatic events and sea-level rise (Ministry of Environment, Science, Technology and Innovation [MESTI] 2013). Recent trends indicate that extreme warming and more rainfall variability are projected to occur across the nation even in the short term (Klutse et al. 2020). Those climate changes are affecting agricultural productivity and working to undermine food security with multiplier effects on household incomes, livelihoods and poverty levels in rural communities (FAO 2016).

Given the high vulnerability of many agricultural systems in SSA to climate change risks, and the lack of effective mitigation efforts to limit global warming, the implementation of adaptation responses has become increasingly important (Dolšak and Prakash 2018). Adaptation refers to long-term actions and decision-making processes utilised by households and communities to generate production and livelihood resilience in light of climate change risks (Moser and Ekstrom 2010). Adaptation strategies can be applied at household, community, regional, national and international scales. However, due to the complexity of climate change and the range of endogenous local development challenges, an integrated approach should be adopted to comprehensively implement adaptation actions at multiple scales to generate sustainable outcomes (O’Brien and Hochachka 2010). That integrated approach also needs to be reflexive in relation to the Indigenous and modern knowledge systems and the associated socio-cultural understandings and technologies available to smallholder farmers.

Indigenous knowledge (IK) represents the skills, beliefs and practices embedded in the cultural traditions of Indigenous people, developed through long histories of interaction with the natural environment (United Nations Educational, Scientific and Cultural Organisation [UNESCO] 2017). Empirical evidence suggests that farmers and pastoralists in Indigenous communities are utilising different IK systems to find management solutions to changing environmental conditions within their local landscapes (e.g. Bardsley 2003; Smith and Sharp 2012). In SSA, Indigenous knowledge systems, which are developed, learned and inherited over generations, are playing new roles for climate change adaptation (Nyong et al. 2007; Reiji et al. 2013). For instance, farmers are reviving rainwater harvesting techniques, diversifying production systems, changing traditional planting calendars or entreating ancestral spirits for timely rains to mitigate risk (Laube et al. 2012; Gumo 2017; Kihila 2018). However, there is limited understanding of how IK and related technologies evolve to respond to change over time in relation to both modern development opportunities and climate change risks.

Particularly in relation to Ghana, there is a growing body of literature on the importance of IK in climate change adaptation (e.g. Antwi-Agyei et al. 2014; Armah et al. 2013; Bawakyillenuo et al. 2013; Cobbinah and Anane 2016; Dapilah and Neilsen 2019). For instance, Antwi-Agyei et al. (2014) and Tambo (2016) show that small-scale farming households in north-east Ghana are utilising agro-ecological IK to design seasonal calendars that facilitate adaptation by way of improved crop planning and diversifying to less climate-sensitive Indigenous crops. Those strategies help to establish and sustain resilient rural livelihoods and even increase opportunities for local food production (Nyong et al. 2007). Yet, there remains a dearth of understanding regarding how IK and technologies in Ghana are being utilised at multi-spatial scales. A multi-scalar analysis of Indigenous knowledge is particularly important for a comprehensive understanding and targeting of local adaptation interventions to facilitate resilience in light of multiple threats to local livelihoods (Gentle et al. 2018).

This study aims to develop understanding of how smallholder farmers in northern Ghana are implementing and evolving Indigenous adaptation strategies at household and community scales.

Specifically, we address three research questions: (i) How do northern Ghanaian smallholder farmers perceive climatic risks and their impacts on agriculture at the farm level? (ii) What Indigenous adaptation strategies are being implemented by farmers at households and community scales in response to climate change risks, and how are they spatially prioritised across locations in northern Ghana? (iii) How have Indigenous adaptation strategies of smallholder farmers evolved and changed over time? Addressing these questions will generate learning about the complexity of local knowledge systems, as otherwise resource-poor farmers attempt to weld Indigenous and modern knowledge systems together to guide interventions to assist policymakers to develop effective adaptation interventions targeted at multiple scales.

7.2 Methodology

7.2.1 Descriptions of the study sites

This research was carried out in northern Ghana, which is a semi-arid region in the West African Sahel. The study covers 6 communities (Brutu, Danko, Kpalung, Nabogu, Dua Nayire and Bogorogo) within three districts, namely Nandom, Savelugu and Bongo, located in the upper west, northern and upper east regions of Ghana (Figure. 7.1).

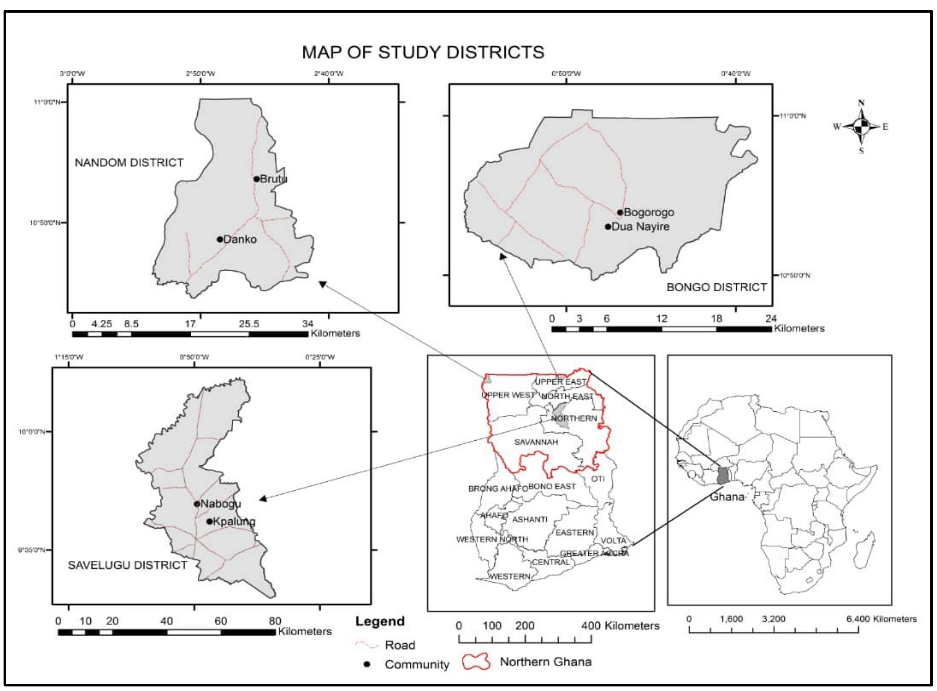

Figure 7.1: Location of the study sites in northern Ghana

The upper west, northern and upper east regions are predominantly rural and dominated by Indigenous ethnic groups of Dagaabas, Dagombas and Gurunes. Small-scale, dryland agriculture is the main livelihood activity for the people in all three regions, and poverty levels are high (Ghana Statistical Service [GSS] 2012). The regions experience variable rainfall patterns, which affect agricultural activities and production levels (GSS 2014a, b, c). Food insecurity is a significant problem in all the three regions of northern Ghana, due to poverty and low agricultural productivity (World Food Programme [WFP] 2012). Unlike the upper west and upper east regions, the northern region has been one of the major areas in Ghana where land ownership and chieftaincy related conflicts have become common, and that lack of human security further impacts on livelihoods and food security (Marfo et al. 2019).

Nandom district is one of the biggest districts in the upper west region, which is located in north-western Ghana within the Guinea Savanna Agroecological zone (GSS 2012). It has a total area of 568 km^2, with 95% of the total population of 46,040 living in the rural areas (Nandom District Assembly [NDA] 2014). About 98% of households engage in crop production including millet, guinea corn and groundnut in the district (GSS 2014a). The annual average rainfall amount ranges between 916 and 1246 mm, which normally starts in May and ends in September/October (Sam et al. 2020).

Savelugu district in the upper east region is located within the southern Guinea Savanna Agroecological zone and covers a total area of 2023 km^2 (GSS 2014b). The district has a total population of 139,283 of which 89% are smallholder farmers (GSS 2014b). About 97% of households in Savelugu district cultivate crops such as rice, groundnut, yam, cowpea and cassava, and the district has an average annual rainfall amount between 1005 mm to 1150 mm (GSS 2012; Tay 2012). The rainfall distribution is more irregular than the upper west, and sometimes excessive rainfall during the peak of the rainy season can cause flood events (Jarawura 2014).

Bongo district is located in the upper east region and lies within the Guinea and Sudan Savanna Agroecological zone (Kumasi et al. 2019). It has a land area of 460 km^2, which is inhabited by 84,545 people, with 96% of households engaged in rainfed agriculture (GSS 2014c; Kumasi et al. 2019). Bongo district has average annual rainfall volumes between 600 and 1400 mm, which supports a range of crop production, but especially sorghum (GSS 2012). It experiences very high temperatures of up to 40°C before the onset of the rainy season, and droughts are particularly severe, which impacts on crop productivity (GSS 2014c).

7.2.2 Data collection and sampling

This study applied a mixed-methods approach using an interpretivist perspective to develop socio-ecological understanding by systematically gathering quantitative and qualitative perception data at household and community levels between September and December, 2019 (McChesney and Aldridge 2019). The data collection approach was sequentially designed within a framework of integral theory, where quantitative research preceded and provided learning to guide the qualitative phase (Creswell and Creswell 2018). A three-stage sampling approach was employed, involving a purposive sampling of the study districts and a subsequent systematic random sampling of farm-households. The first stage involved the selection of the three districts in northern Ghana, which were identified by researchers as highly vulnerable to climatic risks and known to continue to utilise IK and technologies in their farming systems (see Etwire et al. 2013; Kuwornu et al. 2013). Two communities were randomly selected from each district (Brutu and Danko communities from Nandom district, Kpalung and Nabogu communities from Savelugu district, Dua Nayire and Bogorogo communities from Bongo district). In the second phase, the study undertook questionnaire-based structured interviews of farm-household heads. In the third phase, the study conducted focus group discussions on key issues, adopting purposive sampling of lead farmers.

During the second phase, a face-to-face survey was conducted to gather quantitative data of farmers' experiences of climate change risks and Indigenous adaptation strategies at household and community levels. An earlier reconnaissance trip in the district helped to identify the important perception indicators for the study. The questionnaire was pre-tested to ascertain content validity and internal consistency. Out of the total farming household population of 1181 from the six rural communities, 299 households were chosen for questionnaire administration using the formula: $n = N/1 + N(\alpha^2)$, where *n* is the sample size, *N* represents the total population, and 'α' is the precision level which was set at 5%. Proportionally, 81 household heads were sampled from 321 households in Nandom, 87 from 345 households in Savelugu and 131 from 515 households in Bongo.

In the third phase, focus group discussions were organised to generate qualitative data from lead farmers on adaptation actions undertaken individually and collectively by farming households and communities. In all, 12 separate focus groups involving a total of 60 participants (30 males and 30 females) were invited for further discussions with five participants in each of the 12 focus groups. Participants were recruited through an invitation to lead farmers with at least 30 years of farming experience who had indicated a willingness to participate during the second phase. Participants deliberated on climate risks and Indigenous practices in the study districts at household and community levels. The focus groups were conducted in the local dialects in each location, Nandom (*Dagaare*), Savelugu (*Dagbani*) and Bongo (*Gurune*) with the help of local field assistants, and each discussion lasted between 60 to 90 minutes. The discussions were framed by a series of questions covering farmers' perceptions of climate risks and associated impacts; Indigenous adaptation strategies at household and community levels; and the evolution of Indigenous adaptation practices in relation to climate risks. The study followed all ethical procedures with approval (H-2019-058) from the Office of Research Ethics Compliance and Integrity at the University of Adelaide, Australia.

7.2.3 Data analysis

The survey data were analysed quantitatively with the help of SPSS version 21 (Pallant 2020). Statistical procedures including cross-tabulation were employed to analyse respondents' perspectives on and experiences of climate change risks and Indigenous adaptation strategies implemented at household and community levels. Also, a one-way analysis of variance (ANOVA) was used to compare the differences in farmers' perceptions and adaptations across the three study districts (Kim 2014). The qualitative data from focus group discussions were analysed thematically to detail adaptation strategies and their evolution at the household and community level. The interview data were recorded on audiotape with participants' consent and transcribed from local dialects (*Dagaare, Dagomba and Gurune*) to English with the help of local language transcription experts. It is recognised that some of the subtle complexity of voiced responses was lost during translation. Nevertheless, the emergent themes were categorised and associated narratives identified to detail support using direct quotations for claims generated through the quantitative analysis. In this manner, the qualitative results were triangulated with the quantitative results to develop a more thorough understanding of local risks and opportunities for adaptation.

7.3 Results

7.3.1 Socio-demographic characteristics of household survey

The survey respondents are adults, with an average age group of 36–45 years across the study districts (see Table 7.1). The majority of smallholder farmers had no formal education, which in itself could be an important barrier to climate information access (e.g. from technical sources or mass media) and is likely to limit the adaptive capacities of farmers (Ndamani and Watanabe 2016). There were more household respondents from Bogorogo than in other communities, which also reflects data from 2010 national population census of Ghana (GSS 2014c). The average household size of respondents was 4 to 7 inhabitants across all three districts. Respondents owned an average land size of less than 2 ha, which is equivalent to the global average for smallholder farmers in many developing countries, and particularly in SSA (Lowder et al. 2016).

Table 7.1: Socio-demographic attributes of respondents across study communities

Communities	Districts	Number of households	Average age (years)	Average household size	Educational level	Average land holdings (ha)
Danko	Nandom	119	3.33	2.07	1.90	1.60
Brutu		202	3.53	2.33	1.84	2.86
Nabogu	Savelugu	202	3.09	2.80	1.45	1.75
Kpalung		143	3.64	3.25	1.75	2.39
Dua Nayire	Bongo	188	3.25	2.35	1.77	2.00
Bogorogo		327	3.99	2.29	1.45	1.63
Minimum			1	1	1	1
Maximum			6	4	4	5
Mean			3.53	2.49	1.65	1.24
Standard deviation			0.08	0.06	0.05	0.07
Age: 18-24yrs=1, 25-35yrs=2, 36-45yrs=3, 45-55yrs=4, 56-65yrs=5, >65yrs=6 Household size: 1-3=1, 4-7=2, 8-11=3, >11=4 Education: No education=1, Basic=2, secondary/Technical=3, Tertiary=4 Land holdings: <2ha=1, 2-3ha=2, 4-5ha=3, 6-7ha=4, >7ha=5						

NB: The variables were numerically coded as follows:

7.3.2 Perceived climate risks and impacts on agriculture at the farm level

Smallholder farmers in northern Ghana perceive that they are experiencing more variable rainfall, increased temperature and more extreme climate events (see Table 7.2).

Table 7.2: Perceived climate risks and impacts at the farm level in northern Ghana

Perceived climate risks	Study districts			Total n=299(%)	One-way ANOVA (*p*-value)
	Nandom n=81(%)	Savelugu n=87(%)	Bongo n=131(%)		
Erratic rainfall	67(82.7)	84(96.6)	124(94.7)	275(92.0)	0.00**
Prolonged droughts	76(93.8)	82(94.3)	119(90.8)	278(93.0)	0.74
Increased temperatures	74(91.4)	83(95.4)	108(82.4)	266(89.0)	0.01**
Frequent flood events	41(50.6)	77(88.5)	96(73.3)	212(70.9)	0.00**
Frequent wildfires	74(91.4)	78(89.7)	111(84.7)	263(88)	0.86
Perceived impacts					
High incidence of diseases/pests in crops	73(90.1)	85(97.7)	114(87.0)	272(90.9)	0.19
Disappearance of Indigenous crop species	74(91.4)	81(93.1)	100(76.3)	254(84.9)	0.00**
Decreased crop productivity	76(93.8)	80(92.0)	126(96.2)	284(95.0)	0.08
Disruption of cropping calendar	75(92.6)	78(89.7)	121(92.4)	290(97.0)	0.10
Loss and damage to crops	79(97.5)	81(93.1)	121(92.4)	266(89.0)	0.00**

** denotes statistically significant at the 5% significant level

Most of the 299 respondents, (93.0%) identified prolonged drought as the major climate risk experienced over the last few decades. Severe drought events were recognised as becoming more regular across each of the study districts, Nandom (93.8%), Savelugu (94.3%) and Bongo (90.8%). This finding was emphasised during the focus group discussion when a female participant at Bogorogo in Bongo said: '*Drought is our major problem as farmers in this community and the situation is worse during the dry season'*. Erratic rainfall was reported by most respondents (92.0%) as the second most important climate risk they have been experiencing. However, there were some statistically significant differences (F = 8.21; $p < 0.05$) in respondents' answers across the study districts. More respondents at Savelugu (96.6%) and Bongo (94.7%) perceived of increasingly erratic rainfall than those at Nandom (82.7%), perhaps because the latter is further to the west with less rainfall variability (Nkrumah et al. 2014). Also, a large proportion of respondents (89%) perceived increases in temperatures, but again results varied significantly (F = 5.12; $p < 0.05$) across the districts, with respondents at Savelugu (95.4%) and Nandom (91.4%) more likely to perceive temperature increases than those at Bongo (82.4%). Location may again play a role here, because Bongo is to the north-east where average temperatures are regularly warmer anyway (Issahaku et al. 2016).

The perceived climate risks, particularly in relation to temperature and rainfall, largely align with meteorological records over the past five decades (see Figure 7.2). Although records also indicate rising temperatures, a limited trend in rainfall totals are observed. There is some indication of more variable inter-annual rainfall in the three districts, although the available average data conceals any intra-annual variability.

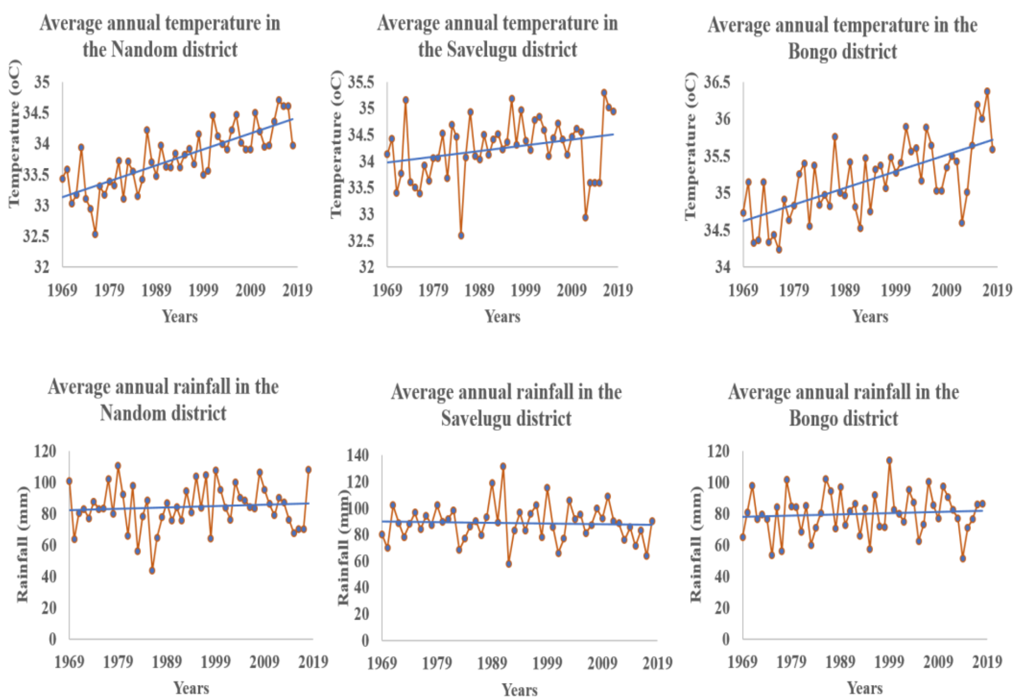

Figure 7.2: Meteorological data of average annual temperature and rainfall in the study districts

Source: Ghana Meteorological Agency (2019)

A large proportion of respondents (70.9%) observed more frequent flood events, but that observation varied significantly across the study districts ($F = 17.70$; $p < 0.05$) with more observations at Savelugu (88.5%) and Bongo (73.3%), than at Nandom (50.6%). Farmers at Savelugu expressed concern about more regular flooding in the region during the focus group discussions. A male participant at Kpalung in Savelugu said that: '*Every year we are confronted with flooding issues, and yet nothing is done about it. Last year, for example, I lost all my crops* *and livestock due to flooding during the rainy season*'. A large proportion of respondents (88.0%) also perceived more frequent wildfires, although the level of observation varied only slightly across the districts, Nandom (91.4%), Savelugu (89.7%) and Bongo (84.7%).

The smallholder farmers reported that climate change was having significant impacts on their farming activities. Almost all respondents (97.0%) reported that their cropping calendar had been disrupted due to increasingly erratic rainfall regimes, which make it increasingly difficult to predict patterns. A male participant from Kpalung in Savelugu noted that: '*It is now difficult to predict when the rains will fall. This has forced me to adjust my planting calendar'.* Most respondents (95.0%) perceived that the multiple climatic stressors have resulted in decreased crop productivity. Many of the respondents mentioned that due to the rainfall uncertainties and extreme climate events, the seasonal crop output of their dryland systems has been declining in recent years. A large proportion of respondents (90.9%) also perceived that climate change has intensified incidences of crop diseases and pests. Farmers particularly highlighted the increasing fall armyworm (*Spodoptera frugiperda*) infestations, which affect their productivity. Reflecting on this issue, a male farmer at Dua Nayire in Bongo said that: *'The fall armyworms have been destroying my maize farm. When they attack the crops, they feed on the seeds and destroy them. Last year, the pests destroyed half of my one-acre maize farm'.*

Most respondents (89.0%) mentioned that they had experienced loss and damage to crops as a result of wildfire or flood events. That experience of respondents varied significantly ($F = 9.76$; $p < 0.05$) across the study districts with more respondents at Nandom (97.5%) perceiving crop losses than in Savelugu (93.1%) and Bongo (92.4%) districts, perhaps because respondents in Nandom experience particularly strong winds and wildfires, which can destroy crops. Since most farmlands are in low-lying areas, respondents mentioned that floods significantly affect their crop output and disrupt their livelihoods. Farmers, again particularly at Savelugu, voiced concerns about perennial flood impacts during focus group discussions. A male participant from Nabogu said that: '*One major problem for us is the floods, which occur every year and destroy our farms. When the Bagri dam is opened upstream, the problem becomes more severe*'. Most respondents (84.9%) perceived that one or more crop species have disappeared due to the changing climatic conditions, although there were some statistically significant differences ($F = 8.25$; $p < 0.05$) in responses across the study districts. For instance, a higher percentage of respondents in Nandom (91.0%) and Savelugu (93.0%) perceived the loss of crops than those at Bongo (76.0%).

7.3.3 Indigenous adaptation strategies in response to climate change risks

7.3.3.1 Indigenous adaptation strategies at the household scale

Respondents were specifically asked whether they are employing any adaptation strategies, and the responses were analysed from the reduced cohort (n = 213) of the total sample who were taking specific actions in response to climate change risks. The 86 respondents not adapting were largely of the view that the recent climate change risks they face are temporary and natural, and they are optimistic things will change for the better in the future.

A majority of the adapting households (94.4%) indicated that they use organic matter from droppings of livestock. The manure are obtained from livestock coops near the house and spread on farmland, either before or after crop cultivation, to improve soil quality, reduce water loss and increase yield. (see Table 7.3).

Table 7.3: Indigenous adaptation at household and community levels

Household-level adaptation	Study districts			Total n=213(%)[i]
	Nandom n=64(%)	Savelugu n=55(%)	Bongo n=94(%)	
Irrigation	33(51.6)	50(90.9)	55(58.5)	146(68.5)
Rainwater harvest	57(89.1)	41(74.5)	78(83.0)	176(82.6)
Relocating farms to water sources	44(68.8)	54(98.2)	77(81.9)	175(82.2)
Changing planting time	49(76.6)	35(63.6)	77(81.9)	161(75.6)
Organic manure	64(100)	53(96.4)	69(73.4)	201(94.4)
Mulching	49(76.6)	53(96.4)	78(83.0)	180(84.5)
Mixed cropping	61(95.3)	53(96.4)	60(63.8)	174(81.7)
Mixed farming	21(32.8)	54(98.2)	92(97.9)	167(78.4)
Raising ridges and mounds	58(90.6)	27(49.1)	77(81.9)	163(76.5)
Agroforestry	27(42.2)	54(98.2)	66(70.2)	147(69.0)
Planting drought resistant crops	43(67.2)	40(72.7)	48(51.1)	131(61.5)
Crop diversification	57(89.1)	44(80.0)	92(97.9)	193(90.6)
Neem leaf extract	64(100)	53(96.4)	69(73.4)	186(87.3)
Community-level adaptation				
Investment in irrigation	46(71.9)	44(80.0)	66(70.2)	156(73.2)
Tree planting	43(67.2)	48(87.3)	81(86.2)	172(80.8)

Taboos	33(51.6)	22(40.0)	40(42.6)	95(44.6)
Rituals for rainmaking	22(34.4)	30(54.5)	94(100)	146(68.5)
Congregational prayers	50(78.1)	39(70.9)	67(71.3)	156(73.2)

[i]The percentages were calculated based on the sample cohort of adapting farming households and communities

Adapting farmers either applied the solid droppings directly onto the soil, or mash the droppings after soaking them in a barrel of water for some days, and sprinkle them on the soil under crops. At Brutu in Nandom a male participant said that: '*… I have been using more organic manure than I used to do because I am not getting enough yield due to the extreme climate events which are affecting the quality of the soil. Even though I sometimes use inorganic fertiliser, I still apply more organic manure…'*.

Crop diversification was another Indigenous strategy implemented by many adapting farming households. Many adapting respondents (90.6%) reported that they have partially diversified their crops by shifting from the sole cultivation of food crops that require a lot of water to include more tree cash crops that do not require as much. While crop diversification is one of the oldest Indigenous risk management practices on farms in northern Ghana, many people are now cultivating cash crops to spread the risk of crop failure and to improve incomes. A male participant at Kpalung in Savelugu said that: '*I have been planting cashew for the past ten years. There is good market for that, and I am taking advantage of it to increase my income...'*.

Agroforestry was also identified as an important adaptive strategy to mitigate the risks of extreme climate events. Agroforestry is conceptualised as the planting of forest trees or cash crops together with field crops. More than half of the adapting farmers (69.0%) indicated that they have been using IK to cultivate Indigenous trees with food crops on their farmlands. Also, respondents (61.5%) indicated that they continue to cultivate Indigenous crop varieties that are more resistant to severe droughts than potentially higher yielding modern varieties. For example, households have been using their IK to cultivate traditional millet variety as an important staple to avoid unstable food supplies between farming seasons.

Neem (*Azadirachta indica*) extracts are utilised by many farmers to control fall armyworm (see also Shaiba et al. 2019). A large proportion of respondents (87.3%) mentioned that they are utilising IK to prepare and apply neem leaf extract to control the spread of crop pests and diseases, particularly fall armyworm. This practice is not widespread in many other communities, especially those in the towns. A female participant at Danko in Nandom said that: '*About five decades ago pests were not attacking my crops like what has been the case in recent years. Last year like this, my backyard garden was attacked by fall armyworm which destroyed my sorghum. So, what I did was that, I applied neem leaf extract to control the pests'*.

In managing water stress during severe drought periods adapting households employed several Indigenous strategies such as local hand-watering irrigation (68.5%), traditional rainwater harvesting (82.6%) and the relocation of farms to water sources (82.2%). Farmers utilised IK to harvest rainwater directly from rooftops and store it in traditional pots or barrels for irrigation in their backyard farms for a couple of days. Many used the traditional method of digging temporary holes on the farms to harvest and store rainwater for irrigation during drought periods. Irrigation is usually by hand-watering, where farmers manually fetch water and sprinkle on crops rather than use hoses. However, farmers also employ the traditional relocation of their farming activities to nearby water sources to enable temporary irrigation of crops. It was observed that because of increasing land tenure challenges, the traditional relocation of farming activities was not widespread across study districts.

Over half of respondents (75.6%) utilised IK to adjust their cropping calendar by planting with the late rains around June/July as rains became less unpredictable. In addition, mixed cropping was identified by farmers as another important adaptation strategy to reduce climate change impacts. A large proportion of respondents (81.7%) used IK to implement mixed cropping by cultivating different varieties of Indigenous food crops such as millet and sorghum on the same plot of land. Many of the farmers are intensifying the mix of crops to maximise land use and reduce the risks of single crop failure due to climatic variability.

Many adapting households (78.4%) applied IK to combine the cultivation of crops and the rearing of livestock on the same plot of land, especially on a small scale in their yards. They stressed that livestock such as cattle and donkeys are used to plough the land for planting and manure is used to fertilise the soil, while the crops such as millet and sorghum are used to feed the livestock, other farm animals and the family. Mulching is another important Indigenous adaptation strategy implemented by farmers. Respondents (84.5%) indicated that they have been applying dried or fresh leaves as mulch for crops to help mitigate the impacts of extreme temperatures on soil moisture and improve soil nutrition.

Over half of adapting households (76.5%) protect their crops against erosion, particularly during the peak of the rainy season by planting on ridges or mounds. This adaptation strategy was commonly practised by household farmers, particularly for the cultivation of millet yam (*Dioscorea sp.*) and vegetables. Respondents stated that they have been using IK to raise ridges in rows to follow the slope contours to ensure better water and crop root penetration, and provide channels for runoff water to be conserved on the farm without water-logging crops. A male at Brutu in Nandom said that: '*In the 1980s, I was not planting on ridges. At that time floods and the winds were not that severe and frequent as we experience in recent years. But, now if I don't raise ridges for the millet, the strong winds will destroy them'*.

At the household level, adapting farming respondents had different adaptation priorities across the study locations (see Table 6.3). For instance, farmers at Nandom prioritised neem leaf extract (100%) and organic manure application (100%), while those in Savelugu prioritised agroforestry (98.2%), mixed farming (98.2%) and relocation of farms closer to water sources (98.2%) as important adaptation strategies to mitigate climate change. Farmers at Bongo were more interested in crop diversification (97.9%) and mixed farming (97.9%). The next section will focus on how farming communities utilise IK collectively to adapt to climate change risks.

7.3.3.2 Indigenous adaptation strategies at the community scale

Adapting farming households were asked about the Indigenous strategies adopted by their communities in response to climate change. Only the reduced cohort of adapting community members (n = 213) responses are analysed according to their identification of community-based adaptive actions to mitigate climate change risks (see Table 7.3).

A large proportion of adapting households (80.8%) identified Indigenous tree planting as an important adaptation strategy at the community level. Communities are collectively planting Indigenous trees to draw up sub-soil nutrients and create pest-predator habitat, to provide shade and shelter, and to serve as meeting grounds for community deliberations and cultural activities. Plantings receive support from district assemblies and a range of international non-governmental organisations as they are seen as a method to reduce the impacts of climate change and extreme weather events. A male participant at Bogorogo in Bongo said that: '*In the last thirty years, we have been planting many trees in our communities. This is because strong winds are destroying many of our buildings and crops. Because of that, the Bongo chief and his elders have integrated tree planting as part of our annual festival celebration, so that the impacts of the strong winds on our communities can be reduced'*.

Respondents (73.2%) stated that communal investment into irrigation infrastructure was another Indigenous strategy collectively implemented by communities in response to drought. Communities pool their resources together, particularly during traditional festivals to build or construct Indigenous wells to help farmers get access to water to irrigate their crops. A female participant at Danko in Nandom said that: '*We have been contributing money to help the construction of irrigation projects because many of our rivers are now drying up quickly due to the severe droughts'*.

Communities also utilise congregational prayer as a form of Indigenous strategy to mitigate the impacts of climate change risks. Nearly three quarters of adapting households (73.2%) mentioned that community members usually meet to communicate with God to generate solutions to their problems, including droughts. They stated that prayers and religious consultations through libation have been part of their Indigenous traditional practices for a long time. However, religious organisations in the communities are now meeting explicitly to pray for more regular rainfall, to avert the increasing rate of climate disasters. A female participant at Danko in Nandom said that: '*Every year, the Roman Catholics meet at the Grotto to pray, and regular rainfall is usually one of the things we are normally asked by the Priest to pray about. God controls the Universe, and if there is anything wrong in the universe, He has the power to reverse it to our advantage. When we pray, we sometimes get the results immediately or in the future'*.

Specific rituals for rainmaking is a closely related Indigenous strategies employed by communities in the study districts. Well over half of the adapting households (68.5%) acknowledged that their communities consulted traditional deities or gods and performed rituals for rainmaking during long periods of droughts. They emphasised that the heads of clans and traditional leaders of the community usually gather around a deity or god to perform rituals calling for rains. According to the respondents, rituals have become an important adaptation strategy in recent decades due to climate change. A male participant at Dua Nayire in Bongo said that: '*In recent years, when the rains are not coming during the rainy season, the Bolga chief asks all regents to come to Dua to perform animal sacrifices to the gods. After the sacrifice, they chant to request for the rains from the gods. Once the incantations are done, the rains usually come two to three days later'*.

Taboos are traditional rules and regulations that bar people from taking certain actions that are considered sacrilegious. Just under half of adapting households (44.6%) indicated that traditional leaders have been using the IK to institute community-wide taboos to protect water and forest resources which are believed to be habitats of ancestral deities. For example, it is forbidden to cut down trees around water catchment areas. While respondents recognised that taboos are not necessarily directly for climate change adaptation, they protect natural resources, and indirectly support community resilience.

Again, there are different levels of community adaptation actions across the study locations in northern Ghana (see Table 7.3). Respondents at Nandom indicated that their communities are collectively prioritising congregational prayers (78.1%) while communities at Savelugu and Bongo prioritise Indigenous tree planting (87.3%) and rituals for rainmaking (100%), respectively. Communities in northern Ghana are thinking and working collectively to help mitigate global climate change risks at the local level, often in association with new, modern ideas.

7.3.4 The evolution of adapting farming households' indigenous practices

Adapting farming households were specifically asked whether they were using their IK independently of modern approaches or whether they were looking to evolve their IK over time in association with new ideas and technologies. Again, the study analysed only the survey results from the reduced cohort of individual adapting farming households (n = 213). The majority of adapting farming households (84%) indicated that their IK and technologies have changed over recent decades. Male respondents identified more evolving Indigenous practices than female respondents in Nandom (64.1%), Savelugu (79.7%) and Bongo (54.3%) districts (see Figure 7.3).

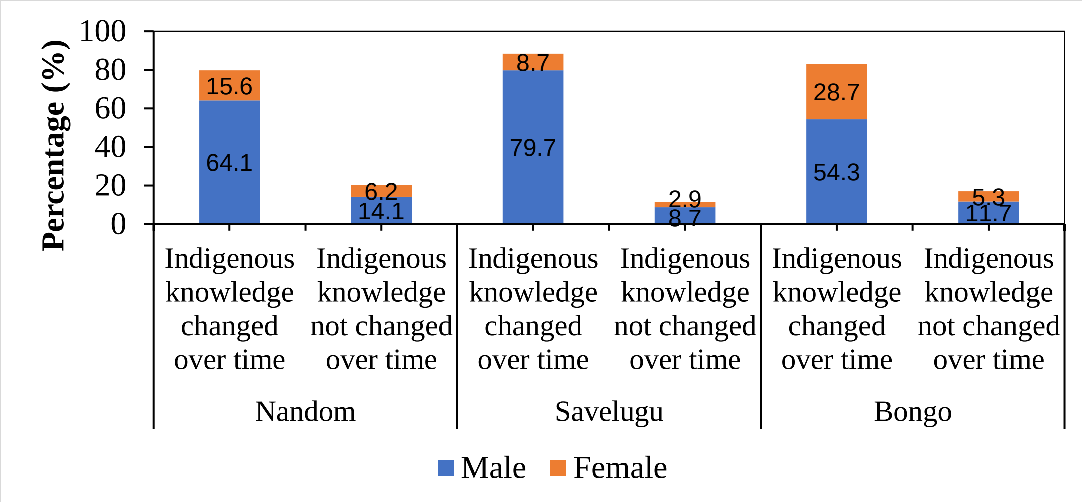

Figure 7.3: Summary of adapting farming households' Indigenous strategies that have evolved in the study districts

The results from the focus group discussions show that smallholder farmers in northern Ghanaian communities are integrating their IK with modern technologies, particularly in forms such as planting new drought-resistant crop varieties, agroforestry, organic manure and crop diversification for climate change adaptation to improve crop productivity and sustain livelihoods. Because there is no space to go through all examples of this integration, the widespread example of improving soil quality, and the use of new crop varieties are detailed to indicate how adapting farming households' Indigenous adaptation strategies are evolving in northern Ghana (see Table 7.4).

Table 7.4: Evolution of adapting farming households' Indigenous strategies

Indigenous strategies	Study districts		
	Nandom	Savelugu	Bongo
Rainwater harvest	OI	OI	OI
Irrigation	IT	IT	OI
Relocating farm to water sources	OI	OI	OI
Raising ridges or mounds	OI	IT	OI
Planting drought-resistant crops	IT	IT	IT
Mulching	OI	OI	OI
Mixed farming	OI	OI	OI
Changing planting time	OI	OI	OI
Agroforestry	IT	IT	IT
Mixed cropping	OI	IT	IT

Organic manure	IT	IT	IT
Crop diversification	IT	IT	IT
Nee leaf extract	OI	OI	OI

NB: OI denotes Only Indigenous and IT Integrated

During focus group discussions, participants described how they integrate IK with modern approaches to improve soil quality. For instance, a male participant at Brutu in Nandom said that:

> I used to apply only animal manure about thirty years ago. But, in recent years, I have been combining organic manure with artificial fertiliser for better and quicker results. I usually use livestock droppings and other organic materials as manure. I put them in a container and add water till they decay. When my maize begins to grow, I dig holes at the base of the crops, and add the manure. After some weeks before the tassels start bearing fruits, I apply my fertiliser (FGD, 2019).

However, a male participant at Nabogu in Savelugu had this to say:

> The quality of the soil now is not as good as it used to be fifty ago. So, to get a good yield, I have been mixing organic manure and chemical fertiliser for the past two decades. I move my livestock to the farm to graze before I start planting my crops. As the livestock graze the land, their droppings add manure to the soil. After some weeks, I then use the chemical fertiliser to spray over the crops. Since I started doing this, I have seen significant improvement in my yield (FGD, 2019).

At Bogorogo in Bongo, a female participant stated that:

> Ever since the government started subsiding fertiliser for farmers, I have been using fertiliser in addition to poultry droppings. Usually, I don't apply the manure before the fertiliser as others do – I find it a bit tedious. So, I mix them in a bowl and spread them at the base of my crops. I am combining manure with fertiliser because the land is no longer fertile due to erosion (FGD, 2019).

In one further example, farmers across the study districts demonstrated interest in integrating local and modern crop varieties into their cropping systems. During focus group discussions, participants indicated that they integrate drought-resistant Indigenous crop varieties with improved early maturing varieties to diversify their production systems and income sources. A male participant at Danko in Nandom said that:

> I have been cultivating the local maize and *Obatanpa* variety together on the same plot of land. I usually cultivate the two varieties according to rows… I combine the local and modern crop varieties so that when one variety fails to do well, I can get some food and income from the other variety. Last year, I got high yield from both varieties, and I was able to get more money to buy a spraying machine for my farming activities (FGD, 2019).

At Kpalung in Savelugu, a female participant stated that:

> I cultivate Indigenous varieties and the early maturing varieties on two separate farmlands. The two farmlands are small ones … I usually cultivate different types of crops on the separate farmlands. Last year, I cultivated millet and sorghum on one farmland, and maize on the other farmland. I cultivate *Obatanpa* maize, which is a modern variety and matures very early together with my Indigenous millet, which can withstand severe droughts. I get a lot of yield from the *Obatanpa*, which helps me to get more food for my family (FGD, 2019).

Similarly, a male participant at Dua Nayire in Bongo, said that:

> I inherited three different separate farmlands from my late father. I cultivate different crops on all the farmlands every farming season. Usually when the rain starts, I first cultivate only Indigenous maize varieties, which do well even during droughts, on one of the fields. Later, when I realise the rainfall will be regular, I then cultivate my modern variety of maize (*Obatanpa*) on the second field and then rice on the third field. This is what I have been doing to get more income (FGD, 2019).

The desire of many farmers to integrate IK with modern strategies may partly be explained by the intensification of agricultural extension education across the districts, which for example are emphasising modern soil and pest management solutions, which the farmers integrate with IK in their farming systems to reduce the risks of production.

7.4 Discussion

Smallholder farmers in northern Ghana perceive a range of climatic risks, which they claim are impacting upon their agricultural systems, particularly cropping calendars and crop productivity. However, respondents' perceptions of erratic rainfall, increased temperatures and frequent flood events varied across the study districts. Respondents at Savelugu were perceiving more change than those at Nandom and Bongo, perhaps because of recent experiences of extreme events which were not experienced in the past. Similarly, respondents' perception of climate impacts varied across the study locations. Respondents at Nandom perceived more crop loss and damage than at Savelugu and Bongo, perhaps because of recent experience of wildfires during the dry season, which destroyed farmlands. This finding aligns with similar studies in Ghana (see Nboyine et al. 2020) and Africa more broadly (see Calzadilla et al. 2013; Knox et al. 2011), suggesting that climate change is impacting crop yields in dryland communities disproportionally, and opportunities to respond are often limited.

Given the already fragile livelihood situations of rural farming communities in the region, that situation raises important development challenges for hunger and poverty alleviation. Farmers' perceptions were spatially differentiated across northern Ghanaian locations. Many farmers in Savelugu district which is farther south of the Sahel than Nandom and Bongo perceive of more extreme climate events, such as droughts, perhaps because of the weakening of the African Monsoon in West Africa (Shanaham et al. 2009). Therefore, it could be expected that more places that were hitherto not experiencing severe droughts will experience more severe events in the future. The complexity of climate change therefore makes it more important to implement adaptation opportunities at both household and community scales.

Farming households and communities are utilising their IK, skills and practices to implement a diversity of adaptation strategies to promote food security. At the household level, farmers implemented strategies such as organic manure, crop diversification, neem leaf extract, mulching, relocating of farming activities to water sources and rainwater harvesting. However, not all the strategies were practised widely across all communities of the study districts. For instance, the relocation of farms closer to water sources was not popular in Nandom district compared to Savelugu and Bongo, which may be due to land tenure challenges. This finding aligns with Antwi-Agyei et al. (2014) who found similar Indigenous practices among households in North-eastern

Ghana. From the focus group discussions, it is clear that adaptation actions are not only in direct response to climate change, but also to other, non-climatic factors. For instance, the diversification to cashew cultivation by farmers in Savelugu district was attributed directly to recent market demand in northern Ghana. This suggests that farming households are developing resilience against climate change risks within the broader context of all stressors and opportunities that are altering rural livelihood situations (O'Brien and Hochachka 2010).

At both household and community scales, farmers are planting trees to mitigate their vulnerability to climate change risks. Apart from that practical activity however, farming households were individually more focused on implementing tangible Indigenous adaptation strategies, while the community actions were primarily intangible. Community actions in northern Ghana appear to focus on developing individual or social capacities to undertake tasks, rather than the physical activities themselves. That communal goal may be in response to the fragmented governance structures for adaptation planning in Ghana, which are not providing formal guidance for actions in many cases (Dapilah et al. 2020). The complex nature of climate change adaptation governance systems requires a deeper understanding of how the dynamics of community decision-making generate adaptation outcomes at the local level (Hamilton and Lubell 2019). Perhaps traditional communal religious activities could provide a potential vital mechanism across the region for coordinating a polycentric response to risk in lieu of sophisticated state regulations.

For example, the results suggest that northern Ghanaian communities are implementing different Indigenous strategies including tangible and other intangible practices such as investment in irrigation, tree planting, taboos, rituals for rainmaking and congregational prayers, with the aim of mitigating climate change risks. However, from the focus group discussions, it is evident that communities rely heavily on belief systems to undertake adaptation strategies in response to climate change risks. Congregational prayers and rituals for rainmaking were prioritised more by farming communities in Nandom and Bongo than at Savelugu, partly because of the strong attachment to Christianity and traditional religion in those districts. Gumo (2017) similarly found that communities in Kenya have been utilising prayers for rain during drought periods. Farming communities are utilising congregational prayers to generate social capital that in turn enable them to work together and share ideas to manage risks. Such communal activities that generate mutual supportive actions could become more important in a risky, reflexive modernity (Fraser et al. 2003).

Both spatial and cultural dimensions are important for consideration in climate change adaptation planning to improve sustainable livelihoods. At the household level, smallholder farmers at Nandom are prioritising application of neem leaf extract as a biochemical ‘agent’ to fight fall armyworms infestation – an approach that could be more widely supported in the region. Nboyine et al. (2020) similarly report the efficacy of neem extract in controlling rapid invasion of fall armyworms in north-western Ghana. On the other hand, mixed farming is prioritised by farmers at both Savelugu and Bongo, and that could be partly explained by the broader application of the traditional household practice of livestock rearing in many savannah regions (Wood 2013), but again, the approach could be more widely integrated into farming systems. These findings are consistent with findings elsewhere that suggest that adaptation strategies vary across different locations (see IPCC 2014; Macchi et al. 2014), but there are also learnings from one district or system that could provide interesting opportunities elsewhere.

Local IK is being used in association with modern ideas to evolve effective climate change adaptation responses (Nyong et al. 2007). Northern Ghanaian farmers’ Indigenous adaptation strategies in response to climate change risks have evolved in contemporary times with the integration of modern technologies (e.g. application of agrochemical and fertiliser and the use of early maturing improved varieties) to build resilience and enhance food security. Farmers are using modern ideas and information from international non-governmental organisations and local government institutions, particularly agricultural extension departments to inform decisions in their traditional farming systems. In light of this, it is increasingly imperative to continue to promote knowledge integration, rather than a simple replacement of traditional local knowledge and approaches with new, external ideas. Many farmers are already integrating Indigenous and modern knowledge systems to mitigate climate change risks, and the simultaneous promotion of such an integration could be an important mechanism for avoiding maladaptation for improved livelihood and food security in Ghana, but also in other developing rural regions in SSA.

7.5 Conclusions

Northern Ghana represents an important semi-arid region where multiple climatic stressors on rainfed agriculture are generating an urgent demand for adaptation at different spatial scales. This study contributes to the literature by arguing that multi-scalar adaptation interventions are increasingly important for developing sustainable livelihoods. The research findings show that farmers in northern Ghana are perceiving different climate risks that have the potential to undermine their agricultural systems. In response to the changing risks at the household level, farmers are implementing individual tangible Indigenous adaptation strategies including crop diversification and manure application. In contrast, communities are collectively implementing Indigenous adaptation practices, which include intangible ones such as congregational prayers and rituals for rainmaking, with the goal of reducing their vulnerability. Unlike household level adaptation practices, community level adaptation actions seem to be largely focused on interactive approaches for improving social capacity rather than guiding many specific, direct interventions.

Indigenous adaptation strategies need to continue to be appreciated at household and community scales in dryland farming systems as a pathway for strengthening local resilience against climate change risks. It may be necessary to develop intervention methods that are unique to households and communities separately, to generate more acceptable and sustainable outcomes. While traditional practices that work effectively need to be prized, modern practices are having increasing influence, so it will be necessary to support multi-scalar adaptation interventions that integrate Indigenous and modern knowledge, while not degrading local ideas. This is increasingly important because the complexity of climate change risks requires reflexive, dynamic and integrated approaches that can comprehensively reduce potential risks. The spatial prioritisation of farming households' and communities' Indigenous adaptation strategies across different locations suggest that decision-makers will need to formulate and implement location-specific policies to ensure successful adaptation planning at the local level.

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CHAPTER 8: General Discussion

8.1 Overview

Climate change is undermining agricultural systems with cascading effects on livelihoods, food security and poverty levels of households, particularly in marginal rural communities in sub-Saharan Africa (SSA), and particularly northern Ghana. Given the considerable impacts of climate change on agricultural systems and livelihood opportunities of socio-ecological systems in the region, governments, non-governmental organisations, foreign donors and researchers are advocating and supporting farmers to adapt to climatic change by intensifying agriculture through the implementation of modern approaches such as modern seed varieties to improve food security on the continent. Such modern approaches are important in moderating environmental risks, yet the problem of food insecurity remains one of the major challenges in northern Ghana where climate change risks and extremes are intensifying. Given that modernisation policies and innovations imposed on many African countries have not sufficiently addressed food security challenges, farmers in many rural communities in northern Ghana are utilising their Indigenous knowledge (IK) and social networks as important social capital to sustainably address climate change and food security risks. These insights suggest that farmers' IK and technologies can be valued as an important local diversity pathway that can complement modern approaches to mitigate food insecurity in resource-constrained communities in SSA.

Chapters one and two of this thesis introduced the vulnerability of agricultural systems to climate change and food security issues in the Ghanaian context. The chapters also discuss adaptation theory and opportunities for knowledge integration in dryland farming systems. Chapter three provided an overview of the research methods and methodologies and their philosophical underpinnings. Chapter four examined the complexity of IK at regional and continental levels across SSA and argued for the need to adopt a *sui generis* system to ensure effective natural resource management while mitigating resource conflicts in Ghana and the Sahel. Chapter five discussed the importance of integration of local perceptions and scientific evidence to comprehensively understand and address climate change risks. Chapter six presented evidence on the importance of social networks in building individual and community resilience to enhance household food security in northern Ghana. Chapter seven discussed the evolution of IK with modern approaches to mitigate climate change at household and community scales. Given that the thesis is a blended form, this chapter, chapter eight, will provide a summary of the key findings and elaborate on the contributions, theoretical and practical implications of the study. It also presents the limitations and recommendations of the study and future research direction.

8.2 Summary of key findings

The main aim of this thesis was to examine how farming households and communities are utilising IK and technologies to adapt to climate change to improve food security in northern Ghana. To achieve the research aim, this study specifically intended to:

1. Analyse the extent of climate change in the regions of northern Ghana over the last five decades (1965-2015) and identify how those trends and recent changes have been perceived by farmers.
2. Examine farmers' perceptions of climate change impacts on food security and how they are utilising social networks to cope with associated food risks and insecurities.
3. Examine existing IK and technologies and their evolution in response to climate change risks at different local spatial scales.

The study integrated different theoretical (integral theory, adaptation, Indigeneity and social capital) and methodological (quantitative and qualitative) perspectives to develop an understanding of the complexity of climate change and how farming households and communities are utilising IK and their associated social networks to build adaptive capacity to mitigate climate change risks and promote food security. This section provides a synthesis of the key findings based on the objectives of the study.

8.2.1 Integration of local perceptions with scientific evidence provides a comprehensive understanding of the complexity of climate change

As discussed in chapter five of this thesis, the integration of local perceptions and meteorological data is important for successful adaptation practices. Using a mixed-methods approach, the study found that northern Ghanaian farmers have experienced and perceive of climate change and extreme events in their local environment. However, the results revealed that most farmers in the three study districts were more perceptive of changes in temperature and rainfall variability than trends in rainfall averages. The perceptions of farmers were significantly influenced by important socio-demographic factors including location, age, education, IK, place attachment and wealth. It was also found that farmers' perceptions of rainfall trends differ in some respects from the scientific evidence. The convergence and divergence of local perceptions and meteorological data suggest the need for integrated approaches of Indigenous and scientific knowledge systems to gain full understandings of the local complexity of climate change, and ensure effective adaptation interventions for sustainable food production at local levels.

8.2.2 Social perceptions and networks influence food security under climate change context

Climate change impacts all dimensions of food security and social networks play an important role in mitigating food risks in resource-constrained agro-ecological settings. The research found climate change presents food security risks to farming households in rural northern Ghana. Farmers have perceived climate change impacts on crop productivity, income, crop distribution, supply, quality and safety of food. It was also found that age, gender, education, size of household and wealth are important covariates that influence perceptions of food security within a climate change context. Farming households in northern Ghana utilised their social networks as forms of social capital to build their resilience to mitigate climate change and food security risks. Encouraging and maintaining the development of social perceptions and networks will provide an important opportunity for farmers to develop more resilient food systems, particularly in rural communities where formal support for adaptation interventions is limited.

8.2.3 Different Indigenous adaptation practices to climate change risks exist at household and community scales

The research found that farming households and communities in northern Ghana are implementing diverse Indigenous adaptation strategies to mitigate climate change risks. At the household level, farmers are utilising their IK to individually implement tangible strategies such as rainwater harvesting, organic manure application and the use of neem leaf extract in response to climate change. However, farming communities are also collectively implementing more intangible strategies including congregational prayers, rituals for rainmaking and taboos in managing their local environmental risks. It was also found that farmers' adaptation strategies are evolving and changing over time with most people combining their Indigenous traditional and local knowledge with modern technologies to sustainably reduce potential risks and enhance food security. Farmers integrated strategies in undertaking irrigation, organic manure, planting drought-resistant variety, practicing agroforestry and diversifying crops. These dynamics suggest that neither IK nor modern approaches alone will be sufficient to address the complexities of climate risks alone, hence the need to integrate both knowledge systems for effective adaptation outcomes at a local scale. Also, it was evident that though farmers employed most of the adaptation strategies to address climate change, there were other non-climatic factors such as poor soil and land tenure arrangements, which influenced farmers' adaptation decisions and choices at the farm level.

8.3 Theoretical contributions and broader implications of the study

8.3.1 Theoretical contributions of the study

This study has made several contributions to the academic literature by expanding knowledge on climate change, IK and food security. The response to the first objective of the thesis, which has been published in *Applied Geography*, has added to the existing literature on the need for integrated approaches to understand and address the complexities of climate change. The work to address the second objective of this research is an unpublished manuscript. This contributed to the global discourse on the important pathways needed to sustainably mitigate food security risks within a climate change context and in resource-constrained regions, particularly SSA. In doing so, the study argues for the need to utilise social networks as an important social capital to help rural farmers and communities to mitigate household food insecurity. The response to the third objective of the thesis, which has been published in *Climatic Change* also expands knowledge on the importance of IK in climate change adaptation to mitigate risks and promote food security at households and community levels in semi-arid regions of SSA. In addition, the study has identified place attachment and IK use as important variables that can significantly influence social perceptions of climate change and associated risks. These variables can help researchers to generate new hypotheses and questions for further investigation, particularly in SSA.

The thesis adopted the integral theory to develop understanding of the need to integrate Indigenous and modern knowledge systems and approaches to holistically understand and address environmental risk issues. This framework is emerging among geographers and environmental researchers as an important tool for analysing and understanding environmental risks holistically, which will be particularly important for future research. Compared with more conventional approaches, this research has contributed to integral thinking by adding important empirical insights to the literature. This is important in providing understanding of the relevance of adopting an integrated approach to comprehensively address the complexities of climate risks.

By integrating different perspectives and approaches to understand the human-environment relationships in northern Ghana, the integral theory used in this thesis has helped to justify the significance of integral thinking in helping to comprehensively understand local and regional climatic changes. That theoretical approach has also been effectively utilised to frame understanding of the adaptation practices implemented by farmers to mitigate climate change at different spatial scales in dryland farming systems and landscapes. The utilisation of this approach, particularly in northern Ghana, could provide a paradigm shift in thinking to help environmental practitioners develop effective and sustainable interventions for mitigating climate change and food security risks at multiple local scales.

This research provides insights to policymakers on the need to develop an integrated approach in assessing and managing climate change risks at local, regional and national levels. Given that the Ghana Climate Change and Adaptation Policies have not significantly considered the importance of knowledge integration, the empirical evidence of this study provides an opportunity for the government, development practitioners and policymakers to consider the integration of different perspectives and knowledge systems in future climate change and agricultural policies to ensure sustainable outcomes. Also, given the complexity of climate risks in northern Ghana, it is increasingly important that local, regional and national governments in Ghana and SSA develop adaptation interventions that are multi-scalar to help build the resilience of farming systems in resource-constrained communities. Also, this research may be very useful to local authorities in assisting to develop group and community social networks to help households reduce their vulnerability to food security risk.

8.3.2 Theoretical and policy implications of findings

This research has broad implications for theory and practice. Similar to other parts of the Sahel, northern Ghana is also undergoing climatic changes and associated risks, particularly food insecurity (see chapter two), which are perceived by farmers through the utilisation of IK. In theory, there is a broad consensus that farmer’s lived experiences and perceptions should be prioritised and integrated into local, regional and national discussions of climate change adaptation to facilitate sustainable food systems. Thus, if adaptation can be successful in facilitating sustainable livelihood outcomes in dryland farming systems, then the importance of local perceptions cannot be under-estimated. Social systems, particularly farmers are confronted with complex and urgent multiple social and environmental risks, which lead them to make decisions based on their perceptions, that are not necessarily scientific. However, as 'ultimate applied scientists' they rely on their perceptions to implement adaptation practices to ensure sustainable food security (Sherran and Darnhofer, 2018). Local perceptions are particularly important in Africa because farmers in rural communities largely rely on their ethno-climatological knowledge and experiences acquired for many years to develop understanding of the complexity of their local climate to improve farming systems and undertake adaptation actions. The results here parallel others, such as suggested by Tume et al. (2019), who noted that farmers in the Bemenda highlands of Cameroon have been using IK to make accurate predictions of socio-ecological changes in their local environment. Given that farmers are the best interpreters of their local needs and capacities within a given farm system, any interpretation on behalf of a third party to support adaptation must benefit from understanding their perspectives (Soubry et al., 2020a).

The disparity between local perceptions of rainfall changes and meteorological evidence (see section 5.4.8), suggests that relying on perceptions alone in local climate prediction is not sufficient and potentially misleading. This suggests the need for an integration of local perceptions with scientific evidence to ensure a comprehensive understanding of the climate trends and shifts in local environments to ensure successful adaptation interventions. Also, the relevance and quality of climate and related data (e.g. for agricultural applications) are particularly important for developing an understanding of the opportunities to build the capacity of local people. It is also important for meteorological institutions to provide and analyse accurate and reliable data for better understanding of climate change and effective adaptation decision-making. Having data and information that are appropriate for planning and decision-making is essential. Moreover, the spatial variation of farmers' perceptions of climate change across different locations (see sections 5.4.2, 5.4.3, 5.4.4 and 5.4.5) provides important insights that suggest that socio-ecological systems will experience disproportional climatic risks within and across regions, particularly in dryland areas. Such spatial heterogeneity of social perceptions of climate change risks also suggests the need to understand local climatic dynamics to inform adaptation interventions that are unique for specific local and regional locations.

The trust in the utilisation of IK in northern Ghana has helped farmers and communities to develop and implement diverse strategies to build local resilience. As examined in chapter seven, households and communities in northern Ghana are implementing tangible and intangible strategies to improve food security (see sections 7.3.3). Thus, the opportunity of farmers in exploring local diversity has become important in SSA, particularly northern Ghana where many households and communities are vulnerable to environmental changes. In other developing countries such as Vietnam, Son et al. (2019) suggest that many ethnic minorities such as the Yao people in Bac Kan are generating opportunities from IK to adapt to climate change in rural communities. Such local diversity of indigenous applications is important for development of rational approaches to address malnutrition and poverty issues within rural margins to enhance the resilience of human-ecological systems (Hinrichs, 2003; Soleri et al., 2008). Promoting local diversity through Indigenous ways of managing natural resources can be helpful to ensure the achievement of sustainable development targets of eliminating poverty and hunger in SSA. The evidence in northern Ghana could be very important for researchers to examine how IK can also contribute to the discussion, especially when external modern technologies and systems have shortcomings in being able to address food insecurity and poverty in marginal communities.

In fact, the green revolution technologies aimed at transforming agriculture and eliminating hunger has not fully addressed the food insecurity issues in Africa, especially in northern Ghana where poverty and limited access to assets and poor infrastructure continue to present major challenges to rural agricultural farmers and communities (Nyantakyi-Frimpong and Bezner Kerr, 2015; Richards, 1985; Wise, 2020). It is therefore not surprising that many farmers in the Delta State of Nigeria prefer IK to scientific approach in making farming decisions (Ebhuoma and Simatele, 2019). The Eurocentric idea of modernity does not sufficiently take into account the knowledge systems and economic pressures of local people who are already vulnerable. Such ‘imposed innovations’ rather than ‘induced innovations’ by governments and international development partners can impact upon the cultural dimensions of food security (Dawson et al., 2016; Kansanga et al., 2019a). It is in this light that political ecologists are advocating for the need to balance development prescriptions and changing environmental conditions to generate opportunities for sustainable agriculture, food security and livelihood in developing countries, particularly in SSA (Batterbury, 1997; Nin-Pratt and McBride, 2014; Versillo et al., 2020).

Community action is therefore critically important in the adaptation process. The collective goal among individuals and groups in the adaptation process helps socio-ecological systems and communities to demonstrate resilience in a complex environmental change. Community-level adaptation is facilitated by the conscious effort and ability of people to deliberate on and share ideas regarding emerging environmental risks and to generate opportunities for community-based response and sustainable resource management (Auer et al., 2020; Schipper et al., 2014). Community-based adaptation involves both tangible and intangible collective actions of people for increasing local resilience to mitigate social and ecological risks (Schipper, 2007; Heltberg et al., 2009). Particularly in Africa, intangible collective practices of belief systems and spiritualities among communities, such as in northern Ghana supports social capital theory, which provides an important framework to understand community-based adaptation and natural resource management. Within the broader adaptation discussion, collective actions of social systems are key for food systems adaptation in resource constrained communities (Soubry et al., 2020b). In fact, the collective action, cohesion and social capital of communities are important elements for both understanding current adaptation processes and building adaptive capacity at the community level (Hamilton and Lubell, 2019; Nyahunda and Tirivangasi, 2021; Ziervogel et al., 2021). Also, such collective mobilisation of resources, and actions can effectively work towards challenging and transforming fundamental political and social structures to improve local adaptation (Pelling et al., 2015).

Given the complexity of climate risks in the Sahel in recent years, local farmers and communities are evolving their adaptation practices over time by integrating different knowledge systems. Chapter seven of this thesis provides evidence of such evolution in northern Ghana where farmers across the study districts are integrating both IK and technologies with modern approaches to address complex social and environmental issues, particularly climate risks (see section 7.3.4). That evolution challenges the idea that IK is static in climate change adaptation process. The result shows that there are going to be individual and collective responses that will be evolving in dynamic and fluid ways to address important local environmental risks in SSA. Thus, learning about the evolution and reflexivity of socio-ecological systems is particularly important to understand that, in a risk society, people are not going to apply only IK but many will evolve with new sophisticated ideas to address complex problems for sustainable development (Bardsley et al., 2021; Glass and Newig, 2019). Such evolution in reflexive societies in Ghana and Africa will be imperative for climate change adaptation theory and planning.

To this end, this thesis is actually challenging the concept that has to be either or between Indigenous and modern knowledge in the adaptation theory. The findings of the thesis, thus, helps to advance the need for knowledge integration to understand the complexities of climate change adaptation, which is particularly important for socio-ecological resilience in dryland farming systems in the Sahel, such as northern Ghana. Knowledge integration in farming systems is even more important given the complexity of climate change, which has rendered the utilisation of either Indigenous or modern knowledge insufficient in addressing the risks, while limiting adaptation opportunities for sustainable livelihoods. By integrating Indigenous and modern knowledge systems to provide a holistic understanding of socio-ecological systems resilience, that approach could be useful in the adaptation theory, and practice to promote sustainable agriculture and food security.

This research also provides insight on the need to develop and maintain households' social networks to mitigate food security risks. Lessons learned in a place like northern Ghana mirrors the challenges of food insecurity in a climate change context in the Sahel. Recent literature shows that even under low emission scenarios global food security will be severely threatened and countries, particularly in the Sahel will be more vulnerable to food risks in the future due to climate change (Frank et al., 2017; Kummu et al., 2021; Tai et al., 2014). In light of the high vulnerability, social networks have become an important social capital that is providing opportunities for poor households and communities to adapt to climate risks (Moore and Westley, 2011) and promote food security (see section 6.3.6). It offers communities the ability to show resilience collectively through communal support and interdependence with each other in areas of resources and assets, especially during losses and damages due to climate change (Folke et al., 2005; Kansanga, 2017). Factors such as place attachment, community networks, leadership and community cohesion are very useful avenues through which communities can support themselves to become more resilient (Faulkner et al., 2018; Nyahunda and Tirivangasi, 2021).

Thus, with climate change manifestations and risks expected to be severe in the coming years, building contextual social networks and associated inherent resources of rural populations can be an important social capital to facilitate agriculture and community resilience (Nyantakyi-Frimpong et al., 2019). Providing communal support through the principle of ‘collective common goal’ will not only create new opportunities for communities to resolve current climate change impacts but also renew optimism and hope for dealing with future climate change risks (Maclean et al., 2014). For instance, the establishment of good relationships between individuals and community groups has been identified as an important social capital that thrives well on the principle of reciprocity in helping northern Ghanaian households deal with harvest and risks of food insecurity under climate change (Yaro et al., 2015). Thus, lessons can be learnt from the northern Ghana case by resource-constrained communities in SSA, where formal support for adaptation remains limited or non-existent and where there is potential to develop and integrate social networks into adaptation planning and practice.

From a practical perspective, the findings on the disparity between perceptions of rainfall and meteorological evidence (see section 5.4.8) provide an opportunity for policymakers to consider the integration of social and physical data in climate change analysis. The Ghana National Climate Change Policy (NCCP), which was implemented in 2013 to understand the nature of climate change and mitigate potential impacts in the country recognises the importance of “integration” as an important tool for effective adaptation (Ministry of Environment, Science, Technology and Innovation, 2013). The policy emphasises vertical and horizontal integration of approaches across sectors and spatial levels. However, it appears such approaches have not adequately generated the desired adaptation outcomes, particularly at the local level. For example, the Ono-Village-One-Dam irrigation programme by the Government of Ghana (GoG) to help farmers adapt to perennial droughts is bereft with implementation challenges partly due to the lack of involvement of users, and integration of local and scientific data in understanding climatic risks and vulnerabilities of beneficiary communities in northern Savannah regions (Amenuveve, 2020). Thus, this study will provide an important insight to assist policymakers to comprehensively understand climate change and associated risks and vulnerabilities for effective adaptation planning and practice.

Indigenous adaptation practices have been part of the traditional farming systems in many parts of SSA, which influence local policies, particularly on food security. The findings of this study are timely at a time the Government of Ghana is recognising the importance of IK in climate change adaptation. The Ghanaian National Climate Change Adaptation Strategy (NCCAS) and National

Adaptation Plan Framework (NAPF), which are intended to enhance agricultural adaptation also recognise the crucial need to explore IK as an important complementary tool that is cheaper than modern technology in mitigating the impacts of climate change risks on agricultural systems (Environmental Protection Agency, 2018; GoG, 2012). This means that the government may be interested in implementing and scaling-up the findings of this study to help socio-ecological systems in marginal areas, particularly in northern Ghana to develop effective resilience against climate risks. Particularly, this study will provide insights to assist the policy and decision-makers in Ghana identify the differences in adaptations at household and community levels. This spatial difference in adaptation will be particularly useful to help the government, NGOs, development partners and practitioners to understand and develop adaptation interventions that are multi-scalar to address specific needs.

Finally, given the challenges climate change will present in future, understanding Indigeneity and its inherent complexities will provide a mechanism for policymakers to develop a *sui generis* system to assist in managing natural resources and mitigating resource conflicts in Ghana. Such understanding of Indigeneity is well acknowledged and suggested by climate justice theorists as being critically important for making visible the most urgent impacts of climate change that have been marginal in policy discussions in developing countries (Gathii, 2020; Hicks and Fabricant, 2016; Sekine, 2021). A *sui generis* framework will help to protect IK while ensuring the conservation of environmental resources in Indigenous communities in northern Ghana. Establishing a *sui generis* system for IK systems within the broader legal framework of Ghana could provide opportunities for managing resource conflicts in the northern Savanna regions, which are expected to intensify under changing climatic conditions in future. Thus, a *sui generis* system will provide a comprehensive system or approach to guide traditional leaders and the national and local government authorities to protect Indigenous land rights and ownership regimes in Ghana while ensuring a peaceful co-existence between Indigenous farmers and resident migrant pastoralists from the Sahel. Such peaceful atmosphere will be increasingly important for promoting socio-economic development in northern Ghana, which remains underdeveloped since independence due to ethnic and resource conflicts as well as structural challenges (Kansanga et al., 2019b; Osei-Kufour et al., 2016). In fact, policymakers in Ghana can use examples from Kenya, Cameroon and South Africa as reference points to understand the effectiveness of a *sui* *generis* system for biodiversity conservation and protection of traditional knowledge (Kuriuki, 2020: Tonye, 2003).

8.4 Limitations of the study

Though this study has made important contributions to the discipline, certain limitations were unavoidable and might affect the generalisation and genuineness of some of the research findings, particularly in relation to the data collection and analysis. In light of that, it is important to carefully interpret the study findings within the limitations.

Firstly, the primary data were collected based on people's very subjective perceptions. Such a social perception approach is important for a study of this nature, but the biases and subjectivities associated with the responses might affect the data quality. Thus, it is probable that respondents may have exaggerated or under-reported some of the issues because of information heuristics of past events, particularly in relation to climate risks and impacts in the local environment. Notwithstanding those subjectivities, the data collected provided enough details to develop important insights and understandings of local perceptions of farmers about key climatic changes.

Secondly, there are certain important demographic information respondents may not have been accurately disclosed. In many rural communities in Ghana, as elsewhere, people sometimes do not accurately disclose their age, income and wealth status because of personal reasons. In view of that, many respondents in the communities might have provided erroneous data for the study. As a result, using such independent variables to predict the outcome of other dependent variables may be misleading. However, such variables were important in this study in understanding the probability of their potential associations with other variables based on theory. Moreover, it is important to highlight that many socio-demographic variables such as age, gender, and education, which were used in the study for predicting farmers' perceptions of climate change and food security risks were not controlled. Other confounding factors such as access to information and remittances may likely influence such relationships. Thus, interpretations must be done within the confines of those predictors.

Thirdly, because of financial constraints, only two communities each were selected from three districts to represent northern Ghana. That is a major limitation given the number of communities in the study districts and the likelihood of unique experiences and perceptions of climate change at local scales. However, the geographic, cultural and socio-economic characteristics of communities in northern Ghana are relatively homogenous, and thus are unlikely to significantly affect the validity of the results. Also, notwithstanding the few communities selected, the data collected were adequate to draw together important generalisations to inform theoretical and policy conclusions. It is also important to indicate that the lack of adequate financial resources only allowed the researcher to acquire 50 years of climate data from the Ghana Meteorological Agency. Even though a longer timescale would have helped in identifying significant long-term trends and changes, the available data were adequate in providing understanding of how those trends and changes over the past five decades have been at the local level to corroborate with peoples' perceptions.

8.5 Future research and general recommendations

Further research is required to understand the practical and theoretical opportunities and challenges of IK utilisation in climate change adaptation. This understanding could offer an important opportunity to assist policymakers and other agricultural stakeholders in Ghana to develop local adaptation interventions for sustainable food security, particularly in rural areas in northern Ghana. A strength, weakness, opportunities and threats (SWOT) analysis could be an important tool to assess and evaluate Indigenous strategies and practices to generate and sustain the best opportunities while addressing the challenges to sustainably improve livelihoods. Also, there is additional opportunity to quantify how IK and technologies have evolved and changed over time at household and community scales in Ghana. This could provide an important insight into the level and extent of evolution of IK and technologies in local and regional areas and determining how those evolving knowledge and technologies are differentiated socially, economically, demographically and culturally.

It will be increasingly important for government, non-governmental organisations and development partners to establish vibrant research centers in northern Ghana to help promote Indigenous research and adaptation in association with modern ideas and technologies. The establishment of such centers will help build the adaptive capacity of farming communities to mitigate their vulnerability to climate risks and promote food security. For instance, the centers could provide an opportunity for rural farmers to receive training on how to effectively and efficiently utilise IK and practices and new modern approaches to develop resilience to mitigate climate change risks and to improve livelihoods.

While social networks are key in mitigating food insecurity in many rural communities, particularly in northern Ghana, further research must focus on the challenges of social networks that can potentially impede food security outcomes in dryland farming systems. This is particularly important to ensure that local farmers become resilient in addressing climate change and food insecurity risks. Also, it will be imperative to investigate which aspects of social networks (either household or community level) are a priority to strengthen and enhance to generate the required opportunities to promote food production and ensure sustainable livelihoods.

8.6 References

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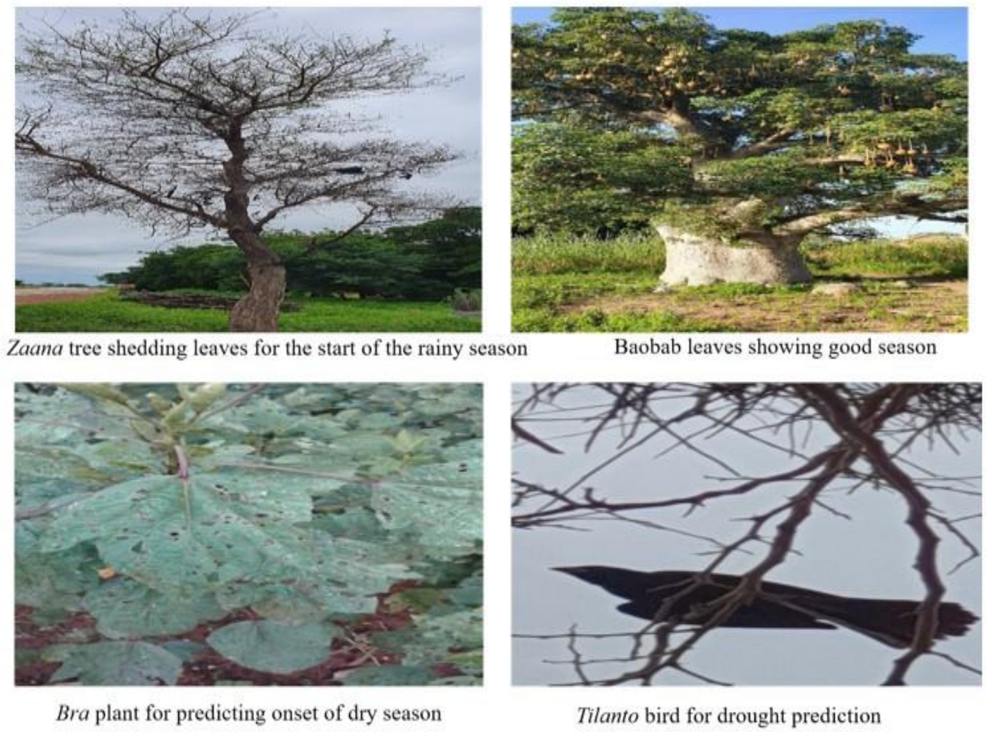
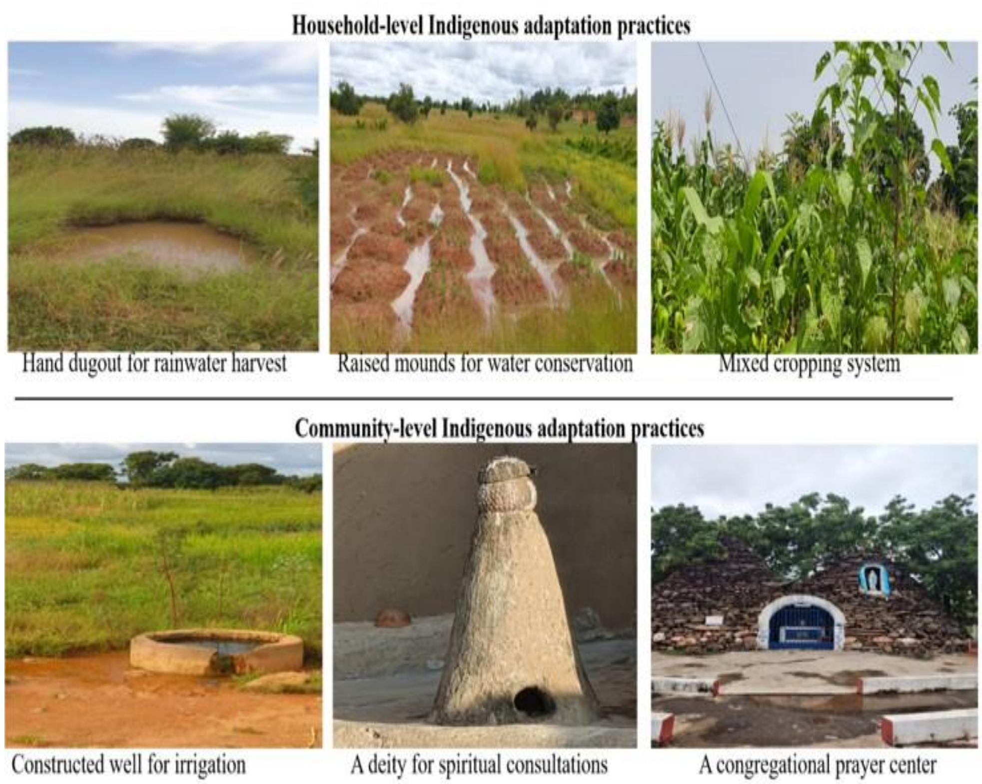


Appendix A: Supplementary Figure on Indigenous Indicators for Weather and Climate Prediction



Appendix B: Supplementary Figure on Indigenous Technologies for Climate Change Adaptation

Appendix C: Ethics Approval Letter

THE UNIVERSITY of ADELAIDE

Our reference 33514

RESEARCH SERVICES
OFFICE OF RESEARCH ETHICS, COMPLIANCE AND INTEGRITY
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18 April 2019

Dr Douglas Bardsley
School of Social Sciences

Dear Dr Bardsley

ETHICS APPROVAL No: H-2019-058
PROJECT TITLE: Climate Change, Indigenous Knowledge and Food Security in Northern Ghana

The ethics application for the above project has been reviewed by the Low Risk Human Research Ethics Review Group (Faculty of Arts and Faculty of the Professions) and is deemed to meet the requirements of the *National Statement on Ethical Conduct in Human Research 2007 (Updated 2018)* involving no more than low risk for research participants.

You are authorised to commence your research on:	18/04/2019
The ethics expiry date for this project is:	30/04/2022

NAMED INVESTIGATORS:

Chief Investigator:	Dr Douglas Bardsley
Student - Postgraduate Doctorate by Research (PhD):	Mr Lawrence Guodaar
Associate Investigator:	Dr Jungho Suh

CONDITIONS OF APPROVAL: Thank you for your responses to the matters raised. The revised application provided on 18/04/19 has been approved.

Ethics approval is granted for three years and is subject to satisfactory annual reporting. The form titled Annual Report on Project Status is to be used when reporting annual progress and project completion and can be downloaded at http://www.adelaide.edu.au/research-services/oreci/human/reporting/. Prior to expiry, ethics approval may be extended for a further period.

Participants in the study are to be given a copy of the information sheet and the signed consent form to retain. It is also a condition of approval that you immediately report anything which might warrant review of ethical approval including:

- serious or unexpected adverse effects on participants,
- previously unforeseen events which might affect continued ethical acceptability of the project,
- proposed changes to the protocol or project investigators; and
- the project is discontinued before the expected date of completion.

Yours sincerely,

Dr Anna Olijnyk

Convenor

The University of Adelaide

Appendix D: Survey Questionnaire

Farm-household survey questionnaire

Research title: Climate Change, Indigenous Knowledge and Food Security in northern Ghana

Project summary

This project seeks to examine the dynamics of how Indigenous farming households respond to climate change risks through the utilization of Indigenous knowledge and technologies in northern Ghana. This study aims to examine and promote methods for sustainable food production and reduce poverty among vulnerable Indigenous households and communities in the semi-arid regions of Ghana.

This research is under the funding support of the Department of Geography, Environment and Population in the University of Adelaide, South Australia, Australia. The project is supervised by Dr. Douglas Bardsley and Dr. Jungho Suh, all in the above-mentioned department. For any information contact the following:

Name: Ass/Professor Douglas Bardsley

Email:

Contact:

Name: Dr. Jungho Suh

Email:

Contact:

Declaration

This survey is intended for only academic purposes. I hereby assure you of your confidentiality and anonymity regarding your responses to the questions.

Identification

Household ID:	Date:
Regional ID	District name:
Community name	Community code
Enumerator name:	

A. Household biographic information

Please answer the following questions by ticking the correct answer

A1. Household size	(a) 1-3 [ ] (b) 4-7 [ ] (c) 8-11 [ ] (d) >11 [ ]
A2. Age	(a) 18-24 [ ] (b) 25-35 [ ] (c) 36-45 [ ] (d) 46-55 [ ] (e) 56-65 [ ] (f) >65 [ ]
A3. Gender	(a) Male [ ] (b) Female [ ]
A4. Highest educational level	(a) No education [ ] (b) Basic [ ] (c) Secondary/Tech. [ ] (d) Tertiary [ ]
A5. Marital status	(a) Single [ ] (b) Married [ ] (c) Divorced/Separated [ ] (d) Widowed [ ]
A6. Family size/Number of dependents	(a) 1-3 [ ] (b) 4-7 [ ] (c) 8-11 [ ] (d) >11 [ ]
A7. Religion	(a) Christianity [ ] (b) Islam [ ] (c) Traditional [ ] (d) Atheist [ ] Others………..

A8. What is your ethnic group?...

A9. Are you an indigene/native of this village? (a) Yes [ ] Go to A10 (b) No [ ] Go to A11

A10. (i) How would you describe an indigenous person?..

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A11. (ii) What qualifies a person to be indigenous?………………………………………………

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A12. How long have you been living in this village?..

A13. Have you always lived in this village? Yes [ ] Go to A14 No [ ] Go to A15

A14. Do your parents come from this village? (a) Yes [ ] (b) No [ ]

A15i. Where did your parents come from?...

A15ii. When did your parents come to this village?..

A16. Have you ever lived in other village or city for work or school for more than a year?

(a) Yes [ ] (b) No [ ]

A17. What is your main livelihood economic activity? (a) Farming [ ] Go to A19 (b) Livestock rearing [ ] Go to A18 (c) Both Go to A18 [ ]

A18. Which livestock do you keep? (a) Cattle [ ] (b) Pig [ ] (c) Guinea fowl [ ]

(d) Chickens [ ] (e) Goats [ ] (f) Sheep [ ] (g) Donkeys [ ] (h) Others……………………

A19. How long have you been engaging in the activity mentioned in A17?

(a) <10 [ ] (b) 10-15 [ ] (c) 16-20 [ ] (d) >20 [ ]

A20. What other livelihood activity do you engage in?...

A21. What is your monthly average income in cedis?..

A22. What is your wealth status? (a) Rich [ ] (b) Poor [ ]

A23. Do you own your farm?   (a) Yes [ ]   Go to A24 (b) No [ ]

A24. What is the nature of ownership of your farm (land tenure)? (a) Owned [ ] (b) Inherited [ ] (c) Rented [ ] (d) share cropper [ ] (e) Owned and rented [ ]

A25i. What is the type of your farm land? (a) Irrigated (b) Dryland (c) Rain-fed

A25ii. What is the size of your farm in hectares? (a) 1-4 [ ]   (b) 5-9 [ ]   (c) 10-14 [ ]

(d) 15-19 [ ]   (e) >19 [ ]

A26. How many separate farm parcels do you have? (a) 0 [ ]   (b) 1 [ ]   (c) 2 [ ]   (d) 3 [ ]   (e) 4 [ ] (f) >4 [ ]

A27i. Are they in different locations? (a) Yes [ ]   (b) No [ ]

A27ii. If yes why?..

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28i. Do you use farm parcels for different agricultural purposes like crop and livestock production? (a) Yes [ ]   (b) No [ ]

28ii. If yes Why?..

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A29i. Are the farmlands easily accessible? (a) Yes [ ]   (b) No [ ]

A29ii. If yes, elaborate explain…………………………………………………………………….

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A30i. Does your household have access to climate information? (a) Yes [ ]   (b) No [ ]

A30ii. Which of the following is your main source of climate information in the community? (a) Personal experience [ ] (b) Media [ ] (c) Religious denomination [ ] (d) NGOs [ ] (e) Agricultural extension officers [ ] (f) Community members [ ] others specify……………………………………………………………………………………………

B. Household food production and security

B1. Which of the following crops do you produce for the family and how much is sold?

Type of crops	Yield in terms of bag	Subsistence (Food)	Sale	Food and Sale
(i) Maize				
(ii) Millet				
(iii) Sorghum				
(iv) Rice				
(v) Groundnut				
(vi) Beans				
(vii) Vegetables				
(viii) Yam				
Others, specify				

B2. Are there periods of the year that your household finds it difficult to get enough food?

Yes [ ] Go to B3 No [ ] Go to B7

B3i. Which period of the year does your household normally struggle to get enough food?

(a) January-April [ ] (b) May-August [ ] (c) September- December [ ]

B3ii. How many months in a year does your household struggle to get food?

(a) 1-2 months [ ] (b) 3-4 months [ ] (c) 5 months and above [ ]

B4. Do you buy more food from the market in times of distress when you have the money available? (a) Yes [ ] (b) No [ ]

B5i. Do you rely on off-farm labour to supplement for constraints in local production? (a) Yes [ ] (b) No [ ]

B5ii. If yes, could you elaborate…………………………………………………………………

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B6i. Do you get support from members of the community when you run out of food? (a) Yes [ ] (b) No [ ]

B6ii. If yes, could you elaborate…………………………………………………………………

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B7. Indicate the extent of your food security/insecurity status in the last 12 months in the following statements? N (never); R (Rarely); OC (Occasionally); S (sometimes) and O (often).

No	Statement	N	R	OC	S	O
		1	2	3	4	5
i	I and my household have eaten less than we should because there wasn't sufficient food					
ii	I and my household are worried about running out of food					
iii	I and my household go to sleep at night hungry because there was insufficient food					
iv	I and my household are unable to eat healthy and nutritious food because of lack of money or other resources					
v	I and my household have skipped a meal because there was not enough money or other resources to get food					
vi	I and my household have eaten a limited variety of foods due to lack of resources					

vii	I and my household have been unable to eat healthy and nutritious food because of lack of money or other resources					
viii	I and my household have suffered from some ailments because of lack of nutrition					
ix	I and my household have lose weight because of insufficient food					
x	I and my household are unable to eat regularly (3 times a day) at all times					

B8i. Does your household ever produce a surplus of food? Yes [ ] Go to B4ii No [ ] Go to B5

B8ii. Do you sell? (a) Yes [ ] (b) No [ ]

B9. Are you building up capital savings from your sales? (a) Yes [ ] (b) No [ ]

B9ii. What is the state of your capital savings? (a) Increasing [ ] (b) Stable [ ] (c) Decreasing [ ]

B10. Are there things you do as a community which are important for food security (e.g. food sharing)? (a) Yes [ ] (b) No [ ]

B11. Have you always done that? (a) Yes [ ] (b) No [ ]

B12. Is it a new idea? (a) Yes [ ] (b) No [ ]

B13. Is it something that your ancestors did? (a) Yes [ ] (b) No [ ]

C. Perceptions of risks and impacts of climate change

C1. Do you perceive/believe that the climate is changing? (a) Yes [ ] (b) No [ ]

C2. What is the nature of the change? (a) Gradual [ ] (b) Sudden [ ] (c) Both [ ]

C3 Do you believe the climate will continue to change in the coming decades?

(a) Yes [ ] (b) No [ ]

C4i. What technologies do you use to forecast the weather? (a) Indigenous [ ]

(b) Scientific [ ] (c) Integrated [ ]

C4ii. Could you elaborate on your answer?...

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C4iii. If you use indigenous knowledge, how long have been using it?..

C5. To what extent do you agree or disagree with the following statements? D (disagree); N (neutral) and A (agree)

No	Statements	D	N	A
		1	2	3
i	Erratic rainfall is more frequent			
iii	There has been a decreasing amount of rainfall			
iii	There have been a late onset of the rainy season			
iv	There has been the early ceasing of the rainy season			
v	There are longer periods of severe drought			
vi	Maximum temperatures are increasing			
vii	Minimum temperatures are increasing			
viii	Flood events are more frequent			
ix	There are severe windstorms			
x	There has been a frequent experience of wildfires			
	Others, specify			

C6. How does climate change impacts your agricultural activities?...

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C7. How much do you agree or disagree with the following statements? D (disagree); N (neutral) and A (agree).

No	Statements	D	N	A
		1	2	3
i	Climate change and extremes reduce crop yield			
ii	Climate change and extremes disrupt the distribution of crops			
iii	Climate change and extremes reduce income			
iv	Climate change and extremes cause reduces in food supply			
v	Climate change and extremes cause food instability			
vi	Climate change and extremes reduce food quality			
xi	Climate change and extremes cause food safety problems			

C8. How much do you agree or disagree with the following statements? D (disagree); N (neutral) and A (agree).

		D	N	A

No	Statements	1	2	3
i	I see the changes as positive rather than negative			
ii	I am trying to learn something from the changes in climate			
iii	I am constantly thinking about climate change			
iv	I am worried that I won't be able to adapt			

C9. Indicate from the following statements what you think is going to be the most important impacts of climate change in the next decade? D (disagree); N (neutral) and A (agree).

No	Statements	D	N	A
		1	2	3
i	There is going to be a food shortage			
ii	Poverty incidence will be very high			
iii	More severe drought conditions will be experienced			
iv	There will be more losses and damages to crops			
v	The frequency of wildfires will increase			
vi	There will be more water shortage			
vii	There will be a high incidence of pests and diseases of crops and livestock			
viii	There will be more severe storms			
ix	Day and night temperatures are going to increase			

x	There will be more flood events			
	Others, specify			

D. Social Network

D1. Do you belong to any group or association? (a) Yes [ ] (b) No [ ]

D2. Do you get support from the groups in the community (a) Yes [ ] (b) No [ ]

D3. Please provide information on the type of group or association you belong to (**Multiple answers allowed**).

No	Name of group or association	Tick	Support/benefits from the group
i	Religious-based societies		
ii	Community-based groups		
iii	Agricultural cooperative societies		
iv	Families		
v	Friends		
	Others, specify		

D4. How do the social networks help you to cope with food insecurity?...................................

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E. Indigenous knowledge and adaptations to climate change

E1. Do you adapt to the changes in climate? (a) Yes [ ] Go to E2 (b) No [ ] Go to F1

E2. Do you use your indigenous knowledge in adapting to climate change? ? (a) Yes [ ] (b) No [ ]

E2i. If Yes, which practices do you adopt individually?...

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E3. Is there indigenous knowledge among the community which is important for climate change adaptation? (a) Yes [ ] (b) No [ ]

E3i. Which indigenous practices are collectively implemented by community in adapting to climate change?

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E4i. Has the use of your indigenous knowledge changed over time? (a) Yes [ ] (b) No [ ]

E5. If you use indigenous knowledge, where did you get it from? (a) Family (b) Community (c) Agricultural extension department (d) NGOs (e) Others specify…………………………………………

E6. If you obtained it from the family, which member of the family did you learn this knowledge from? (a) Grandparents (b) Parents (c) Aunties (d) Uncles (e) Siblings (d) Others specify……………………………………………………………………………………………

E7. Is this knowledge a common practice in the community? (a) Yes [ ] (b) No [ ]

E8i. Has the use of your indigenous knowledge changed over time? (a) Yes [ ] (b) No [ ]

E8ii. If yes, could you elaborate your answer?...

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E9. How effective are indigenous knowledge to you in dealing with climate change risks? (a) Very effective [ ] (b) Effective [ ] (c) No idea [ ] (d) Not effective [ ] (e) Not very effective [ ]

E10. How accessible is indigenous knowledge in this village?...

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E11. What is motivating you to use Indigenous knowledge?...

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E12. If you use modern knowledge only, explain the motivation for doing that?....................

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E13. If you integrate indigenous with modern knowledge, explain the motivation for doing that?...

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E14i. Have you adjusted your entire farming system to deal with climate change? (a) Yes [ ] (b) No [ ]

E13ii. If yes, could you elaborate on your answer?...

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E15i. Do you engage in off-farm activities to diversify your income to adapt to climate change? (a) Yes [ ] (b) No [ ]

E16ii. If yes, could you elaborate on your answer?...

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E17. Are there things you do as a community which are important for adapting to climate change? (a) Yes [ ] (b) No [ ]

E18. Have you always done that? (a) Yes [ ] (b) No [ ]

E19. Is it a new idea? (a) Yes [ ] (b) No [ ]

E20. Is it something that your ancestors did? (a) Yes [ ] (b) No [ ]

F. Institutional arrangements for supporting indigenous knowledge and technologies applications

F1. Do you get support from government institutions? (a) Yes [ ] (b) No [ ]

F2. If yes, which of the following support do you get from government institutions?

	Support systems	Yes	No
i	Financial		
ii	Training		
iii	Community development		
iii	Materials		

iv	Farm inputs (e.g. fertilizer, improved seed etc.)		
	Others, specify		

F3. How do the support systems help you to mitigate climate change risks?...................................

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F4i. Which of the following does the support promotes? (a) Indigenous [ ] (b) Modern [ ] (c) Both [ ]

H4ii. Explain why?...

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F5. Is the support adequate? (a) Yes [ ] (b) No [ ]

F6. Are there any particular conditions attached to the support? (a) Yes [ ] Go to H7 (b) No [ ] Go to H8

F7. What are the conditions attached to the support? …………………………………………………………………………………………………
…………………………………………………………………………………………………

F8. How long have you been receiving this support?

(a) 1-3 years (b) 4-6 years (c) 7-9 years [ ] (d) 10 years and above

F9. How often do you get the support?

(a) Very often [ ] (b) Sometimes [ ] (c) Never [ ] (d) Don't know [ ]

F10i. Do you think it is relevant to integrate indigenous knowledge with existing government policies and programs to adapt to climate change? (a) Yes [ ] (b) No [ ]

F10ii. If yes why?...

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F11. What other support do you need?...

Appendix E: Focus Group Discussion Protocol

Focus group discussion protocol

Focus group discussion with selected leading farmers

Research title: Climate Change, Indigenous Knowledge and Food Security in northern Ghana

A. Perceptions and risks of climate change and food production

1. What is your understanding of climate change in this community? How has the change occurred in the last five decades? Have the changes been gradual or abrupt? Will the change continue to occur in the coming decades?

2. What technologies do you use to forecast the weather in this community? What local indicators help you to identify changes in climate (e.g. Early onset of raining season, late onset of raining season, expecting rainfall, heavy rainfall, onset of drought, prolong drought etc.

3. What are some of the impacts of climate change? What do you think is going to be the most important impacts of climate change in this community in the next decade? Are there opportunities to be generated from climate change?

4. Are there things you do as a community which are important for food security (e.g. food sharing)? Have you always done that? Is it a new idea? Is it something that your ancestors did?

B. Indigenous knowledge evolution and adaptation

1. What criteria do you use to define indigeneity? Is that important? Will it be more important in the future with climate change? Are there barriers to that transition?

2. What knowledge system did you apply in the past two decades? Has that changed in present times? Why?

3. How flexible is your indigenous knowledge in integrating other knowledge systems?

4. How is indigenous knowledge cooperating or competing with modern knowledge?

5. How has modernity, education and urbanization influenced the sustainability of indigenous knowledge?

6. Is there integration of this knowledge at a certain point in time to help solve environmental problems? How important is this knowledge integration?

7. What are some of the things you do as a community (tangibles such as investments in irrigation, *nn)boa* etc) which are important for adapting to climate change? Have you always done that? Is it a new idea? Is it something that your ancestors did?

8. What Indigenous knowledge (intangibles such as belief in gods, sticking to traditional values i.e. conservative) in this community are important for climate change adaptation?

9. In times of crop failures and damages resulting from climate change, how do you cope with the risks in the short term in the community (tangibles and intangibles)? How does the community support people to get food when affected by losses and damages?

10. How important are social networks in helping you to cope with food security risks? Explain

11. How important is off-farm labour in assisting you to adapt to climate change in this community? Explain

12. Are there other off-farm activities that farmers engage in to diversify their income ensure food security? Explain

13. How do indigenous knowledge and technologies promote food crop production?

14. How do the old people transmit indigenous knowledge to the younger ones?

C. Institutional arrangements for supporting indigenous knowledge and technologies

1. Do you get any support from the government or other institutions? What kind of support do you get from the institution(s)?

2. Is the support linked to indigenous or modern knowledge or both? How effective are these supports in helping you to deal with climate change risks?

3. Do you think it is relevant to integrate indigenous knowledge with existing government policies and programs to adapt to climate change? If yes why?

4. How does the support promote your indigenous knowledge?

5. Is the support adequate? Are there conditions attached? How long have you been receiving this support? How often is the support?

6. How do the elderly promote and sustain the indigenous knowledge of the community?

7. Is there anything else you would like to add?

Appendix F: Interview Guide 1

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Key-informant interviews (Agricultural extension officers)

Research title: Climate Change, Indigenous Knowledge and Food Security in northern Ghana

A. Perceptions and risks of climate change and food production

1. What is your understanding of climate change? How has the change occurred in the last five decades? Will the change continue to occur in the coming decades?

2. What technologies are used by the local community to identify changes in climate?

3. What are some of the impacts of climate change risks in this community? To what extent does climate change affect food availability, accessibility, stability and utilisation? What do you think is going to be the most important impacts of climate change in this community in the next decade? Are there opportunities this community can generate from climate change?

4. Are there things the community do which are important for food security? Have they always done that? Is it a new idea? Is it something that their ancestors did?

B. Indigenous knowledge evolution and adaptation

1. What are some of the things the community does (tangibles such as investments in irrigation, *nn)boa* etc) which are important for adapting to climate change? Have they always done that? Is it a new idea? Is it something that their ancestors did?

2. What Indigenous knowledge (intangibles such as believe in gods, sticking to traditional values i.e. conservative) in this community are important for climate change adaptation?

3. How can indigenous knowledge and technologies of farmers help promote food security?

4. How important are social networks in helping farming households to cope with food security risks? Explain

5. Are there other off-farm activities that farmers engage in to diversify their income ensure food security? Explain

6. In times of crop failures and damages resulting from climate change, how do farmers cope with the risks in the short term in the community (tangibles and intangibles)? How does the community support people to get food when affected by losses and damages?

7. Which adaptation strategy between indigenous knowledge and western knowledge is most applicable in this community? And why?

8. What type of knowledge do you recommend to the local community in adapting to climate change?

9. Do you think it is important to integrate indigenous knowledge with existing government policies and programs on adapting to these changes? If yes, why?

10. How does your outfit promote indigenous knowledge and technologies of farmers in this community?

C. Institutional arrangements for supporting indigenous knowledge and technologies

1. Do you support farmers in their agricultural farming practices? What kind of support does your outfit give to farmers? How often do you give this support to the farmers?

2. Is the support adequate? Are there conditions attached? How long have you been supporting them?

3. How effective and sustainable is the support or training you provide to the farmers in adapting to climate change?

4. Do you train farmers on how to adapt to climate change? Does the training cover both indigenous and modern ways of adapting to climate change? If yes, what is the community response with regard to the integration of indigenous knowledge and western knowledge?

Appendix G: Interview Guide 2

Key-informant Interview Protocol

Key-informant interview with traditional authorities

Research title: Climate Change, Indigenous Knowledge and Food Security in northern Ghana

1. Can you give a brief history of this community, particularly your origin or ancestral homeland?

2. What is your understanding of climate change in this community? How has the change occurred in the last five decades? Will the climate continue to change in the coming decades?

3. What technologies help community members to forecast the weather? What local indicators help community members to identify changes in climate?

4. Do you believe climate change risks will increase in the next decade to come?

5. How vulnerable do you think your community is going to be to future climate change?

6. How does climate change affect food production?

7. Are there things you do as a community which are important for food security? Have you always done that? Is it a new idea? Is it something that your ancestors did?

8. How important are social networks in helping farming households to cope with food security risks? Explain

9. What customs and technology practices do you have in place in this community to reduce climate change? E.g. deforestation, the drying-up of rivers, etc.

10. Are there spiritual consultations to help your people deal with climate change?

11. What support do you give to farmers to deal with climate change risks?

12. Who is indigenous in this community and what are the criteria for indigeneity? Is that important? Will it be more important in the future with climate change? Are there barriers to that transition?

13. How is indigenous knowledge cooperating or competing with modern knowledge?

14. How flexible is your indigenous knowledge in integrating other knowledge systems?

15. What knowledge system did indigenes apply in the past two decades? Has that changed in present times? Why?

16. How has modernity, education and urbanization influenced the sustainability of indigenous knowledge?

17. How do the old people transmit the indigenous knowledge to the younger ones?

18. Do farmers integrate this knowledge at a certain point in time to help solve environmental problems? How important is knowledge integration in addressing climate change risks?

19. Do you think it is relevant to integrate indigenous knowledge with existing government policies and programs to adapt to climate change? If yes why?

20. How do the traditional authorities promote indigenous knowledge in this community?

21. How can indigenous knowledge help promote food production?

22. What challenges do traditional authorities face in promoting the indigenous knowledge of the community?

23. Is there anything else you would like to add?