CLIMATE COMPATIBLE AGRICULTURE: INTERFACING SCIENTIFIC, INDIGENOUS AND LOCAL KNOWLEDGE IN THE UPPER WEST REGION, NORTHERN GHANA

by

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DEDICATION

To my late mother, Madam Mamata Bobie-Halubie, and my father, Mr. Salifu M-Buu Dangor.

DECLARATION

I, DRAMANI JUAH M-BUU FILE, student number 63993465 hereby declare that the thesis, with the title: CLIMATE COMPATIBLE AGRICULTURE: INTERFACING SCIENTIFIC, INDIGENOUS AND LOCAL KNOWLEDGE IN THE UPPER WEST REGION, NORTHERN GHANA which I hereby submit for the degree of DOCTOR OF PHILOSOPHY IN ENVIRONMENTAL MANAGEMENT at the University of South Africa, is my own work and has not previously been submitted by me for a degree at this or any other institution.

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I declare that during my study I adhered to the Research Ethics Policy of the University of South Africa, received ethics approval for the duration of my study prior to the commencement of data gathering, and have not acted outside the approval conditions.

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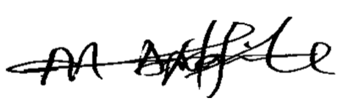
Student signature: 

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ABSTRACT

Climate change is a daunting challenge to smallholder agriculture in northern Ghana over the years. Climatic conditions continue to demonstrate significant levels of variability on annual and decadal bases, making smallholder agriculture more vulnerable. The aim of the study was to explore the potential use of local and indigenous knowledge of smallholder farmers in promoting climate compatible agriculture in northern Ghana and how this interface with scientific knowledge. To respond to the study aim, four research objectives were spelt out and these are further elaborated upon in chapter 1 under section 1.4.

The study adopted a mixed methods research design where quantitative and qualitative approaches were used in data collection and analyses. Data were collected through a household survey, face-to-face interviews, observation, and focus groups discussions. Participants for the face-to-face interviews and focus group discussions were purposively selected, while participants for the household survey were selected through cluster and simple random sampling approaches. The quantitative data were analysed using Statistical Package for Social Scientists (SPSS version 20) and Microsoft Excel (Microsoft Office 365), and thematic analyses conducted for the qualitative data.

The study found that smallholder farmers' perceptions of increasing variability of rainfall and temperature patterns in North-western Ghana were confirmed by meteorological data where annual rainfall was decreasing with increasing annual temperatures over the past decades. It was also revealed that smallholder farmers employed multiple farm and non-farm-based strategies by interfacing scientific, local and indigenous knowledge systems to promote climate compatible agriculture. There were also varied levels of awareness on climate compatible farming practices among smallholder farmers with the need for more awareness creation scientific-based practices. It further emerged that smallholder farmers' decisions to adopt local and indigenous knowledge-based climate compatible practices were variedly influenced by accessibility, reliability, and awareness of knowledge; access to farm capital; land tenure; access to extension services; household demographic characteristics; landscape and farm distance; and socio-cultural beliefs.

Based on the key findings and conclusions emerging from the work, several interventions are suggested. These include sensitisation, education, and training of smallholder farmers on climate compatible practices that effectively mainstream local and indigenous knowledge into scientific practices to improve capacities and enhance increased productivity and food security that should be prioritised by all stakeholders in the agriculture value-chain in northern Ghana. The thesis is another value-add to the growing body of knowledge in Ghana and globally that will enhance policy reformation in the area of focus. Furthermore, new knowledge gaps that emerged can either be taken up for postdoctoral work or by other scholars.

Key words: Climate change, climate compatible agriculture, local and indigenous knowledge, scientific knowledge, smallholder farmers, vulnerability, adoption decisions, awareness, adaptation, North-western Ghana.

ACRONYMS

CIAT	International Centre for Tropical Agriculture
SSA	Sub-Saharan Africa
AGRA	Alliance for a Green Revolution in Africa
FAO	Food and Agriculture Organisation
IPCC	Inter-Governmental Panel on Climate Change
GHG	Greenhouse Gas
USEPA	United States Environmental Protection Agency
MDG	Millennium Development Goals
SDG	Sustainable Development Goals
AfSD	Agenda for Sustainable Development
CSA	Climate-Smart Agriculture
LIK	Local and Indigenous Knowledge
IASG	Inter-Agency Support Group on Indigenous Peoples' Issues
ILO	International Labour Organisation
COP	Conference of Parties
FSIN	Food Security Information Network
GNCCP	Ghana National Climate Change Policy
CCAFS	Climate Change, Agriculture and Food Security
CGIAR	Consultative Group on International Agricultural Research
CSV	Climate-Smart Villages
WAATP	West Africa Agricultural Transformation Program
MoFA	Ministry of Food and Agriculture

NCRC	Nature Conservation Research Centre
MDA	Ministries, Departments and Agencies
CSO	Civil Society Organisations
CCD	Climate Compatible Development
DAFC	Danish Agriculture and Food Council
IFAD	International Fund for Agricultural Development
UNICEF	United Nations International Children Education Fund
WFP	World Food Programme
WHO	World Health Organisation
GDP	Gross Domestic Product
UNDP	United Nations Development Programme
NDPC	National Development Planning Commission
GoG	Government of Ghana
MoF	Ministry of Finance
MMT Co_2 eq	Million Metric Tons of Carbon dioxide equivalent
AFOLU	Agriculture, Forests, and Land-Use
INDC	Intended Nationally Determined Contributions
NDC	Nationally Determined Contributions
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development
SAI	Sustainable Agricultural Intensification
AEI	Agro-Ecological Intensification
NGO	Non-Governmental Organisations

GMO	Genetically Modified Organisms
COCOBOD	Ghana Cocoa Board
REDD+	Reduced Emissions from Deforestation and Degradation
CSCWG	Climate-Smart Cocoa Working Group
CSC	Climate-Smart Cocoa
DRR	Disaster Risk Reduction
UNSGSAB	United Nations Secretary-General's Scientific Advisory Board
CBA	Community-Based Adaptation
SEMA	Sissala East Municipal Assembly
GSS	Ghana Statistical Service
DMTDP	Medium-Term Development Plan
SEDHDR	Sissala East District Human Development Report
PHC	Population and Housing Census
LDA	Lawra District Assembly
LDHDR	Lawra District Human Development Report
GMet	Ghana Meteorological Agency
FGD	Focus Group Discussion
COVID-19	Coronavirus Disease
UNISA	University of South Africa
PNDC	Provisional National Defence Council
SMS	Short Messaging Services
CIKOD	Centre for Indigenous Knowledge and Organisational Development
SPSS	Statistical Package for the Social Sciences

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PART I: INRTODUCTION AND BACKGROUND

This Part contains chapter one of the research, which presents the introduction and background to the study. It also includes the research problem, the aim of the research, the objectives and research questions as well as the significance of the study and how the thesis is organised.

CHAPTER 1: INTRODUCTION AND BACKGROUND TO THE STUDY

1.1 Introduction and Background

The agricultural sector remains a major source of livelihood for most rural population across developing countries globally, including those from sub-Saharan Africa (SSA). Rural communities in SSA extensively practice rain-fed agriculture for their livelihoods and household income (Adebisi-Adelani & Oyesola, 2014; Zake & Hauser, 2014; Pretty, Toulmin & Williams, 2011). As such, the agriculture sector remains a major employer in Africa, where about 70% of the population is engaged as smallholder farmers (Alliance for a Green Revolution in Africa - AGRA, 2017; Menike & Arachchi, 2016).

However, climate change has been a daunting challenge to the agricultural sector for several decades. The climatic conditions in SSA countries, including Ghana are highly variable, making the agricultural sector particularly vulnerable to the impacts of climate change (Food and Agriculture Organisation - FAO, 2017a; Mulwa, Marenya, Rahut & Kassie, 2017). There are increasing changes in temperature, pattern of rainfall and increasing frequency and severity of extreme weather events such as floods, droughts, extreme frost, wildfires, and windstorms (Menike & Arachchi, 2016; File, 2015). The impact of these changes presents several negative implications for rain-fed agriculture. Even though these impacts may vary from one country to another, from one region to another, and from one locality to the next, the implications for food security remain inevitably severer for smallholder farmers who have low adaptive capacities (Ayanlade, Radeny & Morton, 2017; FAO, 2017a; Inter-governmental Panel on Climate Change - IPCC, 2014). Climate change has affected several development interventions in agriculture and food security, health care, education, poverty reduction, ecosystem, and disaster risk reduction initiatives (Ansuategi et al., 2015; Nhamo & Mjimba, 2014). The burden of the impacts of climate change on SSA countries is much severe compared to their contributions to this phenomenon and this unduly subjects them to climate injustice (Care International, 2011).

Although agriculture, including smallholder farming, is a major victim of climate change, it is also an important contributor to climate change (United Nations Framework Convention on

Climate Change - UNFCCC, 2018; IPCC, 2014). According to the UNFCCC (2018), the agriculture sector accounts for about 10-12% of global greenhouse gas (GHG) emissions on one hand and suffers about 84% of economic impacts of drought-related extreme (climatic impacts) on the other hand. Decades long of extensive farming practices by smallholder farmers has caused soil and environmental degradation in many countries (FAO, 2017b). In Ghana, particularly northern Ghana, unsustainable mechanisation practices by farmers have accounted for immense land and environmental degradation. An estimated millions of hectares of forests and arable lands are being degraded and deforested as result of some non-sustainable agricultural cultivation methods, techniques, and practices in the country (Ghana Forestry Commission, 2017). Excessive and improper resource management and use of chemical fertilizer, pesticides and herbicides as means for increasing yields by farmers is further aggravating the impacts of climate change in the country (GIZ, 2012).

Agriculture contributes to global GHG emissions either directly or indirectly with more than half attributable to land use and land use change. The conversion of land and millions of hectares of forests for agricultural purposes result in environmental change with negative impacts on biodiversity and ecosystem services (FAO, 2016a; GIZ, 2012). The sector releases volumes of concentration of carbon dioxide, methane, nitrogen oxide, and other GHG into the atmosphere. The primary sources of these GHGs are fertilisers, improper soil management, burning of crop residues, rice cultivation and livestock farming (United States Environmental Protection Agency - USEPA, 2018). Agricultural emissions from livestock production accounts for about 44% of methane, 29% of nitrous oxide and 27% of carbon dioxide into the atmosphere (Gerber et al., 2013). This makes the livestock supply chain alone accounts for about 14.5% of human-induced GHG emissions globally (FAO, 2016a). The effects of these emissions present several threats to food crop and livestock production (Rojas-Downing, Nejadhashemi, Harrigan & Woznicki, 2017).

According to Olivier, Schure and Peters (2017), carbon dioxide accounted for about 72% of global emissions in 2016, while methane, nitrogen oxide and the other gases accounted for about 19%, 6% and 3%, respectively. Land use, land-use change, and forestry also accounted for an estimated emission of about 4.1 Gt CO_2 eq. in 2016, which resulted in an increase in global total GHG emissions to about 53.4 Gt CO_2 eq. in 2016 (Olivier, Schure & Peters, 2017).

Africa's agricultural livelihoods, economic growth and social progress have been threatened by the linkages between climate change and contemporary disaster events such as floods, droughts, and coastal storms as well as desertification, environmental degradation, and soil erosion (Lisk, 2009). The continent failed to achieve the global targets of the past Millennium Development Goals (MDGs) due mostly to the overwhelming impacts of climatic change that severely affected major initiatives (Ibid.). Despite global efforts at eradicating hunger as contained in the first of the 17 Sustainable Development Goals (SDGs) and the previous MDG 1, about 800 million people still suffer from chronic hunger and more than 150 million children under five years are stunted (FAO, 2016a; United Nations, 2015b). It is therefore posited that the world will require about 70% more of food in order to meet the food requirement of the world population by 2050 (Rojas-Downing et al., 2017). MDG 7, which focused on ensuring "environmental sustainability" was also not achieved.

Environmental degradation and forest loss due to overexploitation continue to rise with severe implications for rural livelihoods (FAO, 2017b). These activities endanger carbon stocks and release considerable volumes of carbon dioxide into the atmosphere. Deforestation and environmental degradation account for about 17% of global carbon dioxide emissions (UNFCCC, 2018). According to the United Nations (2015a), over 5.2 million hectares of forest were lost in 2010. This presents high risk for future carbon emissions. The report further noted that the impacts of climate change and environmental degradation continue to undermine the progress achieved under the MDGs with poor people suffering the most. Also, indiscriminate annual bush fires coupled with intensive and excessive tillage contribute to the depletion of soil organic carbon stocks, which lead to the deterioration of soil fertility and soil water storage capacity. This consequently results in frequent crop failures in many SSA countries (Buah et al., 2017).

With renewed efforts by the global community to achieve sustainable development, the MDGs were succeeded by the 2030 Agenda for Sustainable Development (AfSD) effective 1st January 2016. The 2030 AfSD consists of 17 SDGs and 169 targets to be achieved by 2030 (United Nations, 2015b). The 2030 AfSD aims to transform the world to better meet human needs and the requirements of economic transformation, while protecting the environment, ensuring peace, and realizing human rights. In the Agenda, prominence is given to climate change as it has a direct link to majority of the goals (Nhamo, 2016). This indicates how important the climate change phenomenon is to the global community. Many of the SDGs are interlinked with climate change. Hence, the processes for achieving them must be conscious of actions that will aggravate the incident of climate change. Thus, the processes to achieving the targets of these goals will have to address issues of climate and environmental change directly or indirectly.

SDG 13, which seeks to "take urgent action to combat climate change and its impacts" (United Nations, 2015a: 14) by 2030 will have to be given much attention since climate change has the tendency thwarting the efforts at achieving the goals. SDG 2 seeks to "end hunger, achieve food security and improved nutrition, and promote sustainable agriculture" (Ibid.). However, its achievement is dependent on the success or progress of SDG 13. SDG 13 is a clear acknowledgement by the global community that climate change impacts have a devastating effect on development, particularly agriculture and food security in the context of this study.

Interestingly, the SDGs, unlike the MDGs, are global in nature and are universally applicable despite country differences in terms of national realities, capacities, levels of development as well as national policies and priorities (United Nations, 2015b). This is partly because the global community is confronted with one common daunting challenge, which is climate change. Climate change affects both developed and developing nations across the world and the actions to combating it, even though, may be country-specific require global commitments (from all member states of the United Nations) towards implementations.

Combating climate change (achieving SDG 13) may not only be a central domestic challenge for developing countries but also a most important transformational challenge for the developed world too. This is because of the direct linkages of climate change with other goals including sustainable energy, and sustainable consumption and production which are SDG 7 and SDG 12 respectively (Osborn, Cutter & Ullah, 2015). African nations will have to intensify efforts to address SDG 13 in order to achieve SDG 2 by the 2030 timeline. This is because of the continent is highly vulnerable to climate change. Droughts, floods, pests and diseases and high temperatures are projected to be more frequent, more intense, and longer lasting in Africa (Nyasimi, Amwata, Hove, Kinyangi & Wamukoya, 2014). These will present further and severe threats including crop failure to rain-fed farming in SSA. Therefore, smallholder farmers would need crop varieties and agricultural practices that continue to produce and even produce more under different weather conditions in order to meet the challenges of climate change (Ibid.). Thus, climate action must focus on mitigation and adaptation to the impacts of floods, droughts and/or dry spells, extreme temperatures, sea level rise, water shortages, loss of biodiversity species, food insecurity, the emergence of pests and diseases across Africa (Nhamo & Mjimba, 2014). These must be climate compatible initiatives in agriculture rather than the conventional agricultural practices.

It is in line with climate compatible development that Climate-Smart Agriculture (CSA) has become increasingly an important strategy for achieving sustainable agriculture under increasing impacts of climate change (Taylor, 2018; Torquebiau, Rosenzweig, Chatrchyan, Andrieu & Khosla, 2018). CSA is defined as "agriculture that sustainably increases productivity, resilience (adaptation), reduces GHG (mitigation), and enhances achievement of national food security and development goals (development)" (FAO, 2010: ii). It presents a significant transformation to meet the simultaneous challenges of climate change, food insecurity, poverty, and environmental degradation (Nyasimi et al., 2014). CSA sustainably increases productivity, enhances resilience to climatic stresses, and reduces GHG emissions (Khatri-Chhetri, Aggarwal, Joshi & Vyas, 2017; Lipper et al., 2014). CSA thus, achieves what is known as the 'triple win' pillars of increasing smallholder farmers' adaptation to climate change, mitigation of climate change, and ensuring global food security through innovative policies, practices, and technologies (Torquebiau et al., 2018; Ansuategi et al., 2015).

CSA is also key to achieving the SDGs (Taylor, 2018) since it involves a set of objectives and multiple transformative processes, which allow for new knowledge gaps to be identified and addressed even at the implementation stage (Torquebiau et al., 2018). It integrates traditional and innovative practices, and services for adapting to climate change and variability in a context-specific manner (International Center for Tropical Agriculture - CIAT, 2014). CSA, therefore, presents holistic options for achieving sustainable agriculture under climate change (Taylor, 2018). CSA strategies are also designed with an emphasis on specific local context, which considers the diversity of agricultural systems and priorities of stakeholders in adoption and implementation of initiatives (Andrieu et al., 2017; Khatri-Chhetri et al., 2017). This is because what constitutes climate-smart practice and technology depends on prevailing agro-ecological conditions and opportunities within the specific local environment. Hence, the variations in agro-ecological conditions from one geographical area to another affect what constitute climate-smart practice and technology. One technology and practice could be viewed as climate-smart in one environment but not in another environment due to differences in agro-ecology, market opportunities, and other conditions (Torquebiau et al., 2018).

CSA systems efficiently utilise ecosystem services to support productivity, adaptation, and mitigation (Lipper et al., 2014). The approaches to agriculture are ecosystem-based that build on and strengthen natural services to minimise environmental destruction through agriculture (FAO, 2016a). CSA decisions incorporate a set of measures that foster change towards concurrent consideration of food security, adaptation, and mitigation in land-use practices (Torquebiau et al., 2018; Torquebiau, Berry, Caron & Grosclaude, 2016). The World Bank (2015) noted that adaptation to climate change impacts is necessity due to the growing impacts on food security and agricultural production systems. It has projected with detrimental consequences the reduction in crop yields of up to seven percent in Africa and Asia by 2030. In this regard, the World Bank sees CSA as key to conceptualising the linkages between climate change, population growth, food security and agricultural production (World Bank, 2015). Taylor (2018), noted that a transition to climate-smart practices is not only a priority, but also a matter of compelling urgency in order to make sustainable productivity gains in the agricultural sector. The author advocates for attention beyond approaches that are climate-smart to rather ‘climate-wise’ approaches. He argues that climate-wise approaches are more participatory and explicitly challenge the status quo of disproportionate influence of political debates on agriculture.

The agriculture sector itself also presents significant climate compatible approaches for achieving sustainable agriculture and climate compatible development (England, Stringer, Dougill & Afionis, 2018). England, Stringer, Dougill and Afionis (2018), contend that agriculture is not only oriented towards adaptation, but further offers potential mitigation approaches, which are the basic pillars of climate compatible development. The authors cite agroforestry and access to agricultural extension services as basic approaches for mitigation of GHGs and adapting to climate change. Such access foster rural livelihood portfolios for climate compatible development by increasing adaptive capacity and food security (Mbow, Smith, Skole, Duguma & Bustamante, 2014). Climate compatible agricultural approaches would include seed and crop storage systems, early warning systems for droughts and floods, crop diversification, improving access to markets, and enhanced agricultural research and capacity development (England et al., 2018).

In rural communities of SSA, local and/or indigenous knowledge (LIK) is the basis for community level decision-making on food security, health, education, natural resource management and other economic and social activities (Gorjestani, 2000). It is an institutionalised knowledge, which is built upon and passed on to generations by word of mouth. It is unique to the people from one geographical area to the other (Mapara, 2009). It refers to the knowledge, innovations, and practices of indigenous and local communities, developed from experiences gained over the centuries, adapted to the local culture and environment, and orally transmitted from generation to generation (Inter-Agency Support Group on Indigenous Peoples' Issues - IASG, 2014). It is also collectively owned and takes the form of stories, songs, folklore, proverbs, cultural values, beliefs, rituals, community laws, local language, and agricultural practices, including the development of plant species and animal breeds (Ibid.). LIK is not only a valuable asset to rural communities and their culture, but also relevant to modern institutions and professionals (such as scientists and planners, etc.) who are striving to improve living conditions in rural communities (Boko et al., 2007; Nyong, Adesina & Elasha, 2007).

LIK encompasses mental inventories of the characteristics weather elements (rainfall, temperature, and wind), animal breeds, local plant, crop and tree species and belief systems that enhance the livelihood of the people, health and protect the environment (Mafongoya, Jiri, Mubaya & Mafongoya, 2017; Audefroy & Sanchez, 2017).

Rural communities in Ghana and other SSA countries are mostly engaged in subsistence agriculture, which makes them share an intricate economic and cultural relationship with the natural environment that is directly affected by climate change (International Labour Organisation - ILO, 2017). The sustainability of traditional agriculture in SSA over the decades has been attributable to the application of LIK that brings wisdom from smallholder farmers (Iloka, 2016). There is evidence that smallholder farmers have developed more eco-friendly, sustainable, and location-specific knowledge systems for adapting to climate change over the years. As a result, local and indigenous farmers are increasingly being recognised as innovators and agents of change based on their unique practices (application of local knowledge) in the field of adaptation and sustainable agriculture (ILO, 2017; Kumar, 2010).

Indigenous communities have successfully developed and implemented mitigation and adaptation strategies that reduced their vulnerability to disasters such as droughts, floods, and other extreme events through their own knowledge systems (Ali & Erenstein, 2017). LIK systems provide them the understanding, experience, and knowledge on how both natural and human-induced disasters impact on their livelihoods and health systems. As a result, they are able to develop measures including disaster prevention and mitigation, early warning, preparedness and response, and post disaster recovery measures to sustain life and livelihoods (Mafongoya & Ajayi, 2017). These skills and techniques could provide policy makers with relevant information for building appropriate models on such issues as disaster preparedness and response, impact assessment, conservation of ecological resources and climate change adaptation programmes. The application of LIK in community-level adaptation usually involves a set of organisational changes and localisation of techniques for limiting the negative impacts of climate change (De Perthuis, 2009 cited in Kpadonou, Adégbola & Tovignan, 2012). It is a continuous process and action which revolves and changes over time with focus on reducing the impacts of changing climatic conditions (Jiri et al., 2016).

During the 23rd Conference of Parties (COP 23) of the United Nations Framework Convention on Climate Change (UNFCCC) that took place in Paris in 2015, the body affirmed the contribution and application of LIK in climate change adaptation. This resulted in the launching of a new platform for indigenous and local community climate action to promote the exchange of knowledge, technologies, and practices of LIK among stakeholders. This is because "indigenous peoples and local communities are often on the front line of climate change and have invaluable insights into and perspectives on coping with its effects" (UNFCCC, 2018: 17). Therefore, there is the need for adaptation planning process to take into consideration indigenous and local institutions, knowledge systems and the daily traditional activities of smallholder farmers. This is key to building capacities of rural people who are affected by impacts of climate change (Boko et al., 2007; Tauli-Corpuz et al., 2009). LIK further makes climate change adaptation planning more participatory and a localised process for easy understanding and implementation at all levels (Locatelli, 2011; Agrawal & Perrin, 2009). The social context within which LIK systems are developed and implemented, gives credence to the role of local institutions and local governance in shaping adaptation practices (Agrawal & Perrin, 2009).

There is evidence that smallholder farmers possess enormous knowledge on agricultural practices and technology that include pest management, soil fertilisation, multiple cropping pattern, food preservation, multiple farms, crop and land diversification and using high yielding varieties. These knowledge systems are developed based on the cosmovision of indigenous people (smallholder farmers), which recognises the role of both natural and supernatural forces and agencies in their struggle for survival (Boonzaaijer & Apusigah, 2008; Millar, 2004; Kumar, 2010). This includes the demographic characteristics including culture and spirituality, environmental and ecological characteristics of the people and their surroundings. According to Boonzaaijer and Apusigah (2008: 37), "African cosmovisions often indicate a hierarchy of divine beings (gods), spiritual beings (especially the ancestors) and natural forces (such as climate, diseases, floods)".

Smallholder farmers are seen as primary innovators in agriculture. They have developed crops and cropping systems over the centuries through indigenous knowledge systems, which served as the basis for modern scientific agriculture (Kumar, 2010). Indigenous agricultural knowledge relates to climatic and environmental conditions such as temperature, rainfall, winds, sunshine, soil types, crop pests and diseases, and crop varieties. It also involves management practices such as irrigation techniques, soil management, planting patterns, pest and weed control, and crop selection (Ibid.). It as well involves the organisation of agricultural activities such as resource allocation including land allocation and use of alternative production systems (Derbile & File, 2016; File, 2015; Derbile, 2010). In northern Ghana, smallholder farmers are able to classify agricultural land and identify the respective types of crops that can do well on the different types of land through their own knowledge systems (File, 2015). Farmers are able to classify climatic elements such as rainfall, temperature, sunshine and wind over the year for categorising the agriculture season accordingly (Derbile & File, 2016). This presents them with a calendar of agricultural season and activities to follow and to predict climatic outcomes and extent of impact on agriculture (farm crops and livestock). Based on their years of experience and observation of changes in environmental and weather elements such as rainfall, temperature, sunshine, wind, behaviour of trees, animals, birds, insects, etc., farmers predict and interpret climate change and its impacts on farming (Ansah & Siaw, 2017).

The linkages of farmers' knowledge systems have made smallholder agriculture sustainable over the past centuries. Although, local farmers may not be able to articulate these knowledge systems in a manner that is proactively responsive to the increasing dangers of climate change, they serve as foundation for scientists and experts in policy planning and implementation (Samaddar et al., 2021; Dervieux & Belgherbi, 2020). Nyong et al. (2007) observed that much prominence has not been given to the incorporation of LIK systems into formal climate change adaptation processes even though there is evidence that indigenous knowledge has helped in design and implementation of many sustainable development projects in SSA. Mafongoya and

Ajayi (2017) also observed that, though the contributions of LIK in climate change adaptation processes were articulated about a decade ago, significant work only begun in earnest about five years ago. Therefore, the role of LIK has not yet been articulated and incorporated into the processes of national policy formulation and implementation in SSA countries including Ghana. This is because many policy makers are either not well familiar with the notion of LIK or do not have adequate understanding of its role, to be better able to integrate LIK with scientific knowledge in the design, planning and implementation processes of development initiatives at local, national, and international levels (Ibid.). Hence, many policy interventions that are meant to address agriculture and other basic livelihoods in rural communities are designed, planned, and implemented without adequate recourse to LIK systems of the people and communities. These interventions are therefore misapplied and/or rejected due to inadequate participation and understanding by smallholder farmers (Theodory, 2016). Consequently, many adaptations and sustainable development projects have failed to achieve their intended purposes of building community resilience for sustainable livelihoods in SSA countries over the years.

1.2 Research Problem

It is anticipated that about 70% more food will be needed to meet the food requirements of the rapidly growing world's population, which is estimated to reach about nine billion people by the middle of the century (GIZ, 2012). In Africa, an estimated annual population growth of 2.4% will double the current population of 0.9 billion people by 2050. This will require an increase of about 260% in crop production to meet food needs of this population (Nyasimi et al., 2014). According to the FAO (2017a), the world population is estimated to reach about 10 billion by 2050, an increase of 50% compared to 2013 with the possibility of exceeding 11.2 billion people by 2100. In Africa, the population is estimated to reach about 2.2 billion by 2050 and possibly over 4 billion people by 2100. This will increase agricultural demand (food demand) significantly and will subsequently result in increased pressure on natural resources in low-income countries.

The Food Security Information Network (FSIN, 2018) global report indicated that there was an increase in the number of hungry people globally from an estimated 108 million people across

48 countries in 2016 to about 124 million people across 51 countries in 2017. This is an increase of 11 million people (or 11% increase) globally from 2016. This was attributed to climatic disasters (mainly prolonged droughts), and conflict and insecurity which occur simultaneously in many African countries. The report further revealed that, extreme climatic events were responsible for hunger in about 23 countries with over 39 million food-insecure people in 2017. From this figure, about two-thirds of these countries are African countries with an estimated 32 million people experiencing severe conditions of acute food insecurity. In addition, more than a quarter of the population in SSA is estimated to be undernourished (FAO, 2016a).

Smallholder farmers have limited capacities to appropriately address climate variations and changes. However, smallholder farmers have proven and are proving that LIK systems are strategic resources for building their adaptive capacities to climate change and SSA including Ghana. Based on IKS, farmers have been able to perceive, conceptualise and understand not only the impacts of climate change but also the causes and possible solutions (adjustments) to climate change. Consequently, they can articulate and manipulate different sources of knowledge systems and resources to adequately optimise efforts and improve climate adaptation interventions (Ansah & Siaw, 2017). There is enough evidence that smallholder farmers have adapted to disasters and climatic change impacts for several years through IKS (Bwambale, Muhumuza & Nyeko, 2018). These knowledge systems are in the form of agricultural risks reduction methods, techniques, and practices, which have made traditional agriculture sustainable over the decades. They are mostly developed based on the cosmovision of smallholder farmers which reflect their diverse lifestyles and eco-cultural practices (Kumar, 2010; Boonzaaijer & Apusigah, 2008). The LIK systems are important and key to achieving sustainable agriculture under climate change and are increasingly recognised in national and international efforts (ILO, 2017).

In Ghana, the future impacts of climate change on agriculture are forecasted to be very severe if adaptation efforts are not intensified. These projections will jeopardise food security and intensify poverty levels (FAO, 2017a; GNCCP, 2013). The evidence of the impacts of climate change is real and severe for smallholder farmers, particularly women farmers in northern

Ghana (Abdul-Razak & Kruse, 2017; GNCCP, 2013). The projected temperatures and precipitation for the years 2020, 2050 and 2080 depicted high and low levels for all the years respectively (World Bank, 2010). It is also estimated that desertification in Ghana is proceeding at a rate of 20,000 hectares per annum (Asante et al., 2015). All these changes will have severer consequences for agriculture, which is the main source of livelihoods for millions of rural people, especially in northern Ghana.

The Ghanaian farmer is therefore confronted with the increasing impacts of climate variability and change, increasing household size, and increasing demand for food. All this takes place against a background of limited agricultural production systems. These have increased the risks of agriculture production in recent decades and will continue in the future (Elum, Nhamo & Antwi, 2018). Unreliable rainfall pattern and rising temperatures have negatively affected crop yields in Ghana over the decades and will continue in the future (Iddi, Donkoh, Danso-Abbeam, Karg & Akoto-Danso, 2018; Ansah & Siaw, 2017). The rainfall pattern has become more variable, resulting in late onset and early cessation of rains, limited coverage, low amounts of rainfall and recurrent droughts and floods within the same year (Iddi et al., 2018; Akudugu, Dittoh & Mahama, 2012).

Leading from the above, it has emerged that agriculture needs to be climate-smart and climate compatible to address the challenges of feeding a rapidly growing population in SSA including Ghana (Totin et al., 2018). Climate-smart agricultural methods, practices and technologies significantly achieve climate adaptation, mitigation, and food security through resilient food production systems. In effect, there is growing evidence that smallholder farmers across Africa are embracing climate-smart and climate-compatible innovations that have the tendency to increase food production under climate change conditions (Zougmore, Partey, Ouédraogo, Torquebiau & Campbell, 2018; Nyasimi et al., 2014).

In Ghana, CSA has proven to be a viable pathway for tackling the threats of climate change in Ghana (Ansah & Siaw, 2017). However, there is little evidence of CSA practices among farmers and whether farmers are aware of these practices is still to be explored. This is because, it was only in 2015 that a National Climate-Smart Agriculture and Food Security Action Plan of Ghana (2016-2020) was developed to provide an "implementation framework for effective development of climate-smart agriculture in the ground" (Essegbey, Nutsukpo, Karbo & Zougmoré, 2015: v). This was an effort to translate broad national goals and objectives in CSA from national to the local (community) level through formulation of specific strategies in (i) developing climate-resilient agriculture and food systems for all agro-ecological zones in Ghana; (ii) developing the requisite human resource capacity for climate-resilient agriculture promotion in Ghana; and (iii) elaborating on the implementation framework and the specific CSA activities to be implemented at the respective levels of governance. Therefore, the plan was to define and analyse activities that consider smartness regarding weather information, energy, water, nitrogen, etc. in agriculture and food systems under climate change in the context of Ghana (Ibid.).

Agula, Akudugu, Dittoh and Mabe (2018) corroborate in their study in the Upper East Region of northern Ghana that, few farmers could understand which CSA practices were, in terms of new agricultural technologies, innovations and interventions. They attributed this to the fact that majority of smallholder farmers in northern Ghana have no and/or low level of formal education and are therefore unable to read and understand the nexus between new agricultural interventions (practices and technologies) and agro-ecosystems sustainability. They further found that smallholder farmers had inadequate knowledge on the usefulness of ecosystem-based farm management practices that were climate-smart. Farmers also had inadequate access to information on new agriculture production practices and technologies. The authors therefore suggested that education of farmers was important for smallholder farmers on their choice of activities and practices at the farm level.

Additionally, Buah et al., (2017) discovered that only two communities in two districts in the Upper West Region have CSA experimental fields under the Climate Change, Agriculture and Food Security (CCAFS) programme of the Consultative Group on International Agricultural Research (CGIAR). These fields, known as climate-smart villages (CSVs), were to help smallholder farmers learn and adopt CSA practices and technologies to enhance food security under current climatic conditions. The authors found that only smallholder farmers at Doggoh and Bompari CSVs in the Lawra and Jirapa Districts respectively were exposed to some climate-smart practices and technologies. They were also exposed to climate-smart services such as weather forecast information delivered via mobile phones, planned planting, harvesting and other activities on the farm. Though the researchers reported about scaling up of CSA interventions by CCAFS through CSVs across northern Ghana and other parts of the country in the future, there is, currently, still little evidence and awareness of CSA practices and technologies among smallholder farmers in the Upper West Region.

Moreover, the Government of Ghana, with funding from the World Bank, commenced the West Africa Agricultural Transformation Program (WAATP) in 2018, which has an overall objective of strengthening "regional agricultural innovations system to facilitate mass adoption of climate smart technologies by producers, enhance job creation for the youth and value chain actors' access to regional markets for targeted agricultural products" within the West Africa sub-region (Ministry of Food and Agriculture - MoFA, 2018: ix). It is a five-year program beginning 2018, with MoFA as the implementing ministry. The programme aims to, among other things, accelerate mass adoption of CSA technologies through farmers field schools of CSA practices on identified commodities, as well as "establish community demonstration plots on proven CSA technologies for vegetables, cereals, legumes and root and tubers crops to farmers; and establish farmers field schools of CSA practices on identified commodities" (Ibid.: x). The programme is yet to be fully implemented. This is yet another justification that there is little evidence and awareness of CSA practices among smallholder farmers in Ghana and particularly in the Upper West Region, which needs to be explored.

The LIK has been identified as an important resource for achieving the practice and adoption of climate-compatible agriculture in Ghana (Akrofi-Atitianti, Speranza, Bockel & Asare, 2018; Asare, 2014; Antwi-Agyei, Dougill & Stringer, 2013; Aneani, Anchirinah, Owusu-Ansah & Asamoah, 2012). LIK makes the CSA process more participatory and understandable for smallholder farmers to adopt. It incorporates a combination of traditional and modern scientific techniques for mitigating and adapting to climate change impacts (FAO, 2013). However, the role of LIK in achieving climate-compatible agriculture in Ghana and particularly northern Ghana has not been explicitly and extensively explored. As a result, to my knowledge, there is little research and knowledge on climate-smart and compatible agricultural practices in northern Ghana. The limited work on CSA in Ghana concentrates on cocoa production, which is limited to Southern Ghana (Dohmen, Noponen, Enomoto, Mensah, & Muilerman, 2018; Akrofi-Atitianti et al., 2018; Kroeger, Koenig, Thomson & Streck, 2017; McKinley et al., 2016; Noponen, Mensah, Schroth & Hayward, 2014; Forest Trends and Nature Conservation Research Centre – FT & NCRC, 2012). Although, the agricultural practices of smallholder farmers might indicate a combination of various knowledge systems and practices in agricultural production, there is little research attention on how smallholder farmers interface scientific, indigenous, and local knowledge systema and practices to promote climate compatible agriculture in northern Ghana. It is also unclear whether LIK systems of smallholder farmers offer any opportunity for adopting and practicing CSA for achieving climate compatible agriculture in food and livestock production in northern Ghana. Therefore, this study seeks to explore the role of LIK systems among smallholder farmers in promoting climate compatible agriculture in the Upper West Region of northern Ghana and how LIK interfaces with scientific knowledge.

1.3 Aim of the Research

The aim of the study is to explore the potential use of local and indigenous knowledge of smallholder farmers in promoting climate compatible agriculture in northern Ghana and how this interfaces with scientific knowledge.

1.4 Objectives of the Research

Given the foregone and stated research aim, the following objectives are spelt out:

1. To establish trends in climate change and explore how climatic risk and agricultural vulnerability are assessed through local and indigenous knowledge systems by smallholder farmers in Upper West Region.

2. To explore the dynamics of interfacing the application of scientific, local and indigenous knowledge systems in promoting climate compatible agriculture in Upper West Region of Ghana.

3. To determine the factors that may influence smallholder farmers' decisions in adopting local and indigenous knowledge systems for climate-compatible agricultural practices in Upper West Region.

4. To assess the level of awareness of smallholder farmers on climate compatible agriculture and document adaptation measures developed in Upper West Region.

1.5 Research Questions

Drawing from the aim of the study and the research objectives, the main research question is set out, thus, to what extend is the local and indigenous knowledge systems being utilized in promoting climate compatible agriculture in the Upper West Region of Ghana and how it interfaces with scientific knowledge?

1.5.1 Sub-Questions

1. What climate change trends exist and how do smallholder farmers assess climatic risk and agricultural vulnerability through local and indigenous knowledge systems in Upper West Region of Ghana?

2. What dynamics exist in interfacing scientific, local and indigenous knowledge systems in food crop and livestock production in Upper West Region of Ghana?

3. Which factors determine smallholder farmers' decisions in adopting local and indigenous knowledge systems for climate-compatible agricultural practices in Upper West Region?

4. What is the level of awareness of smallholder farmers on climate compatible agriculture and which adaptation measures have been developed in Upper West Region?

1.6 Significance of the Study

The study will be significant in the following major ways: (i) it will contribute to development policy formulation and building communities of practice in climate compatible agriculture through interfacing scientific, local and indigenous knowledge systems; (ii) it will contribute to the body of literature on climate compatible agriculture through scientific, local and indigenous knowledge systems, and (iii) it will inform further research in the said areas of interest.

The majority of the people in northern Ghana, particularly North-western Ghana are predominantly subsistence farmers who are negatively affected by climate change impacts. In this regard, a sustainable pathway that position smallholder farming in a way that minimises climatic impacts and maximises production is highly desirable and welcoming. Smallholder farmers have been found to be slow in adoption of improved farm practices and technologies brought to them by the government and other related extension workers. This has been attributed to the realities on the ground with farmers passively resisting scientific advice that may not support what they will be experiencing on the ground based on their local and indigenous knowledge. This brings contradictions in the twin knowledge systems – scientific and extension knowledge on the one hand, and local and indigenous knowledge on the other. Therefore, this research will bring to the fore, the understanding and need for policy formulation process and communities of practice in climate compatible agriculture that will seek to make the best out of the twin knowledge systems not only in the Upper West Region, but northern Ghana and Ghana at large. Thus, the study would provide policy planners and implementers at the local level with the understanding on the integration process of the twin knowledge systems for decentralised agricultural planning. The understanding of the perceptions of smallholder farmers, which are embedded in their cosmovision of climatic and weather events will promote climate compatible agriculture practices (Rojas-Downing et al., 2017).

The findings of the study will further serve as a source of knowledge and reference for other researchers. The study will add to the body of literature pertaining to the positive interfacing of scientific, local and indigenous forms of knowledge in promoting climate compatible agriculture. As such, the findings may be useful in the mainstreaming of local and indigenous knowledge into national, regional and district development plans for achieving sustainable agriculture and development in Ghana. Therefore, this may serve as a guide to stakeholders especially Ministries, Departments and Agencies (MDAs) and Civil Society Organisations (CSOs) in facilitating the processes of mainstreaming LIK systems into decentralised development planning at the local level. In the same vein, the gaps that will be discovered in this study will encourage other researchers and scholars to do further research to bridge those gaps so identified.

1.7 Organisation of thesis

The thesis will be presented in four parts as follows:

Part I: This part of the thesis presents chapter one of the thesis, which outlines the introduction and background to the study, the research problem, the aim of the research, objectives of the research, research questions, significance of the study and organisation of the thesis.

Part II: This part presents the literature review, conceptual framework, and methodology of the study. Three chapters are presented here, namely chapters two, three and four. Chapter two presents a review of relevant literature on the concepts of climate change and climate compatible development. The chapter gives an overview of climate change in relation to its impact on smallholder agriculture and how agriculture itself contributes to climate change, a review of the MDGs and SDGs in relation to tackling and reducing the impacts and threats of climate change, and lastly, a review on climate compatible development. Chapter three also presents a review of literature on sustainable agriculture and climate-smart agriculture: interfacing scientific, local, and indigenous knowledge systems, and the conceptual framework of the study. Lastly, chapter four presents the profile of the study municipalities and methodological framework of the study.

Part III: This part of the thesis will present and discuss the findings of the study. It contains four chapters, namely chapters five, six, seven and eight. Chapter five will focus on climate change trends and assessment of climatic risk and agriculture vulnerability. Chapter six will address climate compatible agriculture and adaptation strategies, interfacing scientific, local and indigenous knowledge systems. Chapter seven will present and discuss the factors influencing the use of local and indigenous knowledge in adopting climate compatible agricultural practices. The last chapter in this part (chapter eight) presents the level of awareness of the smallholder households on climate compatible agricultural practices in North-western Ghana.

Part IV: This part is made up of a single chapter – chapter 8 and will present the conclusion and suggestions of the study.

PART II: LITERATURE REVIEW, CONCEPTUAL FRAMEWORK AND METHODOLOGY

This part of the thesis presents a review of relevant literature, the conceptual framework of the study, as well as the profile of the study municipalities and the methodology of the study. The literature review section is presented in two chapters namely chapters two and three.

Chapter two gives an overview of climate change in relation to agriculture as a victim and contributor to climate change. It also reviews relevant literature on the concept of climate compatible development (CCD) and sustainable agriculture.

Chapter three also presents a review of literature on climate-smart agriculture and the role of local and indigenous knowledge of smallholder farmers in promoting sustainable agricultural livelihoods. The conceptual framework will also be presented under this chapter.

Chapter four contains the profile of study Municipalities and the methodology used in generating and analysing the data. The demographic characteristics of the study respondents are also presented in this chapter.

CHAPTER 2: UNDERSTANDING CLIMATE CHANGE, CLIMATE COMPATIBLE DEVELOPMENT AND SUSTAINABLE AGRICULTURE

2.1 Introduction

This chapter presents a review of relevant literature on climate change and its impact on agriculture, and how agriculture also contributes to climate change. It looks at the past MDGs and the ongoing SDGs as part of global efforts at tackling climate change. There is also a review of literature on the concept of climate compatible development (CCD) in relation to sustainable agriculture, which includes approaches such as sustainable intensification agriculture, ecological intensification agriculture and climate-smart agriculture (CSA). A review of literature is also done on the role of local and/or indigenous knowledge (LIK) of smallholder farmers in relation to sustaining agricultural livelihoods by interfacing scientific, local and indigenous knowledge systems in SSA and Ghana.

2.2 Overview of Climate Change and Agriculture

Globally, the phenomenon of climate change is evidenced in rising temperatures, rising sea levels, melting glaciers, precipitation changes and other extreme weather events which impact negatively on agriculture (Danish Agriculture and Food Council (DAFC) & Agriterra, 2019). These present significant impacts on agriculture in the form of low species migration, crop yields and loss of ecosystem goods and services, which pose major threat to food security, household incomes and stable food prices globally (FAO, 2017c). Climate change will also present, in addition to food security and socio-economic status of communities (Muchuru & Nhamo, 2019a), several threats to the availability of, and demand for water and water resources for domestic, agriculture and other livelihood purposes (Muchuru & Nhamo, 2019b).

Agriculture remains the mainstay of the economies of developing countries, as the majority of their populations, particularly rural populations depend on agriculture for their livelihoods (Alam et al., 2017). The agricultural sector has been a major employer and source of livelihood for rural communities in Africa and South Asia, where the rural populations and communities are extensively engaged in rain-fed agriculture for their livelihoods and household income (Menike & Arachchi, 2016; Adebisi-Adelani & Oyesola, 2014). In Africa, for instance, farming is not only an important livelihood activity, but also a key activity for preserving the socio-cultural identities of the local people (Davies et al., 2019).

According to Lipper et al. (2014), the number of people living in developing countries is estimated to increase by 2.4 billion more by 2050, out of which, the majority of them will be living in South Asia and SSA. This will have a corresponding increase on the current numbers of people who will have to depend on agriculture for food and income. Unfortunately, despite the heavily dependence on agriculture by South Asia and SSA for their economic growth and employment, the majority of the people are still hungry; and accounted for about one-third of the world's undernourished people in 2018 (United Nations, 2019). Therefore, building resilience for an increased agricultural productivity and incomes among smallholder producers is not only significant for achieving food security and reducing poverty, but also "a key element and driver of economic transformation and growth" within the "broader context of urbanization and development of the non-farm sector" in SSA (Lipper et al., 2014:1068). It is estimated that the world agricultural production will have to increase (through increased productivity) by 60% to meet the increasing demand from an increasing population by 2050 (FAO, 2016b; Alexandratos & Bruinsma, 2012).

According to Searchinger et al. (2019), the estimated 10 billion people by 2050 will come with a corresponding increase of over 50% in global food demand and about 70% in demand for animal-based foods. As a result, the global agriculture and food production sector is confronted with the double task of finding solutions to climate change, on one hand, and on the other hand, offering opportunities for achieving climate change adaptation and mitigation efforts (DAFC & Agriterra, 2019). Thus, smallholder farmers and the agriculture sector also provide opportunities and solutions for addressing climate change, enhancing food safety, health and nutrition as well as contributing to the generality of rural development.

In Africa, about 70% of the population is engaged in the agricultural sector as smallholder farmers (Alliance for a Green Revolution in Africa - AGRA, 2017). According to Davis, Giuseppe and Zezza (2018), agriculture is the major source of household income to about two-thirds of rural households in Africa compared to other regions. It also serves as source of livelihoods to about 90% of rural households in Africa (Ibid.).

It is anticipated that about 70% more food will be needed to meet the food requirements of the rapidly growing world’s population, which is estimated to reach about nine billion people by the middle of the century (GIZ, 2012). The FAO (2017a) also projected the world population to reach about 10 billion by 2050, an increase of 50% compared to 2013 level, with possibility of exceeding 11.2 billion people by 2100. In Africa, the population is estimated to reach about 2.2 billion by 2050 and possibly over 4 billion people by 2100 (Ibid.). Similarly, Nyasimi, Amwata, Hove, Kinyangi and Wamukoya (2014) also estimated the current population of Africa to double by 2050, in which, it will require an increase of about 260% in crop production in order to meet the food needs of this population (Nyasimi Amwata, Hove, Kinyangi & Wamukoya, 2014). Over the decades, rapid population growth in Africa has manifested, and still manifesting in increasing stress on smallholder farming systems (Binswanger-Mkhize & Savastano, 2017). Therefore, the fundamental concern of major stakeholders in the agricultural sector relates to “how agricultural production responds to higher population density and the development of markets” (Binswanger-Mkhize, & Savastano, 2017:96). The authors see further concerns on ‘how’ and ‘what’ changes will be needed in terms of technology adoption, cropping intensities, use of inputs, capital as well as the required level of soil fertility to promote sufficient crop yields for improving the incomes of smallholder households. These concerns are genuine because of the increasing recognition of the severe impacts of climate change on food systems and agriculture in Africa (Niles et al., 2018).

Notwithstanding being the major employer and source of livelihood for rural communities in most developing countries, the agricultural sector remains one of the most sensitive and vulnerable sectors to climate variability and change (Alam et al., 2017; Menike & Arachchi, 2016). Therefore, climate change has become a major global threat to agriculture, food security and livelihoods of millions of people across the world (Inter-governmental Panel on Climate Change - IPCC, 2014). The impacts of climate change are further projected to be severer for rain-fed agriculture dependent economies due to their low adaptive capacities against extreme events such as floods, droughts, storms, etc. It is also anticipated that the effects of climate change will be felt in the form of changes in agriculture biodiversity, crop cultivation suitability, decrease in input use efficiency, as well as prevalence of pests and diseases that are resistant to different weather conditions (Triodos Bank, 2019).

The IPCC (2014) has noted that the negative effects of climate change will be severer for developing countries as the negative effects on crop production will surpass the positive effects in several regions across the world. There are also projections of increases in maximum temperatures as well as increases in rainfall variability, which will trigger increases in the frequency and intensity of extreme events such as drought and flooding across regions (IPCC, 2014). The effects of these changes will be unevenly distributed across regions and will also exacerbate water scarcity and drought situations in already dry regions by the end of the century (Porter et al., 2014). The United Nations in its 2019 report on the SDGs, revealed that about two billion people across the world were suffering from water stress and has, therefore, sounded the alarm bell that, an estimated additional 700 million people risk displacement by 2030 due to intense water scarcity (United Nations, 2019).

Climate change, therefore, presents a major threat to food security in the form of reduced agricultural production and incomes, as well as increased market risks for agricultural goods and services for both rural and urban populations (Lipper et al., 2014). These impacts can be long-lasting due to increasing uncertainty and risks exposure of rural agriculture to extreme climatic events such as floods, droughts, high temperatures and other extreme events (FAO, IFAD, UNICEF, WFP & WHO, 2018). Rural populations, particularly smallholder farmers are mostly vulnerable due to their low adaptive capacities and exposure of agricultural and other livelihoods systems to interplay of extreme climatic events (such as droughts and flooding), which have become highly variable and unpredictable over the past years (Mutegi et al., 2018). Their vulnerabilities are exacerbated by poor access to weather information, low incomes, low level of education, inadequate access to land, and inadequate access to new crop variety and livestock breeds, among others (Mase et al., 2017).

In SSA, extreme variations in climatic conditions present a daunting challenge to the progress of the agricultural sector (Food and Agriculture Organisation - FAO, 2017a; Mulwa, Marenya, Rahut & Kassie, 2017). Frequent and increasing changes in temperature and rainfall have manifested in extreme and recurrent floods and droughts, which are detrimentally impacting on agriculture (Menike & Arachchi, 2016; File, 2015). This frequent recurrence of extreme events has affected and/or is affecting traditional disaster preparedness and prediction systems of smallholder farmers in local communities in many SSA countries (Mutegi et al., 2018). Although the impact of these changes may vary from one country to another, the general implications for agricultural productivity and food security remain inevitably severer for smallholder farmers (Ayanlade, Radeny & Morton, 2017; FAO, 2017a; IPCC, 2014). The efforts (initiatives/interventions) of policy makers and donors in the agricultural value chain, are also affected in terms of planning for resilient and sustainable agriculture (Mutegi et al., 2018). Several development interventions in health care, education, poverty reduction, ecosystem and disaster risk reduction initiatives have been severely impacted by climate change over the years (Ansuategi et al., 2015; Nhamo & Mjimba, 2014). Therefore, the burden of climate change on developing countries including SSA and Ghana is disproportional to their contributions to climate change - subjecting them unduly to climate injustice (Baptiste & Kinlocke, 2016; Care International, 2011).

The growing impacts of climate change on food systems affect food production, food distribution and nutritional quality of food through the extreme events (Brown et al., 2015; Myers et al., 2014). In the fourth assessment report of the IPCC, Yohe et al. (2007) accordingly noted that, an additional 600 million people could be exposed to hunger by the year 2080 due to impacts of climate change. It is reported that the growth and health status of children, particularly in SSA have been seriously compromised, with the region accounting for about 90% of an estimated 260 million undernourished people in Africa in 2018 (FAO et al., 2019). It is further noted that about nine out of ten of all stunted children globally in 2018 were living in Asia and Africa (Ibid.). FAO et al. (2018) found climate variability and extremes as responsible for global food crises that result in undernourishment. Extreme events such as floods, droughts and extreme temperatures negatively affect all the dimensions of food security including food availability, access, utilisation, and stability among households. Consequently, this results in malnutrition, particularly among children emanating from improper feeding as well as limited health services and environmental health (FAO et al., 2018). The foregoing points to the fact that hunger in Africa is rising, and rising rapidly in SSA, where prevalence of undernourishment has reached about 22.8% in 2018 (FAO et al., 2019). This is out of a broader perspective on global food insecurity, where (moderate to severe food insecurity) an estimated two billion people worldwide, representing 26.4%, are said to be food insecure (Ibid.).

In Ghana, the crop sub-sector contributes an estimated 16.95% of the country's gross domestic product (GDP) (Khalid, Ayamga & Danso-Abbeam, 2019). According to the United Nations Development Programme and National Development Planning Commission (UNDP & NDPC, 2015), Ghana recorded increases in production of some staple food crops such as cassava and yam, which exceeded national demand prior to end of the MDGs in 2015. This corroborates with the report of Ministry of Food and Agriculture (MoFA, 2018a) that there have been increases in production levels of some major food crops such as cassava and yam between 2008 and 2014. This paints a picture of hope towards achieving self-food sufficiency and food security in Ghana. However, maize productivity was reported to have decreased slightly over the same period due to extreme variability of weather conditions as well as high cost of required agricultural inputs (Ibid.). According to MoFA, this led to smallholder farmers' preference for sorghum and millet, which require little or no fertilizer, and which are also drought resistant, especially in northern Ghana. Despite the continued deficit in the production of some cereals such as rice and maize against demand and supply, Ghana was reported to have reduced hunger and food insecurity. Hence, it is food secured country (UNDP & NDPC, 2015). There is also a reported decline in undernourishment among children in Ghana, with the number of children with both wasted and stunted growth from having reduced from 14% in 1993 to 5% in 2014, and underweight children from 23% in 1993 to 11% in 2014 (Ibid.).

The implementation of 'Planting for Food and Jobs' in 2017 by the Government of Ghana (GoG) resulted in significant increases in both the production and yields of major staples. There were increases in the yields of sorghum by 100%, 72% for maize, 39% for soybeans and 24% yield increase for rice (Ministry of Finance-MoF, 2019). Meanwhile, livestock production has also shown an increasing trend over the few years (MoFA, 2018a). In furtherance to improving livestock production in Ghana, an estimated 53,500 of livestock, comprising of breeds of pigs, sheep, cockerels, and guinea fowls were distributed to smallholder farmers for rearing under the 'Rearing for Food and Jobs' programme of the GoG during the first half of 2019 (MoF, 2019).

2.3 Agriculture as a contributor to Climate Change

Agriculture is a principal contributor to planetary warming. Major sources of emissions from agriculture include synthetic fertilizer, burning of biomass, enteric fermentation, paddy rice cultivation and manure deposited on pasture (United States Environmental Protection Agency - USEPA, 2018; Lipper et al., 2014). According to Garret et al. (2020:1), the segregated global commercial crop and livestock production systems have substantially contributed "to some of the world's most pressing sustainability challenges, including climate change, nutrient imbalances, water pollution, biodiversity decline, and increasingly precarious rural livelihoods". These sources release significant volumes of concentration of carbon dioxide, methane, nitrogen oxide, and other GHG into the atmosphere (Niles et al., 2017; USEPA, 2018). It is estimated that agriculture and associated land-use change account for 24% of total global emissions (Smith et al., 2014), while the global food system also contribute up to 35% of GHG emissions (Niles et al., 2018). Growth in these sources of agricultural emissions will also present different and varying adverse impacts on biodiversity and ecosystem services such as water quality and soil protection, particularly the case that more food must be produced to meet the food needs of the growing world population (Lipper et al., 2014).

It has been suggested that the contribution of the 'green revolution' industries to climate change has been significantly high, with severe environmental and social impacts on smallholder farmers and food systems (ActionAid, 2017). Interestingly, these green industries are resurfacing and re-branding themselves in many forms to green-wash farmers and further exacerbate their vulnerability to climate change (Ibid.). According to Niles et al. (2017), the production and distribution of agricultural inputs such as pesticides, herbicides, synthetic fertilizers, and supplements for livestock systems are major sources of GHG emissions. Meanwhile, Smith et al. (2014) have observed an increase in the global use of fertiliser of about 233% between 1970 and 2010, triggering an increase in the production of fertiliser. Synthetic fertilisers and large-scale industrial livestock production have been significant contributors to climate change through relative high levels of GHG emissions (FAO, 2013). In addition, improper soil management practices, coupled with excessive use of urea and ammonium phosphate fertilizers also release significant volumes of nitrogen into the atmosphere (Umair, 2015). Additionally, several tonnes of methane elsewhere have been released into the atmosphere from landfills, decomposition of biomass and animal manure for agricultural purposes (Ibid.).

The USEPA (2018), estimates emissions from the agriculture sector to have accounted for about 562.6 million metric tons of carbon dioxide equivalent (MMT CO_2 eq), in 2016, representing 8.6% of total GHG emissions in the United States. Emission of methane from manure management and enteric fermentation accounted for 25.9% (Ibid.). The report further revealed that, fertilizer application and other related practices in the United States have accounted for about 76.7% of nitrogen emissions. This makes agriculture the largest source of nitrogen emissions through agricultural soil management activities including burning of farm residues and manure management. Meanwhile, liming and urea fertilization, according to the report, were also responsible for about one percent of total carbon dioxide emissions from anthropogenic activities in the United States. Hence, agricultural activities were found to have accounted for increases in methane and carbon dioxide emissions by 15.8% and 26.5% respectively between 1990 and 2016, while nitrogen emissions also increased during the same period by 14.1% (USEPA, 2018). These gases can last for several decades (Umair, 2015).

Searchinger et al. (2019), maintain that ruminant livestock such as cattle, buffalo, sheep, and goats account for about half of all agriculture production-related emissions, with developing countries and emerging economies accounting for almost 80% of the emissions and will continue into 2050. With the demand for ruminant meat projected to increase by 88% by 2050, the risk of land expansion for pasture and emissions of more GHGs from more livestock production will be further exacerbated (Searchinger et al., 2018). The authors suggested that it will take a reduction of up to 40% in consumption of ruminant meat and products by about two billion global consumers of these products, relative to 2010 consumption levels in order to bridge land and GHG mitigation gaps by 2050.

Agricultural emissions from livestock production accounts for about 44% of methane, 29% of nitrous oxide and 27% of carbon dioxide into the atmosphere (Gerber et al., 2013). According to the Food and Agriculture Organisation (FAO, 2016b), livestock supply chain accounts for about 14.5% of human-induced GHG emissions globally. Dairy and beef cattle are also major contributors to methane emissions (USEPA, 2018). The effects of these emissions will manifest in environmental changes with severe consequences for biodiversity and ecosystems (FAO, 2016b). They will also present several threats to agriculture (food crop and livestock production) (Rojas-Downing, Nejadhashemi, Harrigan & Woznicki, 2017).

It is estimated that, there could be increases in emission of GHG from land-use by 4-99% by 2030 and further by 7-76% by the year 2100 (Smith et al., 2014). Smith et al. (2014), further revealed that of all non-carbon dioxide emissions, an estimated 70% of total emissions is attributed to agricultural soils and enteric fermentation, while the farming of paddy rice accounts for between 9-11%. The authors also found biomass burning and manure management to have respectively accounted for between 6-12% and 7-8% of non-carbon dioxide emissions. According to Vermeulen and Wollenberg (2017), the inclusive emission of GHG from agriculture and land-use changes (AFOLU) amounts to about 5% of total global emissions. However, there is also potential for mitigating land-related emissions of about 20-60% of total cumulative abatement of GHG by 2030, as well as additional 15-40% by 2100 (Smith et al., 2014). The promotion of strategies such as little and/or no tillage, agroforestry, efficient use of nitrogen fertiliser, etc. among smallholder farmers can enhance carbon fixation and low emission (DAFC & Agriterra, 2019).

Therefore, agriculture contributes to global GHG emissions both directly and indirectly through many ways including the conversion of land and forests cover for agricultural and related purposes, that is, crop cultivation and livestock production (USEPA, 2018). Global declining agricultural productivity is attributed to deforestation, land degradation, soil erosion as well as degraded soil carbon sequestration capacity (Xie et al., 2019). In Africa, smallholder agriculture is a major cause of deforestation and forest degradation with about 60% of new agricultural lands driven from uninterrupted forest reserves (European Union, 2017). The European Union further related that the use of fuel wood from savannah burning for cooking and other related activities in Africa also contribute significantly to deforestation. Africa accounts for about 8% of total global GHG emissions, out of which, 36% is attributed to wood burning (Ibid.). It is also estimated that Africa loses about one billion hectares of forest every year through slash and burn agriculture, where carbon emissions per a hectare is equivalent to emissions from 6000 cars (DAFC & Agriterra, 2019). This makes Africa the highest emitter of black carbons and a significant contributor (accounting for 17%) to overall emissions of black carbon globally (Ibid.). However, there is an observed increasing demand for fuel wood for such domestic activities as cooking and heating across the world, including Africa, with about 2.4 billion people globally relying on wood and charcoal as sources of domestic energy (FAO, 2018).

From the foregoing, it is undoubtedly clear that anthropogenic activities are more responsible for climate change (IPCC, 2007). According to Umair (2015:1), about 97% of stakeholders in climate change studies, including experts and researchers, have come to the conclusion that "humans have changed the Earth's atmosphere in dramatic ways over the past two centuries, resulting in global warming". The author further observed that human actions account for the emissions of much of the GHGs. Hence, the painted picture forced the global community to do something to reduce GHG emissions.

2.4 Addressing Climate Change through Global Interventions

There have been several global efforts to address climate change, and these come in the form of global conventions by the United Nations. Such efforts date back to the World Commission on Environment and Development in 1987. Following growing concerns on issues of environment and development, including climate change, the Earth Summit triggered the creation of the IPCC in 1988 (Honneger et al., 2017). The Earth Summit in Rio de' Janeiro, Brazil also witnessed the adoption of the UNFCCC, which came into effect in 1994. The Parties sought to stabilise emissions of GHG concentrations in order to reduce human-induced threats on the climate system (Ibid.). Thereafter, several efforts continued including the Kyoto Protocol, the Bali Action plan, the Durban Platform for Enhanced Action, Doha Climate Gateway through to the MDGs and the Paris Agreement. However, literature on the past MDGs, the current SDGs and the Paris Agreement are examined in this section of the chapter of the study.

2.4.1 The MDGS, agriculture and climate change-related matters

The United Nations' Millennium Summit, otherwise known as the Millennium Declaration, in 2000 midwifed the Millennium Development Goals (MDGs), where member countries of the United Nations carved out a broad vision towards ending extreme poverty and hunger in all forms alongside other development challenges. As a result, the summit came out with eight (8) goals which the international community aspired to achieve within 15 years, thus from 2001-2015. These goals were adopted with 18 targets and 40 indicators as benchmarks for monitoring and guiding the efforts of the international community towards their (MDGs) achievement (UNDP & NDPC, 2015). Among the goals, only one goal (Goal 7) had direct concern of addressing climate and environmental change (Lomazzi, Borisch & Laaser, 2014); which was, to "ensure environmental sustainability" (Attaran, 2005: 956). Though Goal 1, which sought to "eradicate extreme poverty and hunger" (Ibid.), had a link with the environment as it related to livelihoods for income and food security, much emphasis was placed on the social dimensions of (sustainable) development than the environmental aspect (Lomazzi et al., 2014).

According to the United Nations' report on the MDGs, "the MDG target of reducing by half the proportion of people living in extreme poverty was achieved five years ago, ahead of the 2015 deadline" (United Nations, 2015:15). The report suggested a decline in the number of people living in extreme poverty from 1,751 million people in 1999 to 836 million people in 2015. This suggested a significant reduction in the levels of poverty in most developing regions across the world except in SSA where majority of countries could not meet the target (Ibid). Some SSA countries like Ghana, were reported to have met the target by the 2015 deadline (UNDP & NDPC, 2015). On the other hand, the target on hunger was not met albeit some significant progress made. Again, the United Nations (2015) reported that, the number of undernourished people globally amounted to about 795 million people, representing about one in nine people lacking adequate food in 2015. Out of this number, developing regions, such as SSA and South Asia, accounted for about 780 million people, though, there was appreciable reduction to 12.9%

for the 2014-2016 projected period from 23.3% in the 1990-1992 period (Ibid.). Clearly, the foregoing shows a concentration of efforts on social dimension of eradicating poverty than adequately addressing environmental issues, where rural livelihoods depend on.

Goal 7 of the MDGs (ensure environmental sustainability) had the targets of making sure member countries "integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources" and also "reduce biodiversity loss, achieving, by 2010, a significant reduction in the rate of loss" (Carin & Bates-Eamer, 2012:21). In 2015, it was reported that ozone-depleting substances were removed due to the concerted efforts by member states and thus, the world anticipates an ozone-layer recovery by middle of the century (United Nations, 2015). Eliminating about 98% of ozone-depletion substances by close to 200 parties, also meant that, not only about two billion annual cases of skin cancer could be avoided by 2030, but that, an estimated 135 billion tonnes of carbon dioxide equivalent emissions was also averted to mitigate climate change (Ibid.).

However, more still need to be done as efforts made under the MDGs were not exhaustive and proportional across all regions, especially, in relation to matters of climate and environmental change, including the need to eliminate hunger. The threats of deforestation, forest degradation and poor forest management continue to undermine livelihoods of over billion people, as well as animal, plant, and bird species globally (United Nations, 2018). The forest cover continues to decrease and shrink as result of forest degradation, deforestation, and other unsustainable forest management practices. These activities do not only lead to the destruction of livelihoods, fresh water sources, and habitats of animal and bird species, but they also destroy carbon stocks, and causing a release of volumes of carbon dioxide into the atmosphere to cause global warming and climate change (Garret et al., 2020; Triodos Bank, 2019). According to the MDGs report by the United Nations, the livelihoods of over 1.6 billion people across the world are directly provided by an estimated 30% of forest cover of total global land area. However, the shrinking of global forest area due to degradation and deforestation are endangering these livelihoods on one hand, and on the other hand, contributing significantly to carbon dioxide emissions worldwide, leading to more than 50% rise since 1990 (United Nations, 2015). This is attributed to the continuous growth in global carbon emissions across regions due partly to destruction of forests, which releases forest carbon stocks into the atmosphere. This presents a source of great worry as deforestation and forest degradation activities such as forest fires and drought continue to accelerate across Africa, including SSA (Ibid.).

From the foregoing, it is evident that the global community still has a lot to do regarding climate change and environmental degradation, despite some achievements made under the past MDGs. Climate change and environmental variability and change remain significant threats to (national and international) development efforts and initiatives, with much burden on the most vulnerable and the poor in society (Atanga, Inkoom & Derbile, 2017). This is the reason why the world went the route of bringing up the ambitious 2030 AfSD, which is a subject of further deliberations in the next section.

2.4.2 The 2030 AfSD and response to agriculture and climate change-related issues

The MDGs were succeeded by the 2030 Agenda for Sustainable Development (AfSD) in January 2016. This followed a meeting of the United Nations General Assembly in September 2015. Made up of 17 SDGs and 169 targets, the 2030 AfSD aims to move the world to a better place where human needs and the requirements for economic transformation are met without compromising the environment, peace and the rights of people (United Nations, 2015b).

Climate change and environmental variability are increasingly recognised as not only posing disproportionate burden on vulnerable and poor people but are also challenges that continue to threaten global initiatives and the progress made on past efforts (MDGs) (United Nations, 2015a). Consequently, parties to the United Nations have given much priority to climate change and related matters in the 2030 AfSD. Out of the 17 SDGs, 11 of them (namely, SDGs 1, 2, 6, 7, 8, 10, 12, 13, 14, 15 & 17) are directly linked to agriculture, as well as climate and environmental change (Nhamo, 2016). A summary of the 11 SDGs mentioned is presented in Box 2.1. What is also important is that the 2030 AfSD makes it clear that SDG 13 will be addressed under the UNFCCC.

Box 2.1: The 11 SDGs closely aligned to climate change

Goal 1. End poverty in all its forms everywhere

Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture

Goal 6. Ensure availability and sustainable management of water and sanitation for all

Goal 7 Ensure access to affordable, reliable, sustainable and modern energy for all

Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all

Goal 10. Reduce inequality within and among countries

Goal 12. Ensure sustainable consumption and production patterns

Goal 13. Take urgent action to combat climate change and its impacts

Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development

Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

Goal 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development

Source: United Nations (2015b: 14)

From Box 2.1, it is clear that climate change and the 2030 AfSD are intertwined (Northrop et al., 2016). Mockshell and Kamanda (2017) also related that six of the SDGs, namely: SDGs 6, 7, 12, 13, 14 and 15 have significant link with agriculture. The unique and interesting thing about the 2030 AfSD is that it has recognised the fact that the challenges confronting countries in the pursuit of their transformative agenda are interrelated and interlinked, and so the relationships should provide potential solutions to those very challenges (United Nations, 2018). Thus, the SDGs were designed in an interlinked manner, and therefore "requires an integrated approach that recognizes that these challenges – and their solutions – are interrelated" in order to build sustainable and resilient nations (Ibid: 14). These linkages with climate change forewarn all parties to be mindful of any actions that may aggravate the incident of climate change during the implementation process. Meaning that, the processes and actions towards achieving the transformative agenda should seek to address issues of climate and environmental change directly or indirectly. Hence, Nhamo (2016) advocates for the domestication and localisation of the SDGs to suit country-specific policy, institutional and accountability frameworks in order to avoid a one-size-fits-all situation that will be detrimental to the transformative drive.

Therefore, SDG 13, which seeks to "Take urgent action to combat climate change and its impacts" by 2030 (United Nations, 2015b: 14), ought to be operationalised in a multi, inter- and trans-disciplinary manner since climate change has an overarching effect on the achievement of the other goals. For instance, SDG 1 and SDG 2, which seek to respectively "End poverty in all its forms everywhere" and "End hunger, achieve food security and improved nutrition, and promote sustainable agriculture" (Ibid.) can be attained if SDG 13 is adequately addressed. It has been suggested that in order for the global community to end poverty and hunger by 2030, it will involve taking concrete measures that focus on reducing vulnerability to disasters and related incidents across all regions (United Nations, 2018). It will also require fusing nutrition and food security matters into national poverty reduction programmes and initiatives in order to adequately address issues of poverty, hunger, food insecurity and malnutrition (FAO et al., 2019).

After the first three years into the implementation of the SDGs, the United Nations (2019) observes that no significant progress has been made towards ending poverty, hunger, malnutrition, and food insecurity by parties. It noted that "the world is not on track to end poverty by 2030", including hunger and other related issues (United Nations, 2019:4). The report further reveals that millions of people globally are still hungry, with the number of undernourished people increasing from about 784 million people in 2015 to an estimated 821 million people in 2017 (United Nations, 2019). Also, an estimated 151 million children were found to be stunted in growth, 51 million wasted children, while 38 million children were overweight in 2017 (United Nations, 2018).

Africa, including SSA and Ghana, continue to be highly vulnerable and prone to extreme temperatures, droughts, floods, and pests and diseases, which are projected to be more frequent, more intense, and long-lasting (Nyasimi et al., 2014). This exposes the poor and vulnerable to more threats from climate change and environmental degradation in the form of worsening crop failure from rain-fed farming and other natural resource-based livelihoods in, particularly, SSA (Ibid.). Therefore, African countries, particularly SSA countries, must double their commitment and efforts towards addressing SDG 13 in order to make meaningful progress towards achieving SDG 1 and SDG 2 by the 2030 timeline. Nhamo and Mjimba (2014) suggest that African countries must prioritise and focus on development actions that highlight how they are mitigating and adapting livelihoods to the impacts of floods, droughts, extreme temperatures, sea level rise, water shortages, loss of biodiversity species, food insecurity, and emergence of pests and diseases. These actions must be undertaken within the context of climate compatible development that enable smallholder farmers to continuously produce more food under different weather conditions (Nyasimi et al., 2014).

It is suggested that SDGs 1 and SDG 2 can be achieved in SSA if agriculture is adequately and appropriately developed in a manner that, it simultaneously adapts to climate change impacts and mitigates the emission of GHG from agriculture (Williams et al., 2015). Though, challenging to both developing and developed countries globally, SSA countries must prioritise and effectively address the threats of climate change to achieve the transformational AfSD (Osborn, Cutter & Ullah, 2015). Thus, the journey to the 2030 AfSD presents both risks and opportunities to parties (Nhamo, 2016).

The AfSD also recognised the important role of science, technology as well as local and indigenous knowledge in the implementation process and achievement of the SDGs. For instance, to achieve SDG 2, the AfSD targets to "double the agricultural productivity and incomes of small-scale food producers" including indigenous peoples, women, family farmers, pastoralists, and fishers by 2030 by providing them equal access to agricultural land, knowledge, and other productive resources (United Nations, 2015b:15). It is further acknowledged that there is the need for innovation in industries and other areas to promote sustainability and resource-use efficiency through scientific research and environmentally sound technologies (SDG 9.5). It is further noted that there is the need to support and promote domestic technology development, innovation, and research particularly in developing countries in Africa as reflected in SDG 9 (9.b). The decision to offer financial and technical assistance to least developed countries to enhance resilience to climatic hazards based on local resources as contained in SDG 11 (SDG 11.c) gives further recognition of local and domestic knowledge, and technologies in achieving the AfSD (United Nations 2015b). In SDG 13, the target is to "promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and Small Island Developing States, including focusing on women, youth and local and marginalized communities" (United Nations, 2015b:24). Furthermore, SDG 17 (SDG 17.8) aims to enhance and promote the use of appropriate technology including information and communications technology for sharing and dissemination of knowledge and information by recognising the need to "fully operationalise the technology bank and science, technology and innovation capacity-building mechanism for least developed countries" (United Nations, 2015b:27).

2.4.3 The Paris Agreement, agriculture, and climate change-related perspectives

Climate change has been recognised as a threat to agriculture and food security. It represents the greatest obstacle to achieving increased production and food security in many developing regions including Africa (FAO, 2016a, 2016b). Climate change presents both threats to and opportunities for national and sectoral developments (UNFCCC, 2018). To this end, the UNFCCC has the mandate to set the global agenda to address climate change action.

The Paris Agreement was a historic milestone in the fight against climate change and its impacts by parties of the UNFCCC at its 21st Conference of Parties (COP 21) held in Paris, France in 2015. The agreement represents the collective will of parties to tackle climate change through intensified and deliberate actions that seek to achieve sustainable low-carbon growth for the future. The aim of the Agreement, as contained in Article 2 of the Agreement, was "to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by:

(a) Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change;
(b) Increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production; and
(c) Making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development" (UNFCCC, 2015:3).

In the move to achieve this aim, the agreement admonishes parties to be wary of the impacts of the actions and measures they take in their attempts at addressing climate change. This is because of the inherent relationship that exists between climate change actions, responses, and impacts, on one hand, and equitable access to sustainable development and poverty eradication, on another hand (UNFCCC, 2015). In the preamble of the agreement, it was acknowledged that climate change is generally related to human beings and human activities and so parties ought to respect, promote and consider the aspects of human rights of indigenous peoples, local communities, and other vulnerable groups, as well as consider women empowerment, gender equality and intergenerational equity (UNFCCC, 2015). This is because "indigenous and tribal peoples are uniquely at risk of being placed at the forefront of the direct impacts from both climate change and climate-related mitigation and adaptation actions" (Dhir & Ahearn, 2019:1).

In Article 7 (5) of the agreement, Parties acknowledged the need for climate change adaptation actions to "be based on and guided by the best available science and, as appropriate, traditional knowledge, knowledge of indigenous peoples and local knowledge systems" through "a country-driven, gender-responsive, participatory and fully transparent approach" in order for a proper mainstreaming of adaptation actions into national policies (environmental, social and economic policies) of parties (UNFCCC, 2015:9).

The UNFCCC (2016) further recognises the role of indigenous peoples and local communities in upholding and promoting regional and international cooperation among parties and non-party stakeholders of the agreement towards instituting ambitious climate actions. This is further emphasised in paragraph 135 of the decisions (Decision 1/CP.21) adopted by the COP where, in relation to non-Party stakeholders, it "recognises the need to strengthen knowledge, technologies, practices and efforts of local communities and indigenous peoples related to addressing and responding to climate change, and establishes a platform for the exchange of experiences and sharing of best practices on mitigation and adaptation in a holistic and integrated manner" (UNFCCC, 2016:19). The ILO (2019) also acknowledged that traditional knowledge of indigenous and tribal peoples has significant role in combatting climate change and meaningfully achieving the ambitious goals of the two global frameworks (AfSD and Paris

Agreement). According to the ILO, the role of traditional knowledge in advancing improved agricultural practices, weather forecast information and improved management of natural resources on sustainable and resilient basis is increasingly recognised globally.

Prior to the COP 21, Parties to the agreement were tasked to prepare Intended Nationally Determined Contributions (INDCs) which became their Nationally Determined Contributions (NDCs) (after they ratified the agreement), outlining their mitigation actions as contained in Article 4 of the Agreement. The NDCs of Parties represented and highlighted the intended actions and progress to be made by Parties in a manner that reflect their respective country circumstances. These NDCs are common but different in respect of responsibilities and capabilities of parties. The collective progress on the implementation of the NDCs on emission reduction efforts is to be assessed every five years through global stocktaking (UNFCCC, 2015). Thus, 'a hybrid approach' that provide for the combination of both "bottom up nationally determined contributions from countries with a top-down oversight system" was adopted for the implementation of the Agreement to achieve its aim (Mitchell et al., 2018:3).

It is also important to state that the activities contained in the country party NDCs so far have demonstrated an appreciable level of connection and linkage between climate change and the SDGs (Dzebo et al., 2019). According to Dzebo et al. (2019), many countries in their NDCs have highlighted renewable energy and energy efficiency (as contained in SDG 7) as major climate actions necessary for the reduction and mitigation of GHG emissions. The authors are of the view that the use of clean and renewable energy will lessen the dependence on fossil fuels for energy, while increasing energy efficiency by parties which will yield mitigation co-benefits for socioeconomic progress as contained in SDG 8. Consequently, the authors found that about 97% of the activities outlined in the various NDCs were climate change mitigation-related activities, with 31% of the activities quantifying the mitigation targets (Ibid.). There is a linkage that exists between biodiversity, water and soil, which creates the opportunity for achieving low-carbon and climate-resilient development by balancing them with energy, water, and food security. The NDCs, in addition to mitigation, address issues of climate change adaptation. The activities outlined in the NDCs to achieve SDG 15 address significantly mitigation and adaptation issues, where 35% and 29% of the activities were identified to have been directed at adaptation and mitigation, respectively. Many of the NDCs were further observed to have presented CSA as core climate actions for achieving SDG 2 (No hunger) by emphasising "on developing the technical, policy and investment conditions to increase food security and agricultural incomes through climate-resilient, low-emission agriculture" (Dzebo et al., 2019:14). To this end, the authors further observed that about 60% of the activities of the NDCs related to mitigation, 10% for climate change adaptation while 21% simultaneously aimed at addressing both mitigation and adaptation. Thus, climate actions which sought to ensure sustainable agriculture production promote co-benefits for the SDGs such as improved water management (SDG 6) through irrigation and integrated water resource management practices; land-use management and forestry (SDG 15) through soil management and agroforestry; and for ensuring economic growth (SDG 8) through improved livelihoods (Dzebo et al., 2019:14).

In the matter of keeping temperatures well below 2°C, the United Nations Environment Programme (UNEP, 2019) Emissions Gap Report, however, indicates a continuous rising in emissions of GHGs with no indication of peaking in the nearest future as anticipated in the Paris Agreement. The report noted that the world is headed towards a rise in temperature of between 2.9-3.4°C under the current NDCs pledges. In its earlier report, the UNEP (2017) had observed that there was the need for drastic bridging of the emission gap before 2030 if the world wanted to hold global warming to below 2°C. This is because country commitments contained in the NDCs could "cover only approximately one third of the emissions reductions needed to be on a least-cost pathway for the goal of staying well below 2°C" (UNEP, 2017: xiv). It described as "alarmingly high" the emission gap between the actual reductions required to meet the Paris Agreement targets and what is pledged in the NDCs by countries (Ibid).

The UNEP (2019: xv) further intimated that, global emissions would have to be 25% and 55% lower than 2018 levels "to put the world on the least-cost pathway to limiting global warming to below 2˚C and 1.5°C respectively". It warned that the prevailing carbon budget estimates to achieve a well below 2°C temperatures were not adequate to accomplish the target in full implementation of the current NDCs. It further noted that "even if the current NDCs are fully implemented, the carbon budget for limiting global warming to below 2°C will be about 80% depleted by 2030" (UNEP, 2017: xiv). Hence, the report called for a revision of the NDCs in

2020 to enhance bridging the emissions gap by 2030. This anchors on the decision of COP 21 (Decision 1/CP.21) which emphasises on "the urgent need to address the significant gap between the aggregate effect of Parties' mitigation pledges in terms of global annual emissions of greenhouse gases by 2020 and aggregate emission pathways consistent with holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels" (UNFCCC, 2016:2). It is further opined that reductions in GHG emissions alone will be insufficient for achieving temperatures of 1.5°C, and that it must be complemented with large-scale carbon dioxide removal (Mitchell et al., 2018). There are also calls for institutional, governance, financial and policy support to complement existing efforts towards achieving the temperature target set out in the Paris Agreement (Gomez-Echeverri, 2018).

Having discussed in depth perspectives related to agriculture, climate change and LIK from the lenses of the MDGs, the 2030 AfSD (and its 17 SDGs) and the Paris Agreement, the next section is dedicated to presenting the concept of climate compatible development.

2.5 The Concept of Climate Compatible Development

Climate compatible development (CCD) has been recognised as key to the achievement of the SDGs because it maximises the opportunities and minimises the threats of climate change by integrating them into national development policies and programmes (Nunan, 2017; Mitchell & Maxwell, 2010). According to Mitchell and Maxwell (2010:1), CCD is "development that minimises the harm caused by climate impacts, while maximising the many human development opportunities presented by low emissions, more resilient, future". The authors further relate that CCD seeks to address climate change through an integration of adaptation, mitigation and development strategies in a manner that fuses together the threats and opportunities of climate change. Thus, it integrates the triple actions of mitigation, adaptation, and development strategies, rather than tackling them in isolation, as in the case of conventional development practice. It represents a comprehensive approach that integrates mitigation and adaptation initiatives with special focus on reducing emissions and building long-term resilient agricultural and development strategies to projected impacts of climate change (Mallick, Amin

& Rahman, 2012). This integration process demonstrates the interrelated nature of adaptation, mitigation, and development strategies in CCD. It therefore suggests that CCD cannot be achieved when countries seek to address the three strategies (mitigation, adaptation, and development) in isolation (Mitchell & Maxwell, 2010). The overlaps of the 'triple pillars' of CCD points to the fact that "win-win strategies can sometimes be sought rather than triple wins" in the pursuit of CCD (Nunan, 2017:2).

It is related that the integration of climate policy and development goals may not be a new idea, but the exploration of synergies between climate change and development goals only gained significant prominence during the 2000s, with emerging operational concepts, such as 'low carbon development', 'climate resilient development', 'co-benefits', Climate Compatible Development (CCD) etc. (England et al., 2018; Nunan, 2017). Considered as a relatively recent concept, there has not been in-depth exploration of progress on the transitional efforts towards CCD in Africa (England et al., 2018). Nunan (2017) corroborated that there is lack of adequate concrete examples of the 'triple wins' of CCD on one hand, and some trade-offs which serve as obstacles to promoting a widespread adoption of climate compatible practices within and across sectors, on the other hand. The concept of climate compatible development is diagrammatically illustrated in Figure 2.1 below:

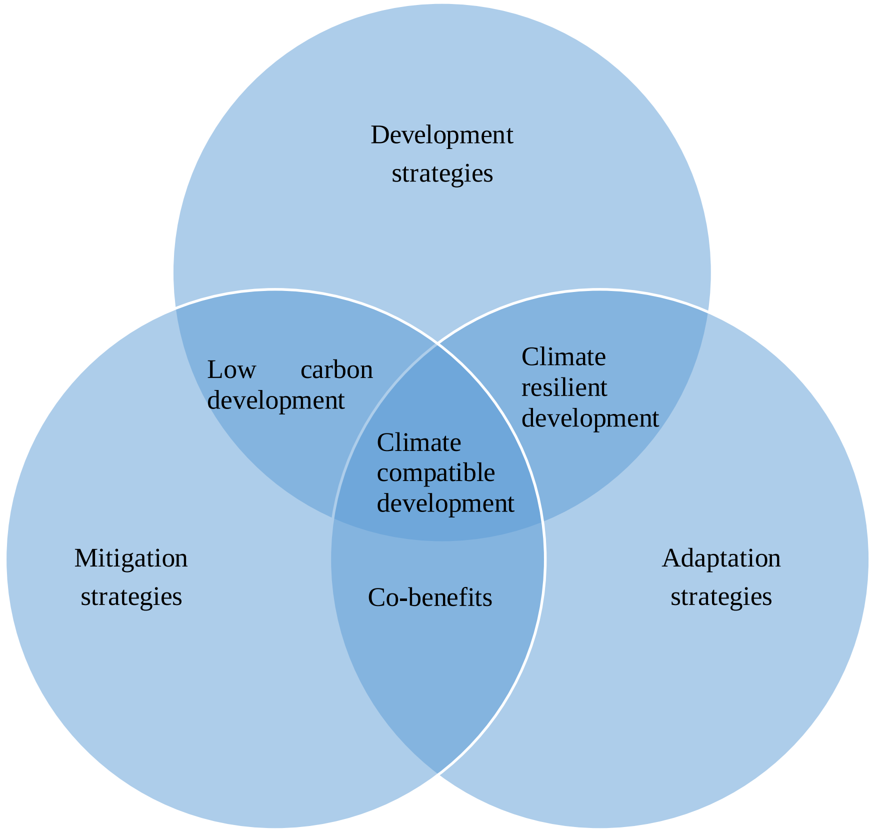


Figure 2. 1: Climate compatible development

Source: Adopted from Mitchell and Maxwell (2010: 1)

From Figure 2.1, the three pillars of CCD (triple wins) each have an intersection with the other and ultimate all of them intersecting to give us CCD. Pursuing development and adaptation strategies together will result in climate-resilient development, while low carbon development is the product for undertaking mitigation and development strategies. The pursuance of adaptation and mitigation strategies together will have co-benefits as outcomes; and CCD is achieved when all the three are jointly implemented.

Mitigation strategies in CCD are concerned with the means of lowering the emissions of GHGs, which include the use of less energy, use of renewable energy (generating more energy from low-emissions sources), establishing and protecting carbon stores such as forests. These may also include sector-specific mitigation strategies that encourage and promote development of low emission technologies, as well as instituting measures to limit high-emission investments across the energy, industry, agriculture, forestry, and transport sectors (Mitchell & Maxwell, 2010). Mitigation can often be a significant co-benefit of actions to improve food security but realizing these benefits may involve additional costs (Lipper et al., 2014). A comparison of the costs of low-emission to conventional high-emission growth pathways gives an appreciation of the need to link agricultural development efforts to generate mitigation co-benefits.

Adaptation to climate change is an increasing matter of urgency in developing countries, considering the growing impacts of climate change on livelihoods and development (Nunan, 2017). No single strategy is sufficient to tackle the menace of climate change, and therefore, there is the need for concerted efforts towards sustainable approaches that achieve two or all the three pillars of CCD. According to Mitchell and Maxwell, (2010), adaptation strategies seek to bring on board measures that will reduce the impacts of climate change to moderate levels at all scales. These may include, but not limited to, building resilient agricultural systems to ensure food security, prioritising disaster risk reduction activities to reduce vulnerabilities and impacts, and developing water management mechanisms as responses to rainfall variability. The authors further noted that adaptation strategies promote multi-level stakeholder participation in climate change decision-making process; enhance adaptive capacities of stakeholders including smallholder farmers, through skills and innovation development (Mitchell & Maxwell, 2010).

In the context of CCD, adaptation overlaps with mitigation on one hand, and overlaps with development on the other hand. As noted earlier, co-benefits are results from the overlap of mitigation and adaptation strategies. It is important to emphasise that the integration of mitigation and adaptation measures for the co-benefits does not compromise the specific benefits that each of them offers, but rather it harmonises the threats and opportunities for sustainable development (Nunan, 2017).

The concept of low carbon development is also critical. Low carbon development, which is the overlap of mitigation and development, concerns itself with attaining economic growth through reduced emissions. Thus, it separates economic growth from GHG emissions, depicting a departure from the conventional burning of fossil fuels for energy to the use of renewable energy sources (Nunan, 2017).

On the other hand, evidence on the co-benefits (overlap of mitigation and adaptation) from mitigation and adaptation strategies is limited to demonstrate how emissions can be lowered in building resilience (adapting) to climate change (Mitchell & Maxwell, 2010). However, Nunan (2017) observed that evidence exist in literature on the co-benefits of mitigation and adaptation, irrespective of whether the terms have been pursued separately or jointly. The author noted that, the means of measuring the two terms differ, with the benefits of mitigation being global in nature, while the benefits of adaptation are experienced and measured against the magnitude of the impacts of climate change at a particular and specific environment.

The overlap of adaptation and development is known as climate resilient development. It represents "a departure from traditional development, as climate resilient development places emphasis on complexity and uncertainty, and on how society can learn and self-organise to create beneficial and sustainable transformations" (Mitchell & Maxwell, 2010:4). It is the development with the ability and capacity to absorb and recover from climatic shocks and stress. It places priority on building climate-resilient individuals, households, communities, and countries by enhancing their adaptive capacities to better respond to and recover from climatic impacts (Nunan, 2017; USAID, 2014). This process therefore calls for multi-stakeholder engagements from local to international levels, as well as multi-sectoral and coherent policy approaches that mainstream and integrate transformative actions on climate change into development discourse (Maxwell, 2017).

According to Mitchell & Maxwell (2010:4), development strategies must "recognise the threats and opportunities presented by the new climate-related development landscape". Hence, there is the need to mainstream the challenges of climate change into development policy and practice (Nunan, 2017). This will enhance the drive towards sustainable development, where development strategies are pursued in a manner that interconnects with adaptation strategies. This interconnection is known as climate resilient development. It focuses on building resilient households, communities, and countries, capable of absorbing and recovering from prevailing climatic shocks and adapting to future shocks without compromising development gains (USAID, 2014). Aligned to CCD is sustainable agriculture, which is the focus of the next section.

2.6 Sustainable Agriculture

The need for new farming land and methods continue to rise as the world population continue to rapidly increase with a corresponding increase in demand for food and competition for agriculture land among other land-use activities due to increasing urbanisation (Xie et al., 2019). This mounts undue pressure on the use of land resources and ecosystem services in order to satisfy human needs. This suggests that agriculture production must be pursued on sustainable basis. According to the GIZ (2012:4), sustainable agriculture involves the process that:

- puts emphasis on methods and processes that improve soil productivity while minimising harmful effects on the climate, soil, water, air, biodiversity, and human health
- aims to minimise the use of inputs from non-renewable sources and petroleum-based products and replace them with those from renewable resources
- focuses on local people and their knowledge, skills, socio-cultural values, and institutional structures
- ensures that the basic nutritional requirements of current and future generations are met in both quantity and quality terms and that agriculture can also generate additional products
- provides long-term jobs, adequate income and dignified and equal working and living conditions for everybody involved in agricultural value chains
- reduces the agricultural sector's vulnerability to adverse natural conditions (e.g., climatic) and socio-economic factors (e.g., strong price fluctuations) and to other risks.

Hence, sustainable agricultural systems are mechanisms that seek to improve sustainability and resilience of production systems through an increased diversity of production activities such as crop diversification, integrated crop, livestock, and forestry systems, over time and space (Garret et al., 2020). To this end, sustainable agriculture presents a complex situation for experts and practitioners on whether or not sustainable agriculture should concern with conventional or organic farming, and/or commercial or subsistence farming (GIZ, 2012).

Consequently, the need emerged for agriculture to be intensified, thus, to produce more and/or maintain production per unit of input with less land (Struik & Kuyper, 2017). This came in the form of sustainable agricultural intensification and ecological intensification pathways (Struik, Kuyper, Brussaard & Leeuwis, 2014). Mockshell and Kamanda (2017) corroborated that, sustainable agricultural practices come under two broad categories namely, sustainable agricultural intensification (SAI) and agro-ecological intensification (AEI). The authors further explained that SAI includes CSA, while AEI includes organic agriculture. Both categories also incorporate conservation agriculture (Mockshell & Kamanda, 2017). Struik and Kuyper (2017:2) observed that many stakeholders have assumed a win-win situation, where emphasis is placed on "increasing productivity while simultaneously improving resource use efficiency and refraining from expansion of agricultural land". The authors noted that there exist some trade-offs in the process of intensification which must be taken into consideration in order to reduce the environmental impacts. Generally, intensification connotes significant use of external inputs such as nitrogen fertilizer in the production process (Mohan, Crute, Simmons & Islam, 2017). Further details regarding the main concepts introduced herein are presented in the next sub-sections.

2.6.1 Sustainable agricultural intensification

Sustainable intensification is thought of as a new paradigm-shift for meeting the food needs of a growing population with limited agricultural land (DAFC & Agriterra, 2019). It has received much attention since 1983 from scholars, practitioners, policy makers and other stakeholders who are proposing it as solution to meeting the increasing food demand of the future population while ensuring environmental safety (Xie et al., 2019). It comes with the objective of increasing agricultural productivity through sustainable practices such as minimum or conservation tillage, intercropping, improved varieties and breeds, and efficient fertilization, which have little or no environmental impacts. Thus, agriculture in developed and developing countries is intensified through soil fertility management, technology transfer and adaptation approaches that avoid extensive clearing of additional land (Tilman et al., 2011).

Pretty (2008:451) defines sustainable intensification as "using natural, social, and human capital assets, combined with the use of best available technologies and inputs (best genotypes and best ecological management) that minimize or eliminate harm to the environment" in the process of agriculture production. These definitions emphasise increasing production and reducing environmental harm and may have become widely cited in sustainable intensification literature. These definitions were later revised to give further clarification when Pretty, Toulmin and Williams (2011:7) defined sustainable agricultural intensification as the process of "producing more output from the same area of land while reducing the negative environmental impacts and at the same time increasing contributions to natural capital and the flow of environmental services". This definition takes cognisance of the area of cultivated land and the ability of the process of production to preserve natural resources and ecosystem services for present and future use. It has become the most widely used definition by scholars, policymakers, and development organisations in the discourse of sustainable intensification agriculture. This definition is similar to and reflects the FAO's definition of sustainable intensification. According to the FAO (2011: vii), sustainable intensification "produces more from the same area of land while conserving resources, reducing negative impacts on the environment and enhancing natural capital and the flow of ecosystem services".

From the above definitions, sustainable intensification generally has to do with increasing yields per unit of land, increasing cropping and input intensity per unit of land and shifting from cultivation of low-value crops to higher market prices crop, while minimising harmful environmental impacts (Pretty, Toulmin & Williams, 2011). There exists a unique meaning of sustainable intensification among scholars, which is, to significantly increase food production through increased yields without causing significant harm to the environment and natural resources due to agriculture (Pretty & Bharucha, 2014; Cassman, 1999). Thus, livelihood sustainability, enhancing food production and preserving ecosystem services are important components of sustainable agricultural intensification (Liao & Brown, 2018).

It has been reported that farmers in Denmark and the Netherlands have demonstrated the ability and capacity of increasing agricultural production through agricultural sustainable intensification, where they have produced more food with less land while limiting the emissions of GHGs (DAFC & Agriterra, 2019). An increase of 45% in milk yield per dairy cow and 33 piglets per sow per year was experienced by farmers due to sustainable intensification (Ibid.). The DAFC and Agriterra (2019) further reported that between 1990 and 2016, farmers in Denmark contributed to the reduction of about 16% GHG emissions through sustainable intensification, while in Netherlands, emissions from ammonia and nitrogen oxides reduced by 70% and 40% respectively for the period 1990-2016.

It is, therefore, suggested that intensification agriculture has the potential of increasing production and protecting forests cover through reforestation and reduced felling of trees in Africa (Montpellier Panel, 2013). It is further relayed that sustainable agricultural intensification in Africa has the potential of opening African economies by leveraging smallholder farmers from subsistence farming to other job opportunities in other sectors such as industry and manufacturing to stimulate economic growth and rural transformation (Arnold et al., 2019; IFAD, 2016). Sustainable intensification is characterised with practices such as fertilizers, soil and water conservation, integrated pest management, conservation tillage, intercropping and integrated use of new crop varieties and animal breeds. These are common practices in Africa which are implemented to increase productivity, bridge yield gaps, and build resilient agricultural systems that conserve ecosystems resources and services (Xie et al., 2019).

Pretty and Bharucha (2014), are of the view that sustainable intensification offers the opportunity for smallholder farmers to increase yields without causing harm to the environment and the ecosystem. It also offers the opportunity to avoid further expansion of agriculture lands into non-agricultural lands in attempt to increase food production to meet food needs of the growing population (Pretty & Bharucha, 2014). According to Pretty and Bharucha (2014), advancement in technology in other sectors could serve as lessons and steppingstone and/or opportunity for sustainable intensification to achieve global, regional, and national development objectives of transitioning towards greener economies and achieving food security. Hence, sustainable intensification does not only aim to increase food production, but also offer solutions to climate change by growing more crops on existing arable land and encouraging the cultivation of perennial crops over annual crops (DAFC & Agriterra, 2019). It is, however, argued that the discourse on intensification predominantly tends to be tilted towards increasing food production in order to meet the needs of a future doubled population over environmental conservation (Hunter et al., 2017). Thus, the food production aspect has been over-emphasised to the neglect of elaborate discussions of specific environmental goals that are to be achieved in the agriculture sector by 2050.

It must be noted that sustainable intensification comes with environmental consequences such as pollution of surface and ground water and water resources, emissions of GHGs, etc. from the use of agro-chemicals in the bid to increase agricultural yields and food production to meet the food needs of the population (Palm et al., 2017; Trimmer et al., 2017). These have the tendency of disrupting ecological and social systems. Hence, there are suggestions for a quantification of environmental targets and assessments in the agriculture sector in order for people to appreciate the future environmental impacts of increasing food production through intensification (Hunter et al., 2017; Trimmer et al., 2017; Tilman et al., 2011). Some scholars are advocating for equal emphasis on increasing food production and protecting the environment, if agriculture is to be made sustainable (Rockstrom et al., 2017; Pretty & Bharucha, 2014). To increase production and promote sustainable ecosystems, Smith et al. (2017) proposed that sustainable intensification should be assessed from five perspectives, namely productivity, human well-being, economic, social, and environmental sustainability. Basing on sustainability principles, Mahon et al. (2018) also suggested seven systems from which sustainable intensification should be evaluated. These included resource, resource users, resource units, governance, interactions, outcomes, and environmental systems.

The projections of a doubling global population by 2050 and the consequent need to increase food production of over 60% from 2005/2007 levels (Alexandratos & Bruinsma 2012) and between 100% and 110% (Tilman et al., 2011) in order to meet food needs of such population, is argued to be an exaggerated and misinterpreted phenomenon which has resulted in a simplified “goal of doubling yields” and “a produce-at-all-costs mentality” without clear environmental considerations (Hunter et al., 2017:386). This has led to increased use of pesticides, herbicides, fertilizers, which are harmful to the environment, water resources (including marine life and fisheries) and human health (Hunter et al., 2017). These and other approaches including agricultural expansion through conventional land clearing have unclear environmental impacts and trade-offs (Mockshell & Kamanda, 2017; Tilman et al., 2011). Thus, the conversion of additional lands for agriculture (extensification) results in deforestation, and degradation of forests and land resources as well as destruction of carbon footprints.

On the other hand, increasing production on existing cropland (intensification), using new varieties and breeds, increased use of inputs, and other practices and innovations, will also contribute to GHG emissions and other environmental threats (Palm et al., 2017). Thus, expansion of agriculture through land clearing and intensification of agriculture on existing land, all have environmental consequences. Therefore, Tilman et al. (2011) noted that the approaches and methods to expand agriculture to meet food demand of between 100% and 110% of the projected population for 2050 is a determinant of the environmental impacts of such agricultural production systems. According to the authors, the current trajectory of agricultural extensification in developing countries and intensification in developed countries could result in clearing of about one billion hectares of land globally for agricultural purposes by 2050. This will also result in emission of 3 Gt y-1 carbon dioxide and about 250 Mt y-1 of nitrogen use (Tilman et al., 2011). On the other hand, intensification of agriculture on existing lands and avoiding additional conversion of lands in low-yield developing nations, coupled with technological improvements and transfer of technologies that foster high yields and adaptation could only result in clearing of 0.2 billion ha, 225 Mt y-1 of nitrogen use and emission of 1 Gt y-1 of GHGs (Ibid.). Therefore, the authors suggested that agricultural intensification in developing countries is key to sustainable food security for the future population, but it must be prioritised in order to reduce the negative environmental impacts in the form of high GHG emissions levels, extinction of species, pollution of ground and surface, and loss of ecosystem services (Ibid.).

Three factors, namely: socio-economic, farmers' own characteristics and natural environmental factors could underpin the achievement of sustainable agriculture intensification (Xie et al., 2019). Socio-economic factors such as inadequate access to information, access to market, crop output prices, transportation cost, access to credit and other factors are determinants of adoption of sustainable intensification practices among smallholder farmers in SSA and other parts of the globe (Ibid.). Providing access to stable markets for farmers, access to transportation system, access to credit and input, provision of quality agricultural information to farmers through agriculture extension officers, among other related services are key to promoting the adoption and successful implementation of sustainable intensification practices among farmers in SSA (Clay, 2018). In Africa, the level of sustainable intensification is measured mostly by the extent to which farmers are provided with quality and timely agricultural extension services, access to credit and market (Ibid.). However, the provision of these services in many African countries, including SSA countries, has been a major challenge due to differences in regional and socio-economic conditions.

The adoption of sustainable intensification practices and technologies such as minimum tillage, mulching, intercropping, crop rotation and other practices in Africa are mostly influenced by household characteristics of farmers such as gender, family size, level of education, years of experience and age of farmers (Xie et al., 2019). For instance, the practice of intercropping leguminous crops with maize was largely found to be high among women in Malawi because of nutrition and market potential of these crops (Snapp et al., 2018). In addition, climate change, in the form of changes in precipitation and temperature, is a major natural factor that influences farmers' decisions in adopting sustainable intensification practices. Thus, climatic events such as floods and droughts mostly cause low crop yields which affects household food security and incomes. In addition, land topography, soil quality and soil fertility are other factors that influence farmers' decisions to adopt sustainable intensification practices (Xie et al., 2019).

The foregoing presents a triple interconnection and interaction of natural systems, economic systems, and institutional systems with human actions within the framework of sustainable intensification (Xie et al., 2019). These human activities can be detrimental and may lead to unsustainable economic, environmental, and institutional systems which may not necessarily present a win-win situation in all times and situations (Triodos Bank, 2019; Struik & Kuyper, 2017). Therefore, there is the need for continuous reconsideration of policies and institutional systems by policymakers and practitioners in order for sustainable intensification to meet up the challenges of climate change, energy scarcity, depleting ecosystem and natural resources, market globalisation and population growth (Xie et al., 2019). This is because "sustainable intensification is a combined result of various drivers such as social and economic development, policy system, natural factors and technological development" (Ibid.:13).

Typically, in SSA, the majority of farmers do not have access to credit for financial support in order to improve yields through improved seed varieties, crop insurance, advanced technology and improved agro-chemicals (Ifeanyi-Obi et al., 2017; Dumenu & Obeng, 2016). As a result, smallholder farmers tend to continuously embrace traditional farming practices, which do not only improve yields and food production, but also limit local innovations and transformation of farming systems (Xie et al., 2019). This is mostly attributed to the fact that most national policy measures tend to present one-size-fit-all measures rather than specific local measures, resulting in disconnection between policies of governments and the real challenges confronting smallholder farmers in Africa (Dumenu & Obeng, 2016). This challenge is further exacerbated by the growing risks of climate change which affects long-term planning and investment behaviours of farmers; making them to prefer short-term investments as a risk-reducing strategy (Xie et al., 2019). The application of sustainable intensification practices depends on regional and situational context, varying within the context of differences in regional environments, historical developments, and current land-use practices (Weltin et al., 2018). However, literature reveal that land, water, and soil resources conservation practices such as multiple cropping, no-tillage and mulching are commonly applied across Africa (Perez et al., 2015).

Sustainable intensification agriculture has been criticised for its inability to describe and explain technologies and practices in detail and in simple terms for adopters (smallholder farmers). Hence, the meaning and processes of it remain unclear and ambiguous at global, regional, national, and local levels (Xie et al., 2019). Tittonell (2014) corroborated that the proponents of sustainable intensification have not been able to translate it into workable strategies to achieve convincing results in order to make it a better alternative for smallholder farmers. It is also criticised on the basis that, it has deliberately been loosely defined in a manner that accommodates any agricultural related models and technologies under the guise of sustainable intensification (Tittonell, 2014). Civil society organisations and other bodies have warned that sustainable intensification is only being used as a window-dressing and green-washing strategy by multinational companies, particularly fertilizer and other agro-chemical manufacturing companies, to perpetuate their unsustainable technologies and practices that are injurious to the environment (Anderson, 2014; Collins & Chandrasekaran, 2012). This has been described as a 'wolf-in-sheep clothing' (Collins & Chandrasekaran, 2012). Tittonell (2014) also shares the view that sustainable intensification is currently been used by players in both public and private sectors to justify any form of intensification, without much recourse to present and future environmental consequences.

Another shortfall of sustainable intensification agriculture relates to the inability to explicitly explore and establish the effects, duration and linkages of sustainable intensification which hinders effective long-term implementation. There is lack of adequate systematic and comprehensive research on sustainable intensification to provide tangible evidence within the context of environmentally-friendly results (Xie et al., 2019). These, in addition to the implementation cost, further expose smallholder farmers to worse agricultural risks. Some experts also believe that sustainable intensification is still being experimented with ecological theory (ecological intensification), which calls for the integration of livestock, crops, and agroforestry in order to improve soil fertility and productivity without harmful environmental impacts (Petersen & Snapp, 2015; Cassman, 1999).

From the foregoing, sustainable intensification should be assessed from productivity, socio-economic, and environmental sustainability perspectives to ensure its adoption and successful implementation (Smith et al., 2017). It should equally be evaluated from resource systems, resource users, resource units, governance, interactions, outcomes, as well as environmental perspectives to address the inefficiencies associated with it (Mohan et al., 2018).

2.6.2 Ecological Intensification

Ecological intensification emerged as a paradigm-shift in the search for sustainable agriculture production systems that can provide adequate food for the global population up to 2050 and beyond. It is reported that ecological intensification ('intensification ecologique') became popular among francophone researchers in the 1980s, when it was used to refer to practices of pastoralists in the tropics (Tittonell, 2014). It presents some defined set of principles and means for increasing yields of major cereals and improving agro-ecosystems globally (Tittonell & Giller, 2013).

Tittonell (2014:58) defines ecological intensification as the "means to make intensive and smart use of the natural functionalities of the ecosystem (support, regulation) to produce food, fibre, energy and ecological services in a sustainable way". This definition echoes ecological intensification as a process that embraces approaches that deliver synergies for sustainable livelihoods and tackles trade-offs through livelihood adaptation and mitigation practices. Ecological intensification processes differ and extend beyond the design and scales of analysis within the context of a single crop and farm, to include multiple crops, wider and complex landscape farm perspectives (Tittonell, 2014).

Tittonell and Giller (2013:76), define ecological intensification as "a means of increasing agricultural outputs (food, fibre, agro-fuels and environmental services), while reducing the use and the need for external inputs (agrochemicals, fuel, and plastic), capitalising on ecological processes that support and regulate primary productivity in agro-ecosystems". Ecological intensification incorporates traditional farming systems into its models and farming practices, thereby ensuring smallholder farmers' participation in a manner that depicts them as innovators and knowledge generators (Falconnier et al., 2018; Tittonell, 2014). According to Falconnier et al. (2018), the integration of smallholder farmers' mode of intensification in terms of practices and technologies into policy interventions in SSA has the potential of lifting majority of smallholder farmers out of poverty through sustainable intensification agriculture. Ecological intensification focuses on increasing yields of major cereal crops and, at the same time, bridging the yield gaps through scientific and technological advancements (Tittonell & Giller, 2013).

According to Cassman (1999:5953), ecological intensification is about "whether further intensification of [cereal] production systems can be achieved that satisfy the anticipated increase in food demand, while meeting acceptable standards of environmental quality".

Progressively, ecological intensification has developed from a plot scale, where it emphasises on improving agronomic approaches and crop yields, to multidisciplinary approaches that encompass integrated ecosystem services and biodiversity (Xie et al., 2019). That is, it emphasises the incorporation of socio-economic development into environmental sustainability for a largely diversified development discourse (Ibid.). Tittonell (2014:53) corroborated that ecological intensification is more ideal approach to sustainable agriculture for smallholder farmers because it emphasises "landscape approaches that make smart use of the natural functionalities that ecosystems offer" in agricultural production process including ecosystem services and bioenergy. The author further noted that, ecological intensification places smallholder farmers as generators of locally adapted knowledge and technologies by appreciating the use of indigenous knowledge and local resources in agricultural production systems and processes (Tittonell, 2014). Mockshell and Kamanda (2017) also corroborated that, agricultural approaches under ecological intensification centre on the past knowledge and experimentation of smallholder farmers. This enhances adoption of ecological agricultural practices and technologies among smallholder farmers. Ecological intensification is distinct because it emphasises on processes that offer alternatives in the form of agricultural models that go beyond a set of production and management techniques on a single farm to include multiple farm methods such as diversification of farming systems, organic agriculture, agro-forestry, natural regeneration and restoration of degraded lands and vegetation (Tittonell, 2014). These are implemented within a specific context that integrates culture and local knowledge of farmers and communities.

In the literature of ecological intensification, one may come across other terminologies such as agro-ecology, agro-ecological intensification, and eco-indigenous agriculture (Mockshell & Kamanda, 2017; Tennigkeit et al., 2013; Claxton, 2010). According to Mockshell and Kamanda (2017:3) agro-ecological intensification refers to the "application of ecological science to the study, design and management of sustainable agriculture". From the authors, environmental groups, farmer-based organisations, NGOs, academic researchers, and international donors are the major actors and stakeholders championing agro-ecological intensification. These stakeholders have common interest in transforming agricultural systems to enhance global food security, and to preserve the environment through bottom-up and farmer-led participatory approaches that incorporates farmers' knowledge systems (Lipper & Zilberman, 2018; Mockshell & Kamanda, 2017). It is also suggested that ecological agricultural intensification practices are not only relatively affordable to farmers in terms of cost, but they also help to sequester carbon more effectively, preserve more biodiversity and promote food security better than modern conventional agriculture (Tennigkeit et al., 2013; Claxton, 2010).

Although ecological intensification echoes agricultural approaches such as agroforestry, landscape and other biodiversity related approaches that take into consideration the synergies and trade-offs of different farming approaches, it has been criticised on grounds of ambiguity in the usage of some ecological processes (Tittonell, 2014). It is therefore suggested that ecological intensification should be evaluated from five dimensions, namely, socio-cultural values, economic values, landscape, environmental quality, and management dimensions in order to address any ambiguity (Rodrigues, Martins, & de Barros, 2018).

2.6.3 Differences between sustainable intensification and ecological intensification

The two concepts of sustainable intensification and ecological intensification share emphasis on the need to increase food production, while reducing environmental harm. The differences, on the other hand, exist in their areas of focus. Ecological intensification is focused on ecological principles and environmental sustainability, while sustainable intensification focuses on rational production and consumption (Xie et al., 2019). Thus, sustainable intensification basically emphasises the production process to optimise management of inputs and outputs with little emphasis on resource use efficiency, while ecological intensification focuses much on the use of ecological processes, ecosystem services and resource utilization efficiency in food production.

The differences between sustainable intensification and ecological intensification are well elaborated by Mockshell and Kamanda (2017) using some indicators as in Table 2.1.

Table 2. 1: Differences between sustainable intensification and ecological intensification

Indicator	**Sustainable Agricultural Intensification**	**Agroecological Intensification**
Main actors	▪ Governments, multinational private sector agribusinesses (agrochemicals, fertiliser, seed), researchers, academics, international development institutions	▪ Non-governmental organisations (NGOs), civil society, researchers, academics
Concept	▪ Increase agricultural productivity while simultaneously protecting natural capital ▪ Focus on resource intensification and resource use efficiency ▪ Meet needs of present generation without compromising ability of future generations to meet their needs	▪ Increase agricultural output by capitalising on ecological processes that conserve natural resources in agro-ecosystems ▪ Use holistic approach to rural development including all environmental and human elements ▪ Employ set of practices to mimic nature ▪ View land husbandry as an "an ecology of disciplines"
Vision	▪ Food and nutrition security, poverty reduction, environmental sustainability ▪ Alternative to conventional intensification or industrial agriculture	▪ Food security, pro-poor development, environmental sustainability ▪ Sustainable alternative to hegemonic style of conventional and agro-industrial agriculture
Science	▪ GMOs are tolerated	▪ GMOs are not acceptable
Opposition	▪ Viewed by opponents as "conventional and industrial agriculture model", "business as usual" and "an oxymoron"	▪ Viewed by opponents as "anti-science" and "do-nothing approach"
Land use	▪ **Ecological dimension**	▪ Land sharing (less land is set aside for conservation and less intensive

		production techniques are used to maintain biodiversity)
Spatial arrangement	▪ Land sparing (set aside land for intensive production and set aside part of the land for biodiversity)	▪ Mixed farming and multi-functional crops (e.g., cover crops, agroforestry), mixed crop-livestock systems
Landscape	▪ Monoculture	▪ Building resilient agro-ecosystems through ecosystem services
Agricultural practices	▪ Minimizing damage to the environment through intensification rather than area expansion	▪ Biological interactions in diversified farming systems to enhance productivity
Efficiency	▪ Combining improved varieties and agronomy (good agricultural practices)	▪ Land use efficiency (yield) ▪ Yield gap/yield potential ▪ Efficiency as a ratio (output per unit of input, e.g., water-limited potential)
Seed system	▪ **Economic dimension**	▪ Local seeds (own seed or seed sharing system)
Input use	▪ Land equivalent ratios ▪ Farm or landscape productivity gap/possibility frontier	▪ Low external input use (low cost)
Knowledge generation	▪ External seeds (seed industry)	▪ Local knowledge ▪ Participatory local knowledge generation
Farmers	▪ High external input use (high cost)	▪ Small-scale farmers
Livelihood support	▪ **Social dimension**	▪ Livelihood support of small-scale rural households
	▪ Expert knowledge and local knowledge	▪
	▪ Large-scale farmers	▪
	▪ Livelihood support of large-scale farmers	▪

Source: Mockshell & Kamanda, 2017:10

2.7 Conclusion

Climate change is a single-most major threat to global agriculture, livelihoods, and food security. The impacts are unevenly distributed and much felt in developing countries including SSA countries where adaptive capacities are low. These countries are also coupled with heavy dependence on ecosystem-driven livelihoods such as rain-fed smallholder agriculture. The impacts of climate change thus, are felt in the form of food insecurity and hunger, which culminate into increasing poverty levels and undernourishment particularly among women and children respectively.

On the other hand, agriculture has contributed significantly to the climate change phenomenon over the years, both directly and indirectly, through emissions of GHGs from burning of biomass, enteric fermentation, synthetic fertilizer use, cultivation of paddy rice, manure deposits, etc. The increasing use of synthetic fertilizer, pesticides, herbicides among farmers as well as other unsustainable agricultural activities release significant volumes of carbon dioxide, methane, and nitrogen into the atmosphere. The rearing of ruminants such as cattle, sheep, and goats is another source of GHGs emissions. Savannah and forest burning particularly in Africa is causing deforestation and forest degradation thereby contributing significantly to the emission of GHGs and consequently climate change.

There have been several interventions by the global community at addressing climate change and its impacts. The three of these global interventions namely MDGs, the AfSD and the Paris Agreement have been discussed in this research. Climate change and its related issues have been of utmost concern particularly under the current Paris Agreement and the AfSD.

The CCD concept aims to minimise climatic impacts while maximising the human development opportunities that a low-carbon emission economy offers. CCD integrates the triple actions of adaptation, mitigation, and development strategies to deliver development that is climate resilient, offers co-benefits and of low-carbon emissions.

Making agriculture sustainable amid climate change impacts is important to maintaining rural and smallholder livelihoods in the agricultural sector in developing countries including SSA countries. Agricultural systems must be diversified to enhance resilience in production systems and sustainability. This also includes intensifying agriculture, where more food will be produced per unit of input with less land. Two main concepts were discussed in respect of agricultural intensification namely sustainable agricultural intensification and ecological intensification. Sustainable agricultural intensification advocates for sustainable farming practices such as improves varieties and breeds, conservation/minimum tillage, efficient fertilisation, intercropping among other practices that come with little or no adverse environmental impacts. Ecological intensification on the other hand represents an approach that emphasise agroforestry, landscape and other biodiversity approaches to food production which consider the synergies and trade-offs of the different farming practices that farmers adopt. It is concerned with the use of the natural ecosystem for food production through approaches that build synergies and address trade-offs in the form of climate change mitigation and adaptation. Leading from the perspectives of sustainable agricultural intensification and ecological intensification, the potential role of LIK will play much in the latter and therefore will present an acceptable alternative for smallholder farmers to increase food crop productivity when mainstreamed into agriculture policy and programmes of the government and other relevant stakeholders in the agriculture sector in Ghana.

CHAPTER 3: CLIMATE-SMART AGRICULTURE: INTERFACING SCIENTIFIC, LOCAL AND INDIGENOUS KNOWLEDGE SYSTEMS

3.1 Introduction

This chapter of the thesis discusses climate-smart agriculture and the role of LIK in promoting and advocating for climate-smart agriculture and adaptation to climate change among smallholder farmers within the context of the interface of scientific and LIK systems. A particular focus of the discussion is put on the emergence of CSA among Ghanaian farmers and how these smallholder farmers' agricultural decisions and practices reflect CSA practices and technologies in parts of the country including the Upper West Region.

3.2 Climate-Smart Agriculture

Climate-Smart Agriculture (CSA) has increasingly been recognised as an important approach for achieving sustainable agriculture under the increasing impacts of climate change (Taylor, 2018; Torquebiau, Rosenzweig, Chatrchyan, Andrieu & Khosla, 2018). CSA refers to "agriculture that sustainably increases productivity, resilience (adaptation), reduces GHG (mitigation), and enhances the achievement of food security and development goals (development)" (FAO, 2010: ii). It is an approach that provides opportunity to achieve food security at all levels of development through the integration of adaptation and mitigation interventions in agriculture (Asfaw & Branca, 2018). CSA further integrates traditional and innovative practices, and services for adapting to climate change and variability in a context-specific manner (International Centre for Tropical Agriculture - CIAT, 2014), in order to enhance resilience and sustainable increase in productivity with reduced GHG emissions (Khatri-Chhetri, Aggarwal, Joshi & Vyas, 2017; Lipper et al., 2014). It is a transformational approach that simultaneously addresses climate change, food insecurity, poverty, and environmental degradation (Nyasimi et al., 2014). Hence, CSA increases smallholder farmers' ability to mitigate and adapt to climatic impacts, as well as ensure food security through innovative policies, practices, technologies, and services (Torquebiau et al., 2018; Ansuategi et al., 2015). For instance, farmers are trained and used as extension agents to enhance coordination of farmer field schools and other climate-smart activities (Noponen et al., 2014).

The CSA approach involves a multiple transformative process and a set of objectives, which allow for new knowledge gaps to be identified and addressed even at the implementation stage (Torquebiau et al., 2018). This makes CSA an ideal approach that can significantly contribute to achieving the transformational 2030 AfSD (Taylor, 2018). CSA does not only promote agricultural practices and technologies that are climate-smart, but it also seeks to identify climate financing mechanisms, and appropriate policies and institutional frameworks that can promote sustainable agriculture under climate change (Asfaw & Branca, 2018). The reader should also note that CSA is not a one-size-fit-all approach. Rather, it is an approach that examines the social, economic, and environmental conditions in relation to some specific practices and technologies within the context of specific locations for sustainable agricultural production (Williams et al., 2015). Therefore, any inability to appropriately identify, prioritise and promote CSA practices and technologies within the context of specific socio-economic and environmental conditions in different areas, may affect the implementation of CSA strategies (Khatri-Chhetri et al., 2017).

According to the FAO (2013), CSA concerns itself at the national level, with instituting appropriate policies, technical and financial mechanisms that incorporate adaptation and mitigation strategies into the agricultural sector as means to operationalising sustainable agricultural development and food security. While at the local level, it emphasises on empowering smallholder farmers by strengthening their livelihoods and food security systems through efficient use of natural resources and adoption of relevant technologies and approaches for the agricultural value-chain production, processing and marketing of agricultural goods and services (FAO, 2013). CSA also emphasises on the integration of sustainable water (SDG 6) and land-use practices, ecosystem management and landscape approaches as key to building resilient agricultural systems that achieve sustainable productivity and mitigate GHG emissions (Williams et al., 2015). It advocates for ecosystem-based agricultural adaptation systems that promotes demand and supply value chains in agriculture, while ensuring efficient use of natural resources (Ibid.). Hence, it encourages the integration of science-based technology transfers into agricultural systems through participatory and bottom-up approaches to enhance the complementarities between manufactured capital and ecosystem services (Lipper & Zilberman, 2018).

Khatri-Chhetri et al. (2017), portray that any practice and technology that leads to the realisation of at least one of the triple pillars of increased productivity, adaptation and mitigation can be regarded as climate-smart. Lipper et al. (2014) related that it is not always the case that the application of every CSA technology and practice in every location produces the triple win benefits. The process, should nonetheless, compromise the achievement of the other ‘wins’ (benefits). According to Lipper et al. (2014), climate-smart practices and technologies seek to develop and identify synergies and trade-offs between and among food security, adaptation, and mitigation. These synergies and trade-offs are then aligned and integrated into the planning and implementation processes of sustainable agricultural strategies and are operationalised over short to long-term period within a context-specific perspective at all levels for adoption (Lipper et al., 2014). This addresses the fundamental question of how a large-scale transformation can be achieved since the trade-offs which include costs are also identified (Lipper & Zilberman, 2018). Many sustainable agricultural approaches have seen low adoption by smallholder farmers and are criticised by experts because they primarily focus on the benefits obtainable and ignoring the trade-offs (Ibid). Taylor (2018), therefore, advocates for attention beyond approaches that are climate-smart to rather ‘climate-wise’ approaches in order to achieve sustainable agriculture. He argues that climate-wise approaches are more participatory, and explicitly challenge the status quo of disproportionate influence of political debates on agriculture.

In India, Khatri-Chhetri et al. (2017) observed that the preferences for CSA practices among farmers are characterised by certain commonalities and differences. They noted that, whereas some CSA practices may be commonly adopted by farmers irrespective of their locations, many other practices are specifically adopted to suit the conditions of specific agro-ecological zones. The authors found risk reduction strategies such as rainwater harvesting, crop insurance, weather-based crop agro-advisory, contingent crop planning, and site-specific integrated nutrient management practices as common practices adopted by farmers across all agro-ecological zones. The authors also noted that, farmers in low rainfall agro-ecological zones would have higher preferences and priority for these strategies than farmers in high rainfall zones. It is therefore, concluded that smallholder preferences are shaped by the differences in location, the prevailing climatic conditions, perceived level of risks, and the social and economic conditions of the farmers (Khatri-Chhetri et al., 2017).

Information and education are key to creating awareness of farmers on the benefits and costs of CSA practices in order to influence their decisions in adopting climate-smart farming (Agula et al., 2018). These components also come out clearly in the SDG 13 (United Nations, 2015b) and the Paris Agreement (UNFCCC, 2015). Therefore, appropriate policies and programmes on climate-smart farming should be formulated within a context of location-specific strategies such as soil and water conservation, crop management, and land management to enhance adoption and knowledge sharing among farmers (Mathews, Kruger & Wentink, 2018; Bogale & Bikiko, 2017). Such practices should not only highlight the risk reduction potential but also highlight the financial related opportunities to enhance farmers' adoption. Evidence has shown that farmers prefer risk reduction and financial related technologies due to the potential financial benefits and the likely support from governments and development agencies (Khatri-Chhetri et al., 2017).

Smallholder farmers are mostly associated with ecosystem services and practices such as improved pest, water, and nutrient management; integrated crop, livestock, aquaculture, and agroforestry systems; landscape approaches; improved grassland and forestry management (Lipper et al., 2014). Other practices such as reduced tillage and use of diverse varieties and breeds; integrating trees into agricultural systems; restoring degraded lands; improving the efficiency of water and nitrogen fertilizer use; and manure management, including the use of anaerobic bio-digesters are sustainable and climate-smart strategies that farmers get associated with (Ibid.). These enhance farmers' resilience to climate extremes and also improve soil quality while ensuring significant environmental returns, including sequestration of carbon through regulation of carbon, oxygen and plant nutrient cycles **(**Kroeger et al., 2017).

England, Stringer, Dougill and Afionis (2018) further revealed that many forestry approaches are CSA practices and have proven more successful in mitigation potential than adaptation in

SSA. They attributed this phenomenon to the fact that most forestry policy approaches are predominantly oriented towards mitigation of GHG emissions in the form of biodiversity conservation and restoration. It is reported that the introduction of forestry approaches as climate-smart practices in cocoa production in Ghana resulted in sequestration of an estimated 8648 tCO_2-eq compared to a sequestration of about 2913 tCO_2-eq from conventional farming systems (Akrofi-Atitianti et al., 2018). A further forecast of these approaches (CSA practices) in cocoa farming over three-decade period in the Western Region of Ghana suggested that, an estimated carbon sink balance of 11,743 tCO_2-eq could be achieved (Ibid.). It is also reported that the Ghana Cocoa Board (COCOBOD) has been promoting agroforestry as a CSA practice among cocoa farmers to, among other things, serve as a mechanism for controlling the risk of transmission of swollen shoot virus among cocoa trees (Hutchins et al., 2015). In this direction, cocoa farmers are trained to acquire knowledge on the benefits, and to also equip them with the skills of how and what tree to plant in order to avoid spreading of pests and diseases (Ibid.). Agroforestry and access to agricultural extension services are viewed as basic CSA approaches for mitigating GHGs and enhancing adaptive capacities and food security among smallholder farmers (Mbow, Smith, Skole, Duguma & Bustamante, 2014).

Agroforestry approaches also ensure the improvement of soil fertility, provision of fuel or wood energy, provision of income and assets from carbon trade, enhancing local weather conditions, provision of ecosystem services and reduction of human impacts on natural forests (Mbow et al., 2014). These approaches, according to England et al. (2018), are common approaches in the agricultural policies of many African countries, which portrays hope towards CCD in the African region. CSA practices also include actions such as forest surveys, data dissemination, gender equality (SDG 5), community management of forests, market accessibility, and conservation-based research and development (England et al., 2018). These strategies have both mitigation and adaptation potential with no regrets for development, as they seek to identify and bridge gaps and strengthen the links between rural and forest-based livelihoods in SSA (Ibid.).

Soil and land management practices such as fertilisation using organic manure and appropriate application of chemical fertilizer, mulching, intercropping, replanting (grafting), etc. are some common yield incremental practices among climate-smart farmers in Ghana (Dohmen et al., 2018). However, some of these and many other practices such as livestock breeding, increased mechanisation, excessive and increased use of agrochemicals such as fertilisers and pesticides, offer potential mitigation regrets and potential development losses (England et al., 2018). England et al. (2018) further asserted that, water sector approaches such as preparedness planning for floods and drought disasters, improved irrigation efficiency, and information and data management focus much on adaptation and development potential with little attention for mitigation potential. This corroborates Williams et al. (2015) assertion that African smallholder farmers pay more attention to adaptation than mitigation, despites the synergies that exist between adaptation and mitigation measures. It is suggested that many mitigation obligations, unlike adaptation and development strategies, present undue burden on smallholder farmers, which limits their adaptive capacities (ActionAid, 2017).

From the foregoing, it thus, appears that mitigation measures in Africa are not popular among smallholder farmers (Williams et al., 2015) because mitigation strategies are not directly "linked to enhancing productivity" (Noponen et al., 2014:58). For instance, smallholder farmers must be convinced that GHG reduction strategies such as development of on-farm carbon stocks etc. will directly result in increased yields and productivity. Some challenges such as inadequate policy frameworks, limited access to finance, technology, land and human resources are particularly common challenges affecting implementation of CSA in African countries, including SSA countries (Sibanda et al., 2017; Williams et al., 2015). Other challenges relate to cultural barriers such as norms, values, historical legacies, religious and traditional beliefs and social identities, which may influence farmers to prefer traditional weather information over scientific forecast weather information (Davies et al., 2019).

Many smallholder farmers turn to rely much on traditional calendar dates for farming activities irrespective of any scientific forecast information on rainfall due to perceived inconsistencies and consequent lack of credibility in scientific forecast (Davies et al., 2019; Selato, 2017). The authors further observed that traditional forecast provides farmers with information that is specific to their local context unlike scientific forecast which provides information on a broader spatial and temporal scales. This suggests that although climate change is affecting the accuracy level of traditional systems in recent times (Angula & Kaundjua, 2016), traditional forecasting methods are still widely used in Africa (Davies et al., 2019; Selato, 2017; Jiri et al., 2016). These challenges present dynamic and complex policy implications on CCD and CSA approaches at local, national and international levels (Davies et al., 2019).

3.2.1 Criticisms of climate-smart agriculture

The emergence of CSA in 2009/2010 also met with some criticisms from civil society organisations (CSOs) across the global, with ActionAid International been one of the frontline critiques. Barely two years after CSA was launched by the FAO some CSOs started to blow the alarm bell about the possible environmental effects of the CSA approach. According to Lipper and Zilberman (2018:19), the concept "sparked considerable attention and debate in international and national agricultural and climate change policy arenas", which witnessed "a rallying point for mobilising actions on climate change and agriculture". The authors noted that some differences in meanings and application of the concept resulted in controversies, with much of these controversies having to do with fundamental disagreements in global policies on climate change and sustainable agriculture.

The placing of much priority on mitigation over food security and adaptation from CSA is regarded as a deliberate attempt to create avenue for carbon offset markets and to overburden smallholder farmers in SSA in particular (ActionAid, 2017; Neufeldt et al., 2013). For instance, carbon offsets for soil carbon sequestration is/was seen as an attempt to "shift the burden of reducing greenhouse gas emissions from rich, industrialised countries who had actually created the problem, to poor developing countries that already are facing the biggest burden in adapting to climate change" (Lipper & Zilberman, 2018:22).

CSA is also criticised on the basis that it lacks clear definition of its practices and technologies. It is argued that some destructive agribusinesses could hide under the cover of CSA technologies and practices "to green-wash agricultural practices that will harm future food production, such as industrial agriculture practices or soil carbon offsetting" (Anderson, 2014:2). The activities of these international corporations, which include intensive factory farming of livestock, manufacturing of synthetic agrochemicals and industrial scale mono-cropping are not only injurious to the environment and climate but are also not socially guarded against land grabbing which jeopardises farmers' livelihoods (ActionAid, 2017). It is further argued that what constitutes CSA is ambiguous and questionable since CSA strategies are designed, implemented, and adopted by stakeholders within a specific local context (Andrieu et al., 2017; Khatri-Chhetri et al., 2017). As a result, what constitutes climate-smart practice and technology in one environment may not be applicable in another environment due to differences in agro-ecology, market opportunities, and other conditions (Torquebiau et al., 2018). Hence, what constitutes climate-smart is not generalisable; but depends on the prevailing agro-ecological conditions and opportunities of the specific local environment of smallholder farmers (Ibid.).

Another criticism of the CSA approach relates to the fact that it incorporates the use of manufactured capital inputs such as inorganic fertilizer, machinery, improved seeds, etc. into agricultural production systems (Consortium of Civil Society Organisation, 2015). These are unsustainable practices and contribute to the very challenges that CSA seeks to address.

Despite the criticisms, it is thought that a transition to climate-smart practices in the agriculture sector is not only a priority, but a matter of compelling urgency in order to make progress in sustainable agricultural productivity and also to permit African farmers to access global markets (Taylor, 2018). It has been refuted that CSA does not seek to introduce "new set of sustainability principles, but rather a means of integrating the specificities of adaptation and mitigation into sustainable agricultural development policies, programs and investments" (Lipper & Zilberman, 2018:24). The strategies and practices only tend to emphasise adherence to the principles of sustainable agriculture and food systems. It is a compelling urgency to improve climate change and agricultural governance through effective coordination and building stronger institutions. Therefore, the guidelines for advancing sustainable agriculture and food systems including increasing resource use efficiency, increasing resilience of ecosystems and communities, conserving, and protecting natural resources, etc. are significant components of climate change mitigation and adaptation approaches.

3.2.2 The way forward for CSA implementation

It is important for policy makers and experts not to overemphasise the foregoing challenges of CSA. Rather they should be seen as a window of opportunity through which the implementation process of CSA and CCD incorporates the role of traditional and religious institutions in the dissemination of climate-smart information (Davies et al., 2019).

It has been observed that religious and traditional leaders are very influential in disseminating information to smallholder farmers in SSA and the African continent at large due to the confidence and trust farmers repose in them (Davies et al., 2019). Selato (2017) relates that in the tradition of some communities in Botswana, it is chiefs who give farmers permission to begin planting and harvesting of farm crops regardless of the seasonal forecast on rainfall. It is therefore essential, for traditional leaders to be recognised as facilitators for championing adaptation and other climate-resilient building portfolios through participation to enhance ownership of CSA/CCD initiatives (Davies et al., 2019). Similarly, there is evidence that religious organisations and groups play significant role in promoting CSA through religious education and teaching on environment and climate change (Ibid.). Kassam et al. (2014) relate that soil and water conservation practices such as no-tillage, mulching and crop rotation are promoted among farmers through religious narratives in SSA countries. It is reported that traditional leaders including chiefs, headsmen and village heads in Zimbabwe have played a vital role in the spread and adoption of climate change adaptation strategies among smallholder farmers (Musarandega et al., 2018).

The CSA concept is also premised on the fact that the agricultural sector plays a key role in climate change response. Hence, sustainable agricultural transformation is very significant to achieving food security. It is also important for policymakers to frame and prioritise climate change responses within the context of agriculture being a major contributor and highly vulnerable to climate change, on one hand, and agriculture as a sector that offers other response strategies to climate change, on the other hand (England et al., 2018; Lipper & Zilberman, 2018). The beginning of the concept of CSA saw an analysis of adaptation, mitigation and food security benefits and potential trade-offs of various agricultural practices, in order to identify and link potential and emerging sources of climate finance including carbon markets as a supportive mechanism to the sustainable agriculture transition (FAO, 2013). The process also identified high transactions costs as a major barrier for smallholder agricultural producers to access and benefit from climate finance (Ibid.).

It is further suggested that "site-specific evidence on food security, adaptation and mitigation benefits" on CSA be appropriately established at the local and institutional levels in order to create awareness and increase smallholder farmers' adoption of climate-smart practices (Arslan et al., 2014:19). Lipper et al. (2014:1070) added that extensive research on CSA practices be conducted to provide stakeholders including smallholder farmers, with a better "understanding of what works where and why in different agro-ecologies and farming systems", as well as identify "what constitutes 'climate smartness' in different biophysical and socio-economic contexts". This may also help in establishing the factors that will likely hinder smallholder farmers' adoption of climate compatible agricultural practices as well as proffering possible solutions to them.

3.3 Climate Compatible and Climate-Smart Agriculture in Ghana

Smallholder farmers in SSA are increasingly embracing CSA and other climate-compatible innovations as means to increasing food production under climate change (Zougmore, Partey, Ouédraogo, Torquebiau & Campbell, 2018; Nyasimi et al., 2014). In Ghana, CSA is an emerging approach among smallholder farmers that incorporates the three dimensions of social, economic, and environmental aspects of sustainable development, to prove as a better alternative for tackling the threats of climate change (Akrofi-Atitianti et al., 2018; Ansah & Siaw, 2017; Kroeger et al., 2017; Asare, 2014). Its emergence is also attributed to the fact that Ghana has been criticised for focusing too much on mitigation (reducing emission), with little attention for adaptation measures, resulting in low priority for climate change issues on its policy agenda (GIZ, 2014).

Consequently, a collaborative programme dubbed Market Oriented Agriculture Programme (MOAP) was rolled out by the GIZ and Ministry of Food and Agriculture (MoFA) in two regions namely: Northern and Brong-Ahafo Regions. This was done in attempt to promote climate-smart farming activities that targeted 600 farm households over a period of five and half years (July 2012-December 2017) (GIZ, 2014). The project focused on three important activity areas including developing climate-smart farming systems, providing climate-smart extension services, and drawing climate-smart policies for agriculture in Ghana (Ibid.). Under the climate-smart farming systems, agricultural practices such as soil and water management strategies were developed and adopted as response mechanisms to changes in rainfall in the beneficiary areas. It also covered the village seed system which involved the selection, treatment, and storage of different variety of improved crop seeds for smallholder farmers. The second aspect, which involved the provision of climate-smart extension services saw the training of staff of MoFA including extension officers and agricultural consultants on adaptation practices and strategies to enhance the provision of quality and improved smart extension services for smallholder farmers to effectively adapt to climatic changes. Last but not the least, the project, as part of providing climate-smart policies, assisted MoFA to prepare agricultural sector strategic plan and other related policy documents at local levels and fed into regional and national plans. Political decision-makers were also trained on how to incorporate climate-smart policies into national policies to enhance agriculture development (GIZ, 2014).

According to Hutchins et al. (2015), there have been significant efforts made by the Ghana Government towards addressing climate change in terms of establishing appropriate strategies. The authors related that the national Reduced Emissions from Deforestation and Degradation (REDD+) strategy was one of such efforts by the Government of Ghana. The REDD+ serves as window for other collaborative projects by organisations for tackling emissions from forests destruction activities. One of such collaborative projects was the Climate Cocoa Partnership for REDD+ Preparation project, by Olam, Rainforest Alliance, and the Ghana Forestry Commission, which was initiated "to build cocoa producing areas in degraded lands in ecological corridors, helping cocoa trees become more resilient to moisture and temperature changes due to climate change" (Hutchins, Tamargo, Bailey & Kim, 2015:4).

In 2015, the National Climate-Smart Agriculture and Food Security Action Plan of Ghana (2016-2020) policy was developed to provide an "implementation framework for effective development of climate-smart agriculture in the ground" (Essegbey, Nutsukpo, Karbo & Zougmoré, 2015: v). According to Essegbey et al. (2015), this policy sought to translate broad national goals and objectives in CSA from national to the local (community) level through formulation of specific strategies, including; (1) developing climate-resilient agriculture and food systems for all agro-ecological zones in Ghana; (2) developing the requisite human resource capacity for climate-resilient agriculture promotion in Ghana; and (3) elaborating on the implementation framework and the specific CSA activities to be carried out at the respective levels of governance. Developed and validated through participation of the relevant stakeholders, the plan took cognisance of clear definition and analysis of smartness of activities within the context of Ghana in relation to weather information, energy, water, nitrogen, etc. in agriculture and food systems under climate change (Essegbey et al., 2015). The plan has a broader goal of facilitating and operationalising the Ghana National Climate Change Policy for an "effective integration of Climate Change into Food and Agriculture sector development policies and programmes" (Ibid: 2).

It has been noted that CSA in Ghana is situated within the context of Ghana REDD+ activities, since agriculture contributes significantly to GHG emissions (Forest Trends & Nature Conservation Research Centre – FT & NCRC, 2012). This is a means to making agriculture climate compatible for achieving sustainable food security, economic development, climate adaptation and mitigation in a simultaneous manner. Climate-smart or climate compatible agriculture in Ghana was experimented and tend to concentrate in the cocoa sector (Akrofi-Atitianti et al., 2018; Asare, 2014; Noponen et al., 2014). Cocoa farming is a major agricultural activity, which serves as an employment and income source to many households in cocoa farming areas (Asare et al., 2019). However, cocoa production is confronted with the "triple challenge of increasing agricultural productivity on a limited land area, reducing pressure on remaining forests and other ecosystems, and adapting to the current and future impacts of climate change" (Kroeger et al., 2017:14). Cocoa farming in the country has been identified as a major driver of deforestation and forest degradation (Asare, 2014; Noponen et al., 2014). This is as a result of unguided extensive expansion of cocoa farms into forest reserves in the major cocoa growing areas and absence of land-use planning in Ghana, albeit low yields (FT & NCRC, 2012). Hence, Noponen et al. (2014:58) suggested that "Where land conversion is fuelled by commodity agriculture, it is imperative to engage farmers in climate-smart agriculture (CSA) practices that include the conservation of forests". Asare (2014) found there was a very large yield gap between actual and potential cocoa yields among cocoa farmers in Ghana. The author also observed that although there was increasing encroachment of smallholder cocoa farming into forest reserves, the gap between actual yields (of about 400 kg/ha) and potential yields (of more than 1,000 kg/ha) "remains unacceptably large" among farmers (Asare, 2014:1). Therefore, industry players in the cocoa sector are urged to embrace and promote CSC in order to "increase the productivity of agricultural lands, reduce greenhouse-gas emissions, and increase climate resilience" (Kroeger et al., 2017:8).

Kroeger et al. (2017) observed that low cocoa productivity and incomes among smallholder farmers in Ghana are mostly attributable to poor agricultural techniques, low investment opportunities and decreasing productivity of cultivable lands. They contend that smallholder farmers have poor management practices relating to pests and diseases control, soil and tree management (old age trees), low knowledge on modern techniques, and limited access to improved inputs and financial credit. These factors result in declining cocoa yields, which leads to deforestation due to encroachment into forest reserves by farmers as another way of increasing yields and production (Kroeger et al., 2017). Furthermore, the increasing variability in rainfall and temperatures was observed to be inimical to the productive ability of cocoa trees in Ghana (TF & NCRC, 2012). These were significant threats to cocoa sector sustainability in Ghana. Hutchins, Tamargo, Bailey and Kim (2015) maintained that climate change is not only causing rapid depletion of forest vegetation and mortality of cocoa seedlings, but also impacting negatively on soil health and fertility for cocoa production. They revealed that changes in temperatures and precipitation were responsible for 70-80% seedling mortality among smallholder farmers in Ghana. Unpredictability in rainfall pattern also affected the spraying schedule of cocoa farms against pests and diseases (Hutchins et al., 2015).

Consequently, the Climate-Smart Cocoa Working Group (CSCWG) was established in 2011 to "address issues of sustainability within the sector and to explore the potential for carbon finance or climate mitigation benefits to catalyse changes to the business-as-usual production practices" (TF & NCRC, 2012:1). It was spearheaded by Forest Trends and the Nature Conservation Research Centre, with support from research institutions, civil society organisations, public and private institutions. The CSCWG also sought to enhance people's understanding about the state of cocoa farming and the threats of climate change to cocoa sector sustainability, as well as identify strategies to reduce deforestation of forest reserves through cocoa farming (Asare, 2014). Thus, it was an effort to improve adaptation capacities of cocoa farmers and mitigate GHG emissions, on one hand, and improve livelihoods through increased cocoa yields, on the other hand (FT & NCRC, 2012). Finally, the climate-smart cocoa (CSC), and for that matter CSA, was initiated as an important local adaptation pathway for the cocoa sector to curb poor yields and increasing deforestation that accompanies cocoa farming activities in Ghana (Kroeger et al., 2017; Asare, 2014). This was to promote and maximise the many economic, environmental and development benefits of CSA among cocoa farmers (Asare, 2014).

Climate-Smart Cocoa is defined as "cocoa production that integrates processes, management systems, and/or techniques that increase yields while contributing to climate change mitigation and farm resilience" (Kroeger et al., 2017:12). The CSC approach presents a holistic means to cocoa production where smallholder cocoa farmers have access to extension services, crop insurance, trainings, credit and other climate-smart farming resources and practices as catalysts to reductions in deforestation and forest degradation due to expansion of cocoa farms (McKinley et al., 2016). The CSC approach also seeks to bring stakeholders in the cocoa sector together "to help define a climate smart cocoa farming package, which can bring about high carbon stock cocoa landscapes that offer adaptation and mitigation benefits, in addition to significant yield increases" (FT & NCRC, 2012:3). It seeks to harness stakeholder consensus that increasingly recognises climate change as a danger to cocoa production and sustainability in Ghana. It shifts away from other pathways that focus primarily on increasing yields and incomes through expansionary means where deforestation and forest degradation are eminent (Asare, 2014). It thus, presents a pathway that sustainably and simultaneously increases yields and incomes, whiles building adaptive capacities of farmers and reducing GHG emissions from deforestation and forest degradation through landscape and land-use planning (McKinley et al., 2016).

It is suggested that CSA in the cocoa sector does not only have the potential of increasing yields by 50%-60% among smallholder cocoa farmers, but also has the potential of promoting carbon stocks and reducing emissions from expansion and loss of shade trees through landscape farming (NCRC & FT, 2012). It is estimated that this could reduce emissions from 20 tonnes per tonne of cocoa to two tonnes of carbon dioxide per tonne of cocoa produced, giving a mitigation benefit of 18 tons of carbon dioxide per ton of cocoa (Ibid.). It is also reported that, promotion of climate-smart agroforestry practices among cocoa farmers enhanced the restoration of about 300 hectares of degraded lands and improved on-farm carbon stocks of about 140,000 tons CO_2e of sequestered carbon within two decades (Noponen et al., 2014). Akrofi-Atitianti et al. (2018) noted that CSA in Ghana's cocoa sector has a triple effect of increasing cocoa yields, serving as a solution to soil degradation, pests and diseases, and reducing agricultural GHG emissions from deforestation. According to the authors, cocoa there were observed increases in cocoa yields by 37% higher per hectare on CSA farms over yields from conventional farms. They attributed the increases in yields and productivity to sustainable soil and land management practices such as use of organic fertilizer. Cocoa beans produced from the use of organic fertilizer also earned farmers an additional income than conventional cocoa beans (Akrofi-Atitianti et al., 2018).

According to McKinley et al. (2016), CSC farming places farmers at the advantage of receiving training on sustainable farming practices, including the efficient use of inputs, crop insurance and shade management. They found that these practices increased average yields of cocoa by reducing the risk of yield losses among farmers across 19 cocoa-producing districts in southern Ghana. The authors observed that farmers who had training on input use recorded higher cocoa yields of 156.48kg/ha against 118.07 kg/ha for farmers who did not have training of input use. The use of inorganic fertilizer by farmers also resulted in higher cocoa yields, while there was insignificant increase in application of chemical pesticides, fungicides, and herbicides (McKinley et al., 2016). McKinley et al. (2016) further observed that the probability of indemnity payments to crop insurers were likely to be more for non-CSC farmers than CSC farmers. Hence, they posited that insurance companies would be motivated to work with CSC farmers than non-CSC farmers, particularly when climate variability has the tendency of increasing “the frequency and size of indemnity payments to producers” (McKinley et al., 2016:22). This suggests that crop insurance packages may be expensive for non-CSC farmers and affordable for CSC farmers.

Hutchins et al. (2015), realised that agroforestry as a climate-smart practice helps provide shades for cocoa trees, which require about 70% shade to do well, the intercropping of other plants on cocoa farms to provide shade for cocoa trees. The process also involves a mix of species of naturally generated canopy shade trees on the farm (Asante et al., 2015). This improves soil fertility and health, as well as maximises the use of pesticides and insecticides. Trees such as mango, orange, avocado, etc. are planted for purposes of shade for cocoa trees, food, and income from the sale of the fruits. These trees also offer ecological, environmental, and cultural services such as provision of rural livelihoods, protection of water bodies, fodder and feed for livestock, pest control and other socio-economic benefits (Zagt & Chavez-Tafur, 2014). The trees and crops do not only serve as barriers between cocoa trees, but they also serve as a strategy by which cocoa farmers reduce the risk of spread of cocoa swollen shoot virus, which affects and destroys cocoa trees (Hutchins et al., 2015). Akrofi-Atitianti et al. (2018) also noted that intercropping and other activities such as livestock rearing, bee-keeping and other diversified livelihood activities earned smallholder farmers an extra income than conventional farmers who engaged in limited livelihoods. Cocoa farmers were also reported to have adopted some soil management practices such as use of organic and inorganic inputs, mulching, intercropping and irrigation in order to improve soil moisture and fertility for increased yields (Hutchins et al., 2015).

Consequently, Dohmen, Noponen, Enomoto, Mensah, and Muilerman (2018:2) developed a training manual for use by stakeholders and agricultural extension workers in order to create awareness and draw attention of smallholder farmer, particularly cocoa farmers, to the growing effects of climate change and how to mitigate its effects on agriculture. The manual offered CSA options for different agro-ecological cocoa farming zones in Ghana under varying and specific climatic impact zones. That is, it accordingly recommends CSA practices and techniques in reference to the degree of predicted severity of impacts of climate change on cocoa production based on agro-ecological zones. These practices focus on building strong and resilient cocoa systems to promote long term sustainability and productivity, while protecting existing forests and avoiding further forest degradation (Dohmen et al., 2018).

For the purposes of CSA practices, Dohmen et al. (2018) grouped the cocoa producing areas in Ghana into three zones based on the degree of severity of climatic impacts in each location. The zones included coping and opportunity zone, adjustment zone and transformation zone. The coping and opportunity zone represent a relatively stable and favourable conditions with little changes to suit cocoa production. It presents an atmosphere where cocoa farmers and other stakeholders must focus on and promote management practices that build resilient and sustainable systems as well as protect existing forests cover (Dohmen et al., 2018). The adjustment zone also presents an environment where cocoa production will be confronted with predicted higher annual rainfall, higher annual average temperatures as well as weaker dry season (extreme rainfall in the dry period). Systemic adaptation strategies will have to be adopted by cocoa farmers in order to maintain productivity at existing levels and also, build systemic resilience to increased precipitation and temperatures. Last but not least, the transformation zone presents an environment of predicted prolonged dry conditions perpetuated by decreased precipitation and higher temperatures. This represents an unfavourable environment for cocoa production in Ghana and will require cocoa farmers to diversify their livelihoods to include cultivation of other tree crops that are drought tolerant to provide shade for cocoa trees (Dohmen et al., 2018).

The foregoing suggests that the capacities of field officers and smallholder farmers, not only in the cocoa sector but the entire food crop sector, must be developed in order to better understand and adapt to the different and varying landscape conditions. It is in this direction that landscape approaches are increasingly considered as relevant for building resilient farming systems in Ghana (Noponen et al., 2014; Zagt & Chavez-Tafur, 2014). The landscape approach is an embodiment of CSA practices to improve farmers' livelihoods through integrated set of activities which include climate education, agroforestry, enrichment planting, beekeeping and small livestock rearing (Noponen et al., 2014). These activities enhance local enterprise development through increased production, as well as reduced GHG emissions from deforestation and forests degradation. The climate education includes improving capacities of farmers to enhance effective mitigation and adaptation to climate change for increased productivity (Ibid.). The landscape approach also addresses issues of landscape restoration, private-sector participation, community involvement, and advocates for effective landscape planning and management in relation to promoting agriculture, forests, and biodiversity conservation within the context of climate change (Zagt & Chavez-Tafur, 2014). The approach also helped to reduce risk of encroachment on forestlands by cocoa farmers in Ghana and also, restored degraded lands through agroforestry practices. This suggests that the landscape approach is not a very new concept in Ghana and has, in recent years, been embraced in response to the challenges of deforestation, land degradation, poverty, illegal logging, GHG emissions, poor yields and consequently climate change (Ibid.).

According to Agula, Akudugu, Dittoh and Mabe (2018), farming practices usually determine the health and ability of agro-ecosystems to ensure sustainable agricultural production. Hence, ecosystem-friendly practices such as crop rotation, biodiversity conservation, use of organic manure, mulching, conservative and minimum tillage, intercropping, etc. should be promoted among smallholder farmers in northern Ghana to enhance increased yields, build resilient farming systems and promote low emissions of GHG (Agula et al., 2018). In the Upper West Region of northern Ghana, evidence of implementation of CSA was reported in the Lawra and Jirapa Municipalities, where two communities namely Doggoh and Bompari communities respectively, were chosen as experimental and research fields for CSA practices and technologies (Buah et al., 2017). It sought to identify CSA practices, identify, and diagnose the characteristics of farming systems, as well as suggest solutions to soil fertility challenges through participatory processes in the Upper West Region (Ibid).

The experimental climate-smart project was carried out for two food crops namely: soya beans and maize in Doggoh and Bompari communities respectively over two years (2013 and 2014).

Buah et al. (2017), noted that the two crops were cultivated under four different conditions in each experimental field. The conditions were: (1) conventional tillage with no mineral fertilizer applied; (2) conventional tillage with mineral fertilizer; (3) no-tillage with no fertilizer and (4) no-tillage with mineral fertilizer (Buah et al., 2017:4). It was reported that soya beans yields increased significantly under no-tillage compared with conventional tillage, recording about 132% higher in yields for the 2014 farming season over the previous season. Overall, no-tillage and application of mineral fertilizer significantly enhanced plant growth and yields in Doggoh community experimental field in the Lawra Municipality.

It is also reported that maize growth and yields at Bompari community experimental field in the Jirapa Municipality were significantly higher under no-tillage and fertilizer application in both 2013 and 2014 farming seasons. For instance, maize yields increased by 68% (464 kg ha-1) and 48% (660 kg ha-1) in 2013 and 2014 respectively under no-tillage conditions compared with conventional tillage system (Buah et al., 2017). The authors also found that maize growth and yields were significantly enhanced through mineral fertilizer application, causing an increase of 143% (760 kg ha-1) and 252% (1913 kg ha-1) in in 2013 and 2014 respectively in Bompari community in the Jirapa Municipality (Ibid.).

However, in northern Ghana the adoption of CSA practices has been low due to low level of formal education among farmers, low access to extension services, age of farmers, low awareness on new farming practices, among others (Agula et al., 2018; Akrofi-Atitianti et al., 2018). Evidence of CSA implementation also tended to be concentrated in the cocoa growing areas in southern Ghana (Akrofi-Atitianti et al., 2018; Dohmen et al., 2018; McKinley et al., 2016; Asare, 2014; Noponen et al., 2014). This coupled with inadequate access to information and low awareness on new agricultural practices and technologies, distance of farms from home and level of soil fertility, affect farmers' decisions to adopt climate-smart practices (Agula et al., 2018).

3.4 Local and indigenous knowledge and agriculture

Local and indigenous knowledge (LIK) have been the basis for decision-making at the community level in matters relating to disaster risk reduction (DRR), food security, health, education, natural resource management and other economic and social activities (Dube & Munsaka, 2018). LIK involves how people perceive and understand the variations/changes in weather elements (such as rainfall, temperature, and wind), animal species, crop, and tree species as well as belief systems that support their livelihoods, health, and protection of the environment (Mafongoya, Jiri, Mubaya & Mafongoya, 2017; Audefroy & Sanchez, 2017).

Indigenous knowledge encompasses the knowledge, innovations, and practices of indigenous and local communities, which are developed from experiences gained over the centuries, orally transmitted from generation to generation, and adapted to the local culture and environment of the people (Inter-Agency Support Group on Indigenous Peoples' Issues - IASG, 2014). It is also collectively owned and takes the form of stories, songs, folklore, proverbs, cultural values, beliefs, rituals, community laws, local language, and agricultural practices, including the development of plant species and animal breeds (Ibid.). Indigenous knowledge has to do with the interaction between communities and their environment, and how it has assisted local communities to survive from generation to generation (Iloka, 2016). It consists of the living cultural traditions, which include family and other social institutions, language, naming and classification systems, governance, use of natural resources and conservation practices, rituals, spirituality, and worldviews (UNSGSAB, 2016). These knowledge systems are developed over long periods by local communities and are empirically tested, applied, validated, and transmitted through lived experiences of day-to-day human interactions (oral, written, tacit, practical and other forms) (Ibid.).

According to Eguavoen (2012), the ability to perceive changes using local knowledge systems is informed by factors such as farmers' level of education, years of experience, age, sex/gender, belief systems and general world view. These perceptions are then transformed by smallholder farmers into models to explain and interpret the patterns of climate change (Eguavoen, 2012). The ability of smallholder farmers to understand, forecast and predict extreme weather events and impacts on agricultural systems is based on their personal observations and experiences within their living environment (Arbuckle, Morton, & Hobbs, 2015). These are usually shaped by their cultural values and beliefs. Kupika, Gandiwa, Nhamo and Kativu (2019) also related that climate change is perceived and understood from natural, human, and spiritual perspectives; and that, these can be mainstreamed into scientific weather forecast systems to enhance community preparedness and resilience.

In Midwestern United States, Mase, Gramig and Prokopy (2017), reported that smallholder farmers mostly depend on local knowledge systems to understand, predict, interpret, and respond appropriately to climate change impacts. They further related that the ability of farmers to perceive climatic risks determines their understanding and decisions to implement response strategies (adaptation). For instance, farmers' decisions to adopt practices such as field conservation, crop insurance and livelihood diversification, are mostly informed by their own knowledge systems rather than scientific knowledge systems (Mase et al., 2017). These strategies are also planned and framed within the context of local perceptions of smallholder farmers. Mase et al. (2017) also noted that, farmers' level of education, age, gender, and general attitudes towards innovation are key determinants for the adoption of local adaptation strategies. For instance, the authors found women farmers in the Midwestern United States twice as likely as men to adopt crop insurance as a form of adaptation strategy.

In India, smallholder farmers had observed rising temperatures and decreasing rainfall pattern through their indigenous knowledge systems (Sahu & Mishra, 2013). Consequently, the majority of farmers relied on their own knowledge systems to develop adaptation strategies, which included irrigation, using different planting dates, double seeding, and changing crop mix (Ibid.). According to Sahu and Mishra (2013), the decision of farmers to adopt any of the strategies correlated to factors such as farmer exposure to the climatic risks, frequency, and magnitude of climate change as well as the socio-economic characteristics of the farmers, including level of education, years of farming experience, age, family size, annual income and number of family agricultural labourers. In addition, accessibility to credit facility, size of land holdings, access to irrigation facilities and available irrigated land size, and access to extension services were other determining factors. These factors are dynamic and vary from one location to another (Sahu & Mishra, 2013).

In Sri Lanka, Menike and Arachchi (2016) reported that, the majority of smallholder farmers observed considerable changes in climate in the form of decreasing precipitation and increasing temperatures and winds through indigenous knowledge. These changes manifest in extreme climatic events such as floods, droughts, and destructive winds, which vary from one agro-ecological zone to another. The authors found that the majority of the smallholder farmers were adapting by planting short season crops, planting drought resistant crops, changing planting dates and planting trees. It was also observed that farmers' ability to adapt to any of the strategies was dependent on factors such as size of household, annual income level of farmers, access to climate information, level of education, location or type of agro-ecological zone, membership to a group, access to micro-credit as well as access to input market (Menike & Arachchi, 2016).

Ali and Erenstein (2017), also found that smallholder farmers in Pakistan adopt strategies such as adjustment in sowing time, using short duration crop varieties and use of drought-tolerant crops to reduce climatic risks. The authors observed that farmers' decisions to adopt climate change adaptation strategies were influenced by various factors including, age of farmers, level of education, access to credit, access to extension services, access to land, land ownership, household size, etc. The authors further noted that creating access to education and agricultural extension services for smallholder farmers could enhance the awareness level of farmers in order to effectively adapt to climate change.

According to Kupika et al. (2019), local knowledge and perceptions have created somewhat general awareness of climate change among smallholder farmers and rural communities across Africa. Many farmers' perceptions on changes in temperatures and rainfall in Africa have been found to have corroborated with the analysis of scientific weather data (Kupika et al., 2019; Elum et al., 2017). Eguavoen (2012:6), also observed that farmers' observations of climatic changes and variations, including pests and disease outbreaks have proven to be “very much to the point” and could be relied on for agricultural decision-making. These perceptions are mostly shaped by their indigenous knowledge systems and their experience of long practice. For instance, in Zimbabwe, Kupika et al. (2019) observed that farmers’ perceptions about decreasing trends in total rainfall and increasing mean average maximum temperatures were consistent with analysis of available meteorological data on rainfall and temperature. Therefore, smallholder farmers’ choices for farming practices are influenced by their perceptions of climatic risks and traditional values, beliefs, knowledge, experiences and how these risks can be effectively addressed and/or responded to (Morton, McGuire & Cast., 2017; Arbuckle et al., 2015).

In SSA countries, rural communities are basically engaged in subsistence agriculture, and therefore have direct economic and cultural relationship with the natural environment which is directly influenced by climate change (International Labour Organisation - ILO, 2017). Being aware of this vulnerability of subsistence agriculture to the direct impacts of climate change, rural communities and smallholder farmers have demonstrated resilience and sustainability of traditional agriculture over the years through the application of LIK (Iloka, 2016). Indigenous communities in SSA have, through their own knowledge systems, successfully developed and implemented mitigation and adaptation strategies that reduced their vulnerability to disasters such as droughts, floods and other extreme events (Nyong et al., 2007). This presents evidence that smallholder farmers possess more eco-friendly, sustainable, and location-specific knowledge systems for adapting to climate change over the years. As a result, local and indigenous farmers are increasingly being recognised as innovators and agents of change based on their unique practices (application of local knowledge) in the field of adaptation and sustainable agriculture (ILO, 2017; Kumar, 2010).

LIK systems in SSA provide smallholder farmers with the understanding, experience, and knowledge on how both natural and human-induced disasters impact on their livelihoods and health systems. As a result, they can develop DRR measures including disaster prevention and mitigation, early warning, preparedness and response, and post disaster recovery measures to sustain life and livelihoods (Mafongoya & Ajayi, 2017). The integration of these knowledge systems provides an opportunity to bridge the "persistent knowledge and technology gaps and engendering robust knowledge-policy-society" to appropriately tackle "sustainable development, biodiversity and climate change" (UNSGSAB, 2016:1). Therefore, local and indigenous skills, experiences and techniques serve as a significant reservoir of knowledge and information to policy makers and researchers for building appropriate models on such issues as disaster preparedness and response, impact assessment, conservation of ecological resources and climate change adaptation programmes (Mafongoya & Ajayi, 2017; UNSGSAB, 2016).

The recognition, promotion, protection, and contribution of indigenous and local knowledge is a major way to achieving socio-economic, cultural, and environmental resilience and sustainability in modern societies (Muyambo, Bahta & Jordaan, 2017). As such, development trajectories must recognise and include the potential role of indigenous and local knowledge systems in order to build synergies, as well as identify the trade-offs in matters of food security, climate change mitigation and adaptation, biodiversity conservation, disaster risk preparedness and response (UNSGSAB, 2016). This will not only enhance the promotion of sustainable development, but also provides a diversity of sources of knowledge, innovation, and information to bridge the technological and knowledge gaps that exist during policy formulation and implementation of socio-economic and environmental interventions (Ibid.). Therefore, local knowledge is a significant source of information that can complement scientific information "to inform policy on best practices to build adaptive capacity of rural communities" in SSA (Kupika et al., 2019:12). Claxton (2010) also relates that scientific knowledge on climate change is a product from indigenous and local knowledge of smallholder farmers.

Indigenous agricultural systems over the past centuries survived on local farming practices and techniques that are associated with the conservation of biodiversity and the ecosystem (Claxton, 2010). These are described in modern times as ecological, organic and conservation agriculture, which are increasingly recognised as key to achieving climate change mitigation, biodiversity preservation and sustainable development because they replenish and regenerate the available natural resources (Ibid.). Morton, McGuire, and Cast (2017) also related that rural farmers' agro-ecological values, beliefs and practices are more aligned to land management and natural resource conservation. The authors, consequently, concluded that smallholder farmers are mostly linked to conservationist perspective of production, where production systems are premised on conserving and improving land resources in the long term.

Although extreme inter-annual variations in local weather conditions may impact the efficacy of indigenous and local knowledge systems and consequently, the understanding and adaptive capacities of smallholder farmers (Mutegi et al., 2018), indigenous knowledge remains relevant. Such relevance is to the journey for time-tested solutions to the challenges of climate change, food security, disaster risk reduction and response, natural resource use and biodiversity conservation (Morton et al., 2017). Davies et al. (2019) highlight that, farmers in Namibia rely very much on traditional calendar dates for planting crops than scientific forecast information. The authors found that traditional forecast information was specific to local context unlike scientific forecast, which provided farmers with broad climatic information. The authors observed that smallholder farmers have strict adherence to their traditional values, norms and beliefs which has greatly influenced their decision to adopt CSA technologies and practices such as new crops or cultivars, agroforestry, etc. These norms and belief systems have been passed to them by their past generations. Selato (2017) also observed that farmers in Botswana observe the flowering of trees, the position of stars and the persistence of heavily "pregnant" clouds to predict the amount of rain for the farming season.

Understanding the perceptions of smallholder farmers is key to appreciating the different perspectives on the climate change phenomenon in SSA and Africa at large (Kupika et al., 2019; Mase et al., 2017). According to Kupika et al. (2019), the attribution of climate change to spirituality does not detach farmers thinking from the scientific point of view on the causes of climate change. Thus, although smallholder farmers believe that engagement in abominable acts (such as sexual intercourse in the bush, stealing, etc.) and abandonment of traditional cultural practices are partly responsible for climate change, they also hold the view that human actions such as industrial pollutions, deforestation and other conventional practices are more responsible for climate change (Kupika et al., 2019). Therefore, farmers' perceptions and assessment of climate change and its impacts are relevant for a better exploration of the understanding and response mechanisms of smallholder farmers to climate change (Mase et al., 2017). According to Kupika et al. (2019), most smallholder farmers in Zimbabwe perceived increasing frequency of occurrences of drought, decreasing frequency of flood events, and increasing trend in the occurrence of extreme cold winters and destructive winds associated with hailstorms. The authors also revealed that, farmers were experiencing drier weather conditions, increasing temperatures and unpredictable rainfall timing. The authors further revealed, smallholder farmers' account suggested shortening and shifts in onset of the rainy season from October to mid-December whilst shifting the end of the rainy season from March to April since 2013.

Ambani and Percy (2014), argued that a combination of the use of traditional and scientific seasonal forecasting methods in Kenya proved better for smallholder farmers than relying on traditional methods alone. Singh et al. (2017a) corroborated that the use of participatory approaches in the design of climate information systems enhanced interpretation and adoption for making agricultural decisions among smallholder farmers in Africa. Thus, integration of traditional and scientific knowledge systems creates a complementary process for the provision and delivery of climate information, as well as enhance effective understanding of climatic and agricultural risks among smallholder farmers within the context of local realities (Singh et al., 2017a). Sustainable agricultural approaches including CSA approaches should also be framed in a manner that appeals to the traditional values and belief systems of the local people in order to promote adoption among farmers (Musarandega et al., 2018; Iloka, 2016). This may however require strong and multi-stakeholder engagements between government institutions, communities, experts, and smallholder farmers (Mathews et al., 2018; Singh et al., 2017b).

3.5 Interfacing scientific and, LIK systems for climate change adaptation

Discussions on coping with climatic risks and impacts mostly focus on two main practices: namely adaptation and mitigation, which are separate but complementary in practice (Elum et al., 2017). Although intertwined, adaptation is a more preferred option in responding to climate change by rural farmers because of its ability to restore damages and build resilience.

Consequently, experts and practitioners are increasingly shifting their concentration on politics of climate change and mitigation economics to adaptation strategies because it presents location dynamics and context-specific solutions to farmers (Ibid.). The process of formulating adaptation strategies takes into consideration and mainstream local knowledge systems during policy formulation process to enhance farmers' understanding and adoption (Alam et al., 2017).

The World Bank (2015) has noted with grave concern the growing impacts of climate change on food security and agricultural production systems, and how that could cause a reduction in crop yields of up to seven percent in Africa and Asia by 2030. It calls for prioritisation and implementation of adaptation to include CSA in order to appropriately conceptualise the linkages between climate change, population growth, food security and agricultural production. Tailor (2018) also calls for agricultural practices that are not only climate-smart but climate-wise, where food security is achieved through increased production from resilience and sustainable food systems that reduce GHG emissions and promotes development strategies that are sustainable over time.

According to Porter et al. (2014), the impacts of both historical and future climate change point to significant yield loss of cereal crops in differential proportions across different regions globally. These yield losses are projected to vary with estimated loss of 60% for maize, 50% for sorghum, 35% for rice, 20% for wheat and 13% for barley relative to the location, future climate scenarios and projected years (Ibid.). Elum et al. (2017) reported that climatic impacts (higher temperatures) have had significant burden on vegetable and root crops production in South Africa. The authors found reduction in yields of cabbage and potato by 74.7% and 81.3% respectively. In response to these, the authors related that, smallholder farmers adopted some practices such as changing planting times to match with rainfall, planting early maturing crops, increased use of irrigation and conservation tillage practices in their farming activities. It was further observed that, while cabbage farmers were planting drought-tolerant varieties to adapt to droughts, potato farmers, on the other hand, were concentrated on integrated pest management and crop diversification practices as adaptation and mitigation measures (Elum et al., 2017).

It is therefore imperative to prioritise and effectively implement adaptation measures to achieve livelihood sustainability and food security (Khatri-Chhetri et al., 2017; Alam, 2017; Niles et al., 2017). SSA countries are unable to effectively implement adaptation strategies due to low adaptive capacities, which Wood et al. (2014) attributed partly to the poor socio-economic backgrounds of many rural households. It is therefore suggested that climate change adaptation should be planned and understood within the context of socio-economic conditions, time, location, and community perceptions (Alam et al., 2017). This is because the perceptions of farmers about climate change serve as an entry point not only for farmers in developing response strategies, but also for planners and policy makers to appropriately appreciate the context within which adaptation planning and implementation should be done (Nyong et al., 2007).

Community-based adaptation (CBA) has been emphasised as an appropriate adaptation strategy for smallholder farmers (Reid & Schipper, 2014) since local people and communities have low adaptive capacities and are severely affected by the impacts of climate change (IPCC, 2014). This is because community-based adaptation takes into consideration how communities blend local knowledge with scientific knowledge in understanding climatic risks and uncertainties as well as building locally appropriate responses to those risks and uncertainties (Nunan, 2017). CBA is an enabling activity in the context of CSA that distinguishes itself as a viable option among other technologies and practices for promoting national development and food security under site-specific conditions (Lipper et al., 2014). The CBA approach recognises dynamics in the knowledge, vulnerabilities, needs, capacities and priorities among households and communities (Reid & Schipper, 2014).

Changes in crop sowing dates, adoption of irrigation technologies, use of short duration crop varieties, use of drought-tolerant crops and other farm-level adaptation strategies are usually employed by smallholder farmers to achieve higher crop yields under different climate conditions (Ali & Erenstein, 2017). These are framed within the context of farmers' perceptions of prevailing climatic and environmental conditions over the specific time in their communities (Alam et al., 2017). The decision of farmers to adopt adaptation strategies are much influenced by certain factors including age of farmers, level of education, access to credit, access to extension services, access to land, household size, years of experience, access to inputs, etc. (Ali & Erenstein, 2017).

3.5 Theoretical and conceptual framework

Here, the social identity theory has been chosen for the study of smallholder farmers' production and adoption decisions within the context of the impacts of climate change and variability on smallholder agriculture. The study reviews relevant and related literature on the social identity theory within the context of smallholder farmers' production and adoption decisions of agricultural practices. Following this, the conceptual framework is presented

3.5.1 The Social Identity Theory: A literature review

According to Scheepers & Ellemers (2019) being a member of a group defines one's identity, and that individuals are not only part of groups, but groups are also part of the individuals. According to the authors, groups do not only define individuals by telling who they are or are not, but that groups also determine the feelings of individuals in relation to other members of the group and their activities. These feelings and the perceptions of individuals in respect of the groups they belong to form their social identities (Scheepers & Ellemers, 2019). Therefore, the social identity of an individual refers to the individual sense of belongingness to a group(s) and the emotional feeling that accompanies the sense of membership to the group(s). According to Sulemana and James (2014:50), "A person's identity defines who they are, how they view themselves, how they view the world around them, and how they think as well as want others to perceive them". The authors further noted that a person's identity is influenced by the environment within which he/she lives, which manifests in a distinct relationship with the attitude of the person (Sulemana & James, 2014).

According to McGuire, Morton, and Cast (2013), the identities of persons are maintained through a feedback process that relates the views of society following certain actions by those persons. It is in this regard that the social identity theory seeks to elaborate how people's thoughts, feelings, and behaviours can be understood in group-based activities in any working environment (Scheepers & Ellemers, 2019). The theory comes in two parts namely, cognitive, and socio-structural parts. The cognitive aspect deals with the "processes underlying social identity definition and the motivational assumption that people strive for a positive social identity", while the socio-structural part defines "how people cope with a negative social identity" (Scheepers & Ellemers, 2019:130). Thus, the ability of individuals to identify themselves according to different groups, defines who they are, provides a positive group sense of self-belongingness, as well as satisfies the basic human certainty and self-esteem.

The theory has been applied by many scholars to examine how individual identities of smallholder farmers influence their farming practices, roles, and behaviours (Dakurah, 2018; Morton et al., 2017; Hyland et al., 2016; McGuire et al., 2015; McGuire et al., 2013; Barnes & Toma, 2012). The identity control theory posits that the identities of individuals (smallholder farmers) are verified by a certain motivation that precedes a simple feedback loop process. An identity is considered as verified when the feedback is positively correlated and where it is negatively correlated, it is considered as not verified, and this will consequently require an action by the farmer to either make it positive or entirely change the identity (McGuire et al., 2015). With respect to smallholder farmers, the feedback about their performance in relation to their identities comes from the social and biophysical environments that support agriculture.

According to the theory, negative social identity and/or threats in social groups that individuals belong to are addressed through individual mobility, collective action, and social creativity (Scheepers & Ellemers, 2019). Firstly, the individual mobility has to do with a situation where an individual can seek a membership in another group with high status by exiting his/her group. The second option (collective action) has to do with the whole group seeking improvement in conditions of the group from its prevailing performance. Lastly, the group can be socially creative enough to elevate the social class of comparison to stay relevant. The theory further suggests that there are certain specific factors that determine which option to adopt in addressing any negative identity. This also comes in the form of three socio-structural variables namely, permeability, legitimacy, and stability. Permeability looks at whether it is possible for an individual to move to another group while legitimacy and stability refer to level of fairness in the status differences and whether it is possible to change respectively (Scheepers & Ellemers, 2019). See the figure (Figure 3.1) below.

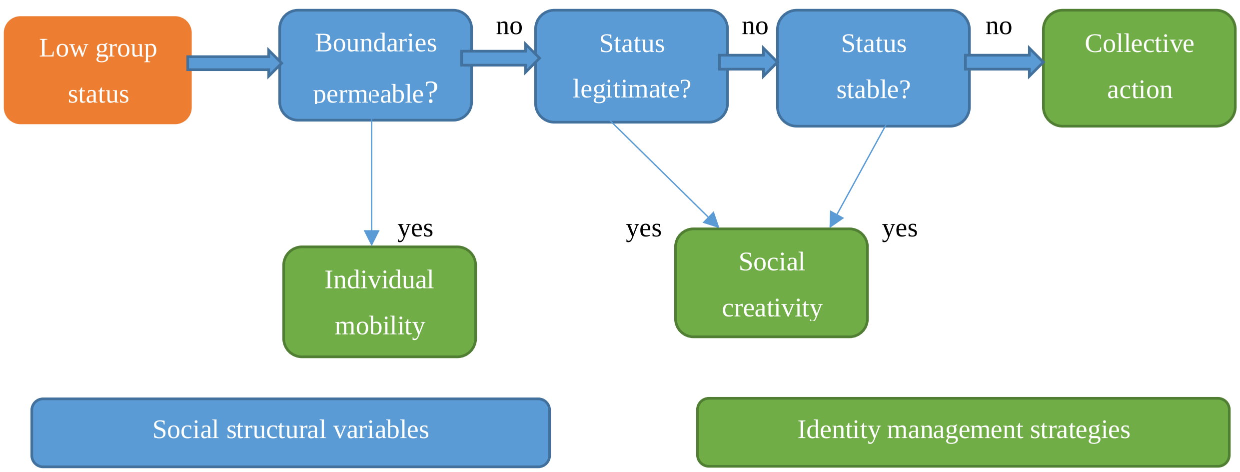


Figure 3. 1:Social-structural variables and identity management strategies

Source: Scheepers & Ellemers, 2019: 134

3.5.2 An understanding of smallholder farmers' production and adoption decisions within the context of the Social Identity Theory

In the context of smallholder agriculture, the emphasis is placed on increases in yields within the context of an ecosystem which is characterised by rainfall variability, loss of soil fertility, increasing soil erosion and increasing loss of biodiversity. The ecosystems within which farms are created are integrated socio-ecological systems with multiple purposes of serving as habitat for biological species such as animals, plants, insects, birds, and other species (McGuire et al., 2015). Meanwhile the ecosystem is being destroyed due to the pursuit for increasing crop yields in a manner that does not recognise the integrated nature and dynamics of the socio-ecological systems on farmlands and the general landscape. The notion that any farm's landscape is a portrait of the owner himself is still relevant to the discourse (discussions and understanding) of farmer identity within the context of agriculture production (Ibid.). That is, the attitudes, experiences, beliefs, and perceptions of farmers on agriculture and how it should be done usually tend to reflect their practices, initiatives, and strategies towards improving and protecting the ecological systems of the farming environment. These practices and strategies are significantly influenced by the knowledge, values, beliefs, past experiences as well as the iterative interactions of smallholder farmers with their immediate social and biophysical environments, including the community, farm, markets (McGuire et al., 2015).

There have been many farmer typologies by different scholars basing on the farming practices employed by the farmers on one hand, and farmers' perception about themselves on the other hand (Sulemana & James, 2014). Identifying farmers on these two grounds, according to Guillem et al. (2012), is inadequate to fully understand the behaviour of farmers and consequently, does not provide adequate insights for policy formulation. However, Sulemana and James (2014:49) believe that, despite the inadequacies, these typologies "can give researchers and policymakers useful insights into how farmers' perceptions about themselves affect their decisions regarding farming practices." According to Barnes and Toma (2012), classification of farmers into distinct groups offers opportunity to ensuring a cost-effective way of directing information and policy interventions at farmers with varied and/or similar attitudes and values. It also enhances adoption and implementation of best agricultural practices and technologies within the context of climate change adaptation among smallholder farmers (Barnes & Toma, 2012).

Two major typologies namely conservationist and productivist farmers have been identified by many scholars (Morton et al., 2017; Sulemana & James, 2014; McGuire et al., 2013). This is premised on the fact that every farmer will want to make profit and not a loss; and will therefore choose the production system that favours him/her, particularly the ability to feed the household. Conservationist farmers orient themselves toward ecological conservation while productivist farmers are basically concerned with increase in yields and productivity. Thus, the productivist farmer aims to increase yields and production through significant use of chemicals such as herbicides, pesticides, insecticides, synthetic fertilizers and heavy reliance on high-technology farm equipment and genetically modified seeds in the agricultural production process with little recourse to environmental well-being (McGuire et al., 2015). Thus, productivist farmers are much concerned about the short-term efficient production of high crop yields per hectare of land cultivated through expansive land cultivation over long-term land management (Morton et al., 2017; McGuire et al., 2013). They are less concern about the negative consequences of surface and ground water pollution from the use of agro-chemicals, increased soil erosion and loss of biodiversity (McGuire et al., 2015).

According to McGuire et al. (2015), the conservationist farmers, on the other hand, are concerned about long-term management of land resources over short-term profits. Thus, they are much concern about reducing water pollution, soil erosion and loss of biodiversity through sustainable agriculture production practices than increasing yields for short-term profits. That is, conservationist farmers emphasise "longer term goals of conserving and improving land resources" by incorporating the "underlying values and beliefs that encompass more than land as a tool to create income and extend beyond annual productivity" (Morton et al., 2017:19). Thus, conservationist farmers combine productivity with environmental conservation (McGuire et al., 2013).

Apart from the productivist and conservationist farmer identities, McGuire et al. (2015) identified two additional farmer identities namely civic-minded and naturalist identity farmers. According to the authors, the civic-minded farmers assume leadership roles, share farm equipment and knowledge with their peers, as well as actively participate in community and farm organisational activities in their respective communities. That is, they recognise their farming roles to include "community leadership and responsibilities to be an active, civic-minded, and engaged member of the local community" (McGuire et al., 2015). The naturalist identity farmer, on the other hand, is defined as "one that balances farm production with a strong interest in wildlife (flora and fauna) either to consume it as hunters, mushroom foragers or fishers, or to appreciate it as a bird watcher or hiker" (McGuire et al., 2015:152). They are associated with farming practices such as use of cover crops, minimum use of pesticide and no-tillage to preserve and maintain biophysical environment for wildlife habitation.

In their study of 'A typology of dairy farmer perceptions towards climate change', Barnes and Toma (2012) identified six typologies of farmers among Scottish dairy farmers within the context of their attitudes, values, and behaviours in relation to climate change. These identities included regulation sceptic, commercial ecologist, innovator, disengaged, negativist, and positivist farmers. According to the authors, farmers with regulation sceptic identity are characterised with high level of scepticism towards environmental and farming regulations, creating a relationship between profit maximising behaviour and regulation scepticism. Here, regulation is seen as an obstacle to production (Barnes & Toma, 2012). This identity of farmers emphasises on profits and efficiency maximisation, and they usually expect least impact of climate change on agriculture production. The commercial ecologist farmers are concerned with production, profit, and resource maximisation while ensuring the need for ecological values in production. They believe that climate change will negatively impact agriculture production, but not in a manner and scale that will significantly trigger changes in their production approaches. Thus, despite exhibiting a bit of pro-environmental attitudes, their actions and adoption of environmental conservation and improvement programmes are motivated by interventions that attach support and compensation to production (Barnes & Toma, 2012). They are also motivated by low-cost 'win-win' technologies, that reduce waste of on-farm resource and provide significant benefits in a cost-effective manner (Barnes & Toma, 2012).

The innovator identity farmers have positive attitudes towards innovation and adoption of improved methods and techniques of farming that enhance maximum profits and reduced production costs. They are willing to adopt practices and technologies that help them to adapt and mitigate the impacts of climate change. Their willingness and passion for innovation and technology adoption are also motivated by resources and profit maximisation including financial rewards. This keeps them focused on win-win practices and technologies in agriculture production process (Ibid.). The disengaged identity framers, according to the authors, have low agreement with production, social and ecological values; they are usually less concerned about climate change and any information that seeks behavioural change (Barnes & Toma, 2012). They have low level of belief in environmental conservation and hence there is very little interest for participating in conservation activities. The negativist identity farmers are profit maximising farmers and believe that climate change will adversely affect farming in the future. suggesting that climate change has long-term impacts that will manifest in loss of productivity and food insecurity (Barnes & Toma, 2012). However, this identity of farmers does not show high level of interest for innovation and adoption of technologies as response mechanisms.

Contrary to the negativist identity farmer, the positivist identity farmers believe that climate change will have positive impact on future farming and income through increased yields and productivity. They are therefore not motivated by decisions towards enhancing profit, innovations, and the environment, and consequently do not have any adaptive response strategies (Barnes & Toma, 2012).

Guillem, Barnes, Rounsevell, and Renwick (2012) also identified four typologies of Scottish farmers in their study titled 'Refining perception-based farmer typologies with the analysis of past census data.' These typologies include Profit-oriented, Multifunctionalist, Traditionalist and Hobbyist. The profit-oriented identity farmer prioritises profit maximisation over ecological concerns in agriculture. That is, they are much concern about maximising profits over concerns for maintaining environmental and social standards. They have negative or complete absent of knowledge and attitudes towards environmental aspects of farming and may only adopt ecologically friendly measures when they are directly connected to financial returns (Guillem et al., 2012). Profit-oriented farmers would usually adopt high yielding crop varieties, increased use of chemical inputs as well as invest in machinery.

The multifunctionalist identity farmer has better knowledge and understanding of ecological processes as well as recognising the need for the application of specific measures in a flexible manner towards enhancing environmental quality and improving the delivery of ecosystem services (Guillem et al., 2012). They are much aware of the impacts of climate change on agriculture and ecosystem services. The multifunctionalist farmers are innovative and are willing to adopt higher yielding crops to improve production. Traditionalist identity farmers have high level of knowledge and awareness about environmental concerns and are, therefore, much oriented towards environmental and social values. Thus, they prioritise social and ecological concerns over financial maximisation by reducing the use of chemical inputs in farming. They are conservative farmers and are very passionate about environmental conservation by adopting a mix of farming activities and practices that are ecologically friendly. The Hobbyists identity farmers have "a strong interest in wildlife conservation and a high awareness of environmental quality" and are generally "more concerned about lifestyle rather than business" (Guillem et al., 2012:230). They have in-depth knowledge and understanding of ecological needs and therefore contribute to biodiversity conservation and heterogeneity of farming landscape.

In the study of how farmers' identity could affect their attitudes towards environmental, farm management and conservation practices, Sulemana and James (2014) identified six typologies of farmers. These include productivist, conservationist, optimist, pessimist, technological, and traditional farmer identities. The authors found that, farmers identified themselves more as "productivist (42%) than as conservationist (32%); as optimistic (48%) than as pessimistic (21%); and preferring technology (51%) more than tradition (21%)" (Sulemana & James, 2014:54).

Hyland et al. (2016) identified farmers as environmentalist, dejected, countryside, and productivist farmers. The environmentalist farmers have high sense of awareness on climate change and demonstrate significant level of environmental responsibility (Hyland et al., 2016). They have appreciable behavioural capacity to adopt and implement mitigation strategies to reduce emissions of GHGs and protect the environment. Hyland et al. (2016) found that environmentalist farmers could attribute climate change to GHG emissions through the manufacturing and use of fertilizer, rearing of ruminants and the management of manure. The dejected farmers are characterised with high level of perceived risks and awareness about climate change, and a significant high level of willingness (behavioural capacity) to adopt and implement adaptation and mitigation measures. However, dejected farmers were found to be unable to link agricultural emission sources, particularly from livestock to climate change (Hyland et al., 2016).

The countryside steward farmers have high sense of environmental responsibility and see environmental protection as a duty and priority. However, they do not believe that emission of GHGs can cause climate change due to low awareness and perception of climate change risks. Consequently, they turn to have low behavioural capacity to adopt and implement adaptation and mitigation measures to address issues of climate change (Hyland et al., 2016). For productivist farmers, the basis for management decisions rest on production and profit-making. They have significant low sense of awareness, perception of climatic risk on farming, and environmental responsibility (Hyland et al., 2016). According to the authors, productivist farmers do not see agricultural emissions as significant contributor to climate change as compared to non-agricultural sources, hence they have low behavioural capacities to implement adaptation and mitigation measures (Ibid.).

Having reviewed substantial literature on the identity theory and how it has been applied within the context of smallholder agriculture and farmers' adoption decisions on farm practices, the next section presents the conceptual framework of the study.

3.5.3 Conceptual framework

Based the foregoing review of literature on the social identity theory as applied in farming decisions of smallholder farmers, the study draws lessons on the social identity theory and the exposure and vulnerability analysis framework to conceptualise smallholder farmers' adoption decisions in North-western Ghana. From the framework, a farmer is conceptualised within the context of being exposed and vulnerable to climate change in the form of rainfall variability and high temperatures which manifest in extreme events such as floods, droughts, heat stress/conditions and loss of soil fertility in North-western Ghana. The impacts of these adversely affect smallholder farming and household food security. Consequently, farmers response to the impacts of climate change through various mechanisms and strategies to adapting to the situation by drawing from either their local and indigenous knowledge, scientific knowledge, or a combination of both local and scientific knowledge systems available to them. However, the level of smallholder framers' vulnerability to climate change and the decisions to adopt any of the knowledge systems-based practices are determined by certain factors which are captured in the framework as determinants. These determinants explain the level of vulnerability of smallholder farmers to climate change on one hand, and how they influence farmers' decisions to adopt climate compatible strategies on the other hand. When the determinants positively relate or correlate to the farmer, it suggests a reduced vulnerability level of the farmer and will positively influence the farmer to adopt best practices that maximise yields for achieving sustainable smallholder agriculture and food security. In the same vein, when the relationship is negative, suggesting a high exposure and vulnerability of smallholder farmers to the impacts of climate change, farmers are still compelled to devise means of sustaining their livelihoods (subsistence farming), albeit low capacities, to survive by adopting farming practices that are appropriate to their current situation. Hence, making the farmer to identify him/herself as a good farmer in any of the situations he/she finds him/herself. That is, the farmer is able to increase production, ensure food security without causing (much) damage to the environment/ecosystem by adopting practices that are climate compatible.

Therefore, a smallholder farmer is identified as a good farmer if the farmer is able to sustain agricultural production and household food security through practices which increase yields and conserve the environment including soil fertility within the context of climate change challenges. It is important to mention that there is always a feedback process among variables in the framework which helps smallholder farmers to take decisions based on the feedback received.

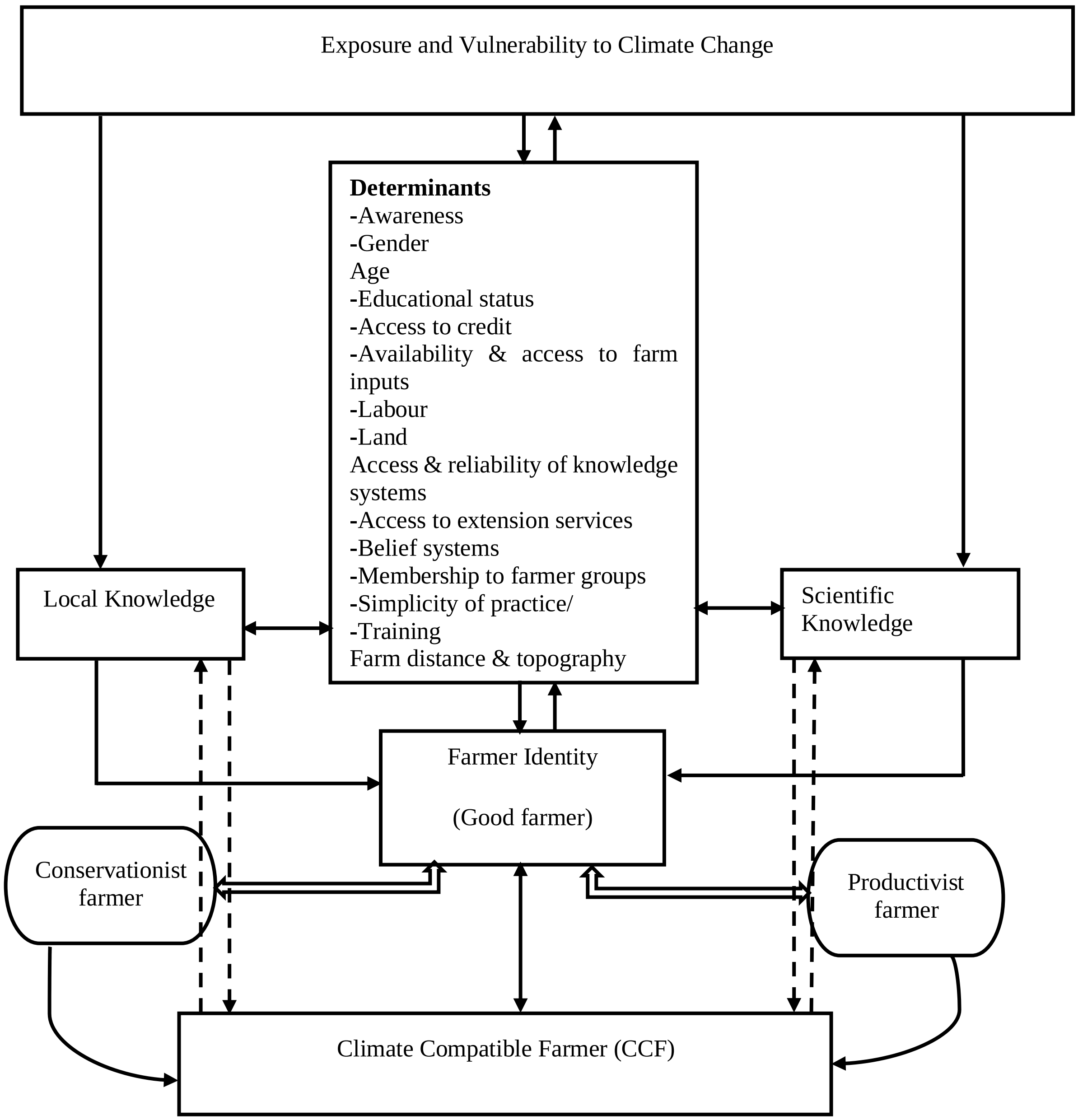


Figure 3. 2: Conceptual framework

Source: Author's construct, 2022

From Figure 3.2 above, the feedback between the level of exposure and vulnerability on one hand, and the determinants on the other hand, determines the type of knowledge-based practices and technologies to be adopted among farmers. Here, a farmer adopts either of the knowledge systems based on his/her households' circumstances with respect to the determinant factors which determine the adaptive capacity of the farmer and his/her household in relation to the level of exposure and vulnerability to climate change. Every farmer wants to be identified as a good farmer irrespective of the situation and context within which they find themselves. Therefore, their practices and use of knowledge systems are informed by the identity the farmer is associated with. Broadly, farmers in North-western Ghana were identified basically as productivist and conservationist farmers. The productivist farmers are usually aimed at maximising production through increased yields by adopting practices such as the use of chemical fertilizer, pesticides, insecticides, herbicides, use of modern farm implements (tractors), improved seeds, etc. The quest for maximising production sometimes leads to the excessive and indiscriminate use of chemical inputs such as pesticides/insecticides, herbicides, and synthetic fertilizer as well as excessive tillage system to the detriment of the health of the soil and the environment. Productivists mostly tend to rely much on scientific practices and technologies, although with limited capacities, that promote high yields with very little concern for the environmental protection. They are also associated with indiscriminate extensification practices which result in deforestation. That is, productivist farmers tend to clear the vegetation on yearly basis for farm extension irrespective of whether their existing farmlands have lost fertility or not.

The conservationist farmer, on the other hand, is concerned with both increase in yields and the protection of the environment from damage. Therefore, conservationists usually adopt practices and technologies that enable them to adapt farming to climate change and at the same time preserve and conserve the environment including land for the present and future use. They mostly turn to adopt local practices such as use of organic manure, mulching, crop rotation, mixed cropping, mixed farming, agroforestry, vegetative natural regeneration, use of traditional pesticides and insecticides, etc. which promotes food security and ensure environmental sustainability.

The activities and practices of these two farmers are evaluated and regulated through a feedback process to maintain their status (identity) as good farmers. The feedback that a farmer gets after comparing and/or evaluating his/her activities as either a productivist or conservationist farmer makes him/her to change or modify his/her practices. This evaluation by both identities of farmers will compel them to take actions that will lead to another identity of farmers known as the climate compatible farmer identity. That is, some productivist farmers will tend to modify their practices to conserve/protect the environment when they get to realise that their quest for higher yields and increased production through practices and technologies that are injurious to the very environment and ecosystem that support their livelihoods. That is, when they get to realise that their activities/practices are rather exacerbating the impacts of climate change, they are compelled to act by adopting practices that minimise environmental damage. In the same way, some farmers who are identified as conservationists will also modify their practices to incorporate aspects of productivism to manage the situation when they think they are not gaining the necessary yields to guarantee household food security through the existing practices. Hence, there will be farmers who are integrating and incorporating both practices of productivism and conservationism, thereby a new identity of farmers is created and known as climate compatible farmers. Therefore, climate compatible farmer adopts practices and technologies that both ensure increased production through high yields and at the same time preserve and conserve the environment and the general ecosystem for present and future use. Also, the climate compatible farmer is associated with the incorporation and integration of both scientific and local and indigenous knowledge for adapting to climate change and promoting sustainable agriculture in North-western Ghana. There are feedback mechanisms for the integration of knowledge systems by the climate compatible farmer. There is also a feedback system between a good farmer and the climate compatible which helps to manage and maintain the standards as a good farmer. In the nutshell, the climate compatible farmer is a good farmer, and the status is maintained through a feedback process

3.6 Conclusion

CSA has emerged as an alternative pathway in the search for sustainable agricultural practices that will enhance food production to meet the growing food needs of the growing world population. It aims at increasing food production, increasing the resilience of production systems and reducing agricultural-related emissions in a simultaneous manner through the integration of traditional and innovative practices and services to achieve food security and development goals. Some of the CSA practices may include integrated crop, livestock and aquaculture and agroforestry systems, landscape approaches, integrated pests, water and nutrient management, reduced tillage, improved water and fertilizer-use efficiency, manure management, rehabilitation of degraded lands, among other practices and technologies. These practices address climate change through mitigation and adaptation and lead to increase in food production.

In Ghana, CSA practices and technologies turn to concentrate in the cocoa production areas of southern Ghana with instances of CSA experimentation among smallholder food production farmers in northern Ghana. A significant number of CSA cases in the cocoa sector have been discussed in this chapter which gives credence to the fact that CSA in Ghana was introduced to cocoa framers and focus of which was to increase cocoa production through integrated processes, management systems and techniques that increase cocoa yields while enhancing climate change mitigation and farm resilience. It was an approach to reduce and/or avoid forest extensification and degradation associated with traditional cocoa farming in Ghana. This has the potential of reducing emissions and promoting carbon stocks through its associated agroforestry practices.

CSA was experimented in the Lawra and Jirapa Municipalities on food crop production to assess the potential of no-tillage and mineral fertilizer use practices for food crop production in the Upper West Region and northern Ghana at large. The CSA concept and its implementation within the context of interfacing of scientific and indigenous knowledge applications, as well as the role of local and indigenous knowledge in promoting CSA practices and technologies among farmers.

CHAPTER 4: STUDY AREA AND METHODOLOGICAL FRAMEWORK

4.1 Introduction

This chapter presents the methodological processes employed in addressing the aim and objectives of the study. It outlines the research design and approach; the sampling design which spells out how and why communities and participants in the study were selected by the researcher; methods of data collection which included interviews, focus group discussions, and field-based observation. It also details how data for the study were analysed and presented by the researcher.

4.2 Description of the study area

The Upper West Region is one of the 16 administrative regions of Ghana, with Wa as its capital town. The region currently has 11 municipalities and/or districts. These consist of five municipal assemblies namely Wa, Sissala East, Jirapa, Lawra, and Nandom, and six district assemblies which include Nadowli/Kaleo, Sissala West, Wa East, Wa West, and Lambussie Districts. Sissala East and Lawra Municipalities were purposively chosen for the study because they are predominantly smallholder farming areas and are exposed to the threats of desertification and varying risk of climate change and variability due to the proximity to the Sahel of neighbouring Burkina Faso. The municipalities also experience a single rainy season from April to September, with a prolonged dry season from early November to March through to early April. They were also chosen because of the variations and differences in topographical characteristics including soil and vegetation necessary for crop farming. The backgrounds of these two municipalities are presented under the following ensuing subtopics.

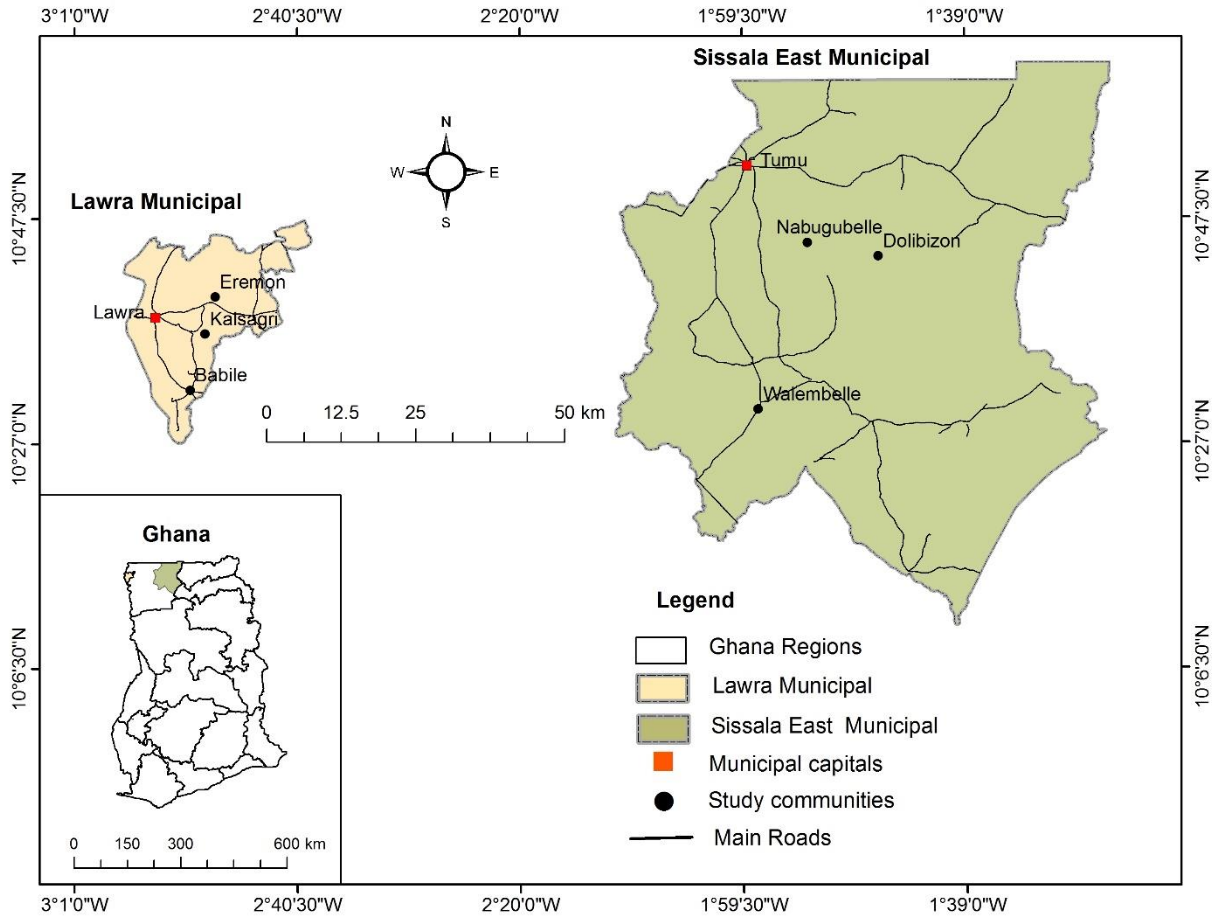


Figure 4.1: Map of study Municipalities

Source: Author's construct, 2021.

4.2.1 Sissala East Municipal

The Legislative Instrument (L.I) 1766 of 2004 established the Sissala East District with Tumu as its capital, following the division of the then Sissala District. The district was then elevated to a municipal status in 2018 by the Legislative Instrument 2280 of 2017 (Sissala East Municipal Assembly - SEMA, 2019). The municipality has one town council, which is Tumu Town Council, and four area councils namely, Bujan, Walembelle, Sakai and Nabulo Area Councils (SEMA, 2018).

Located in the North-Eastern part of the Upper West Region of Ghana, the Sissala East Municipal falls between Longitudes 1.30^0 W and Latitude 10.00^0 N and 11.00^0 N. It has a total land size of 5,092.8 square kilometres, representing 26.7% of the total landmass of the region (Ghana Statistical Service - GSS, 2014a). The Municipal is bounded to the North by Burkina Faso, on the East by Kassena-Nankana and Builsa Districts of Upper East Region, to the South-East by West Mamprusi District of North_East Region, which was carved out of the Northern Region, South-West by Wa East, and Daffiama-Bussie-Issa Districts in the Upper West Region and to the West by Sissala West District, also in the Upper West Region (Sissala East District Assembly - SEDA, 2016).

The location of the municipality presents an opportunity for cross border trade and other activities among the people, which could develop the local economy. According to the Ghana Statistical Service (GSS, 2014a) report, about 84.8% of households in the municipality are engaged in agricultural activities (crop farming and livestock production), with the majority (about 96.9%) of these households engaged in subsistence crop farming. The report further indicated that about 94.9% were rural agricultural households (nine out of 10 households) while about 56.9% of the agricultural households (six out of every 10) were in the urban localities. The people, despite being predominantly subsistence farmers, have achieved remarkable increase in commercial maize farming in recent years. This makes the Sissala East Municipal the food basket of the Upper West Region (SEDA, 2016). This notwithstanding, its location exposes it to the threat of migrants from neighbouring Burkina Faso, as well as smuggling of goods and services from and into the municipality. It is also prone to various security threats, notably the insecurity posed by the insurgence of Fulani herdsmen in the municipality. This has become a yearly ritual (SEDA Medium-Term Development Plan - DMTDP, 2010).

The topography of the Sissala East Municipal could be described as gently undulating. It is generally characterised by gentle latitudes of between 330 and 365m in the northern part, descending to 220m and 290m in the valley of the Sissili River. The municipality is drained by the Sissili River and its tributaries that flow in south-eastern direction to join the White Volta (Sissala East District Human Development Report - SEDHDR, 2010).

From the 2010 population census, the total population of the municipality stood at 56,528 (GSS, 2012). The male population stood at 27,503 and female at 29,025, representing 48.7% and 52.3% respectively. This also puts the male/female ratio of the population at 94 males to 100 females. Tumu, the municipal capital, has 19.03% of the population and it is the only settlement with the status of a town population and infrastructure wise. The projected population for 2017 also stood at 65,122, a projected increase of about 8,594 people from the 2010 figure. This puts the male and female populations in the municipal at 31,683 (48.65%) and 33,436 (51.34%) respectively, as well as a male/female ratio of 51:49 (SEMA, 2018). Settlements in the district are also predominantly rural and hence a highly dispersed settlement pattern, with not less than 10km distance between communities. Few settlements such as Tumu, Wellembelle, Sakai, Challu, Nwanduanu, Bugubelle, and Nabulo constituting about 18.8% have populations depicting urban settlement while 81.2% are rural settlements (SEMA, 2018).

Leading from these, the 2021 Population and Housing Census (PHC) puts the population of the Sissala East Municipality at 80,619 comprising of 39,868 male population and 40,751 female population (GSS, 2021). This gives the male/female ratio as 1:1.02. Thus, there has been an increase from the 2010 PHC total population by 24,091, representing an increase of 42.6% over the decade. Thus, there was an increase of 12,365 in male population and 11,726 in female population from the 2010 PHC figures, representing a percentage increase of 45% and 40.4% respectively. Further analysis of the 2017 projected population figures of the municipality shows that there was an increase of 15,497 in 2021 from the projected 2017 figure, representing an increase of 23.8% in the total projected population. This saw an increase of 8,185 in male and 7,315 in female populations, translating in 25.8% and 21.9% increase respectively. Therefore, in both situations, male population increased more than female population in the municipality, suggesting a future increase in labour force for agriculture and other activities since men mostly form the major labour force in the household in North-western Ghana. The 2021 PHC further revealed that urban population comprised of 18,770 and 61,849 rural population, suggesting that the municipality is still largely rural and dominated by rural livelihood activities. It has 19,262 households with an average household size of 4.0 (GSS, 2021). The foregoing suggests that the growing population will, in the future, put pressure on land for agricultural and other land use purposes in the municipality.

The topography of the municipal is gentle undulating and bounds with fresh granitic and bromine rocks, which weather to form soils of lesser depths rich in minerals for potential crop farming. The geological formations are predominantly characterised by meta-sediments and meta-volcanic rock formation. The type of soils includes Savannah Ochrosols, Tropical brown earths and terrace or alluvial soils in the district support plant growth. These soils are suitable for the cultivation of various crops such as millet, maize, sorghum, yam, and cash crop like cotton. They give higher yields with the least application of organic manure and chemical fertilizers. With adequate rains and good agronomic practices, these soils have the potentials of improving agriculture production (SEDA DMTDP, 2010).

Sissala East Municipality falls within the Guinea Savannah vegetation belt. This vegetation belt is predominantly made up of grasses and trees such as shea, baobab and dawadawa, which are fire resistant trees. The shea tree provides fruits and nuts which are gathered mostly by women. The nuts are processed into shea butter for home use and sale to supplement the household income. Acacia is another common tree found in the Guinea Savannah vegetation belt. These trees provide wood for domestic uses such as construction of houses, fuel (firewood and charcoal), construction of livestock (cattle and sheep) kraals and fencing of gardens in the communities. The grasses, shrubs and leaves of some trees provide fodder for livestock. This has resulted in high influx of Fulani herdsmen into the municipal (SEDHDR, 2010).

The Sissala East Municipal has a tropical continental climate as experienced in the five regions of northern Ghana. Temperatures are generally high during the year, with mean monthly temperatures ranging between 21ºC and 32ºC. Minimum temperatures of 23ºC are recorded during night and maximum temperatures of 42ºC recorded during the day. This temperature pattern favours plant growth in the municipality. The monthly maximum temperature could reach as high as 40ºC prior to the rainy season in the month of May. Temperatures could fall to as low as 12^{o}C in the month of December, when the vegetation becomes dry due to the harmattan winds from the Sahara (GSS, 2014a).

The municipality experiences a single rainy season (May to September/October). The rainfall pattern is highly unpredictable and erratic. There is late onset of the rains and early or abrupt cessation which occurs after planting and plant maturity respectively (File, 2015). Erratic and low amounts of rain mostly characterise the farming season resulting in a series of dry spells. Rainfall sometimes can also be very intensive and will usually result in flooding of lowland farms. The rainfall pattern in the district depicts a decreasing trend over the years. For instance, the mean annual rainfall in 1999 was 121mm as compared to 104 in 2009. Also, the total number of days of rain in 1999 ranged between 70 to 80 days as compared to 51 days of rain in 2009 (SEDA DMTDP, 2010). This pattern affects the growth of staple crops such as maize, groundnuts, bambara beans, sorghum, millet, guinea corn, beans, yam, potato, cassava, etc. The end of the rainy season is followed by a prolonged dry season characterised by cold and hazy weather conditions from early November to March, known as the harmattan season. It is also followed by an intensely hot weather that ends with the onset of early rainfall in April. Minimum temperatures of 12^0 C could, therefore, be recorded in December and maximum of 42^0 C recorded in March (GSS, 2014a).

4.2.2 Lawra Municipal

The then Lawra District was first created in 1988 under the Legislative Instrument 1434 of 1988, with Lawra as the district capital. Lawra served as one of local administrative seats of the British colonial administration in the then Upper West area. In the year 2012, a new Legislative Instrument (L.I. 2099 of 2012) came into force to establish the Lawra District after a new district (Nandom District) was carved out of it (Lawra District Assembly - LDA, 2015). In 2018, the district was elevated to a municipal status by the Legislative Instrument 2279 of 2017 (LMA, 2021). Lawra remains the municipal capital.

Located in the north-western corner of the Upper West Region, the Lawra Municipality shares boundary to the North with the Nandom Municipal in the Upper West Region, bounded to the

East and South by Jirapa Municipal in the Upper West Region and to the West by the Republic of Burkina Faso. The total area of the municipality is about 527.37 square km, representing 2.8% of the total land area of 18,476 square km of the Upper West Region. The estimated number of communities in the municipality is about 157 communities, with about 80% of the inhabitants living in predominantly rural areas (GSS, 2014b).

The 2010 Population and Housing Census recorded a total population of 100,229 for the then Lawra District which included the current carved out Nandom Municipal (GSS, 2012). Therefore, per the 2010 PHC results, the total population for the then Lawra District stood at 54,889 people with a growth rate of 1.9% (GSS, 2014b). It comprised of 26,346 (48%) males and 28,543 (52%) females, indicating a sex ratio of 1:1.08. The district takes a share of 7.8% of the population of the Upper West Region (GSS, 2013). The municipality also has about 88.2% of the population living in rural localities against 11.8% in relatively urban areas (GSS, 2014b). In 2015, the projected population stood at 60,357, comprising of 28,971 males and 31,386 females. The size of the population puts pressure on existing social and economic services, as well as the natural environment (including land for agricultural production). Rainfed agriculture is the main source of livelihood for majority of the people (LDA, 2015).

However, the 2021 PHC recorded data puts the total population of the Lawra Municipality at 58,433, comprising of 28,325 males and 30,108 females (GSS, 2021). This translates in an increase of 3,544 people from the 2010 PHC results, representing an increase of 6.5%. This resulted in an increase in male population by 1,979 and female population by 1,565, representing an increase of 7.5% and 5.5% respectively. An analysis of the 2021 PHC data and the 2015 population projection by the Lawra District Assembly shows that there has been a short fall of a population of 1,924 from the projection made in 2015 against the 2021 figure. This represents a decrease of 3.2%. This also translated in a decrease in the projected male population by 646 and female population by 1,278, representing a decrease of 2.2% and 4.1% respectively.

The municipality is gently rolling with some hills ranging between 180 and 300m above sea level. It is mainly drained to the west by the Black Volta River, which also serves as a boundary between the municipality and the Republic of Burkina Faso (GSS, 2014b). The municipality has Birimian rock formation with dotted outcrops of granite. Even though there are minor traces of some mineral deposits such as gold, manganese, diamond, iron ore and clay in the municipality, these mineral potentials have not been explored. The soils consist mainly of laterite soils, developed from the Birimian and granite weathered rocks. Some strips of alluvial and sandy loamy soils are also found along the banks of the Black Volta River and its tributaries. The nature of soils combined with current pattern of rainfall and traditional land use practices adversely affect crop production and food security in the municipality (Lawra District Human Development Report - LDHDR, 2011).

The municipality has tropical continental climate with mean annual temperatures ranging between 27°C to 36°C (GSS, 2014b). The hottest period is experienced between February and April. The municipality has single rainfall pattern, and it is experienced between April and October during the year. The rainfall pattern is erratic and highly unpredictable. As a result, many young people in the district tend to migrate to the southern part of the country for menial jobs (GSS, 2013).

The municipality lies within the Guinea Savannah vegetation belt and has predominantly short grasses and few woody plants. Trees such as baobab, dawadawa, shea trees and acacia which are predominantly drought and fire resistant are found in the municipality. The vegetation presents a favourable environment for livestock production, which is important for enhancing household incomes. The prolonged dry season is often characterised by indiscriminate bush burning that leaves the area patchy and bare. This affects average annual rainfall totals which translate in low agricultural yields among rain-fed crop farmers in the municipality (LDHDR, 2011). The consequence of the low agricultural production is that men who are traditionally considered breadwinners tend to migrate to Southern Ghana in attempt to eke out alternative source of income.

Subsistence agriculture is the predominant occupation, engaging about 83.5% of households in the Lawra Municipality. It is estimated that about 90.3% of households in the rural localities are agricultural households while about 46.9% of households in the urban localities are also into agriculture. Majority (96.4%) of these households are involved in crop farming and livestock rearing (GSS, 2014b). Food crops cultivated include maize, millet, sorghum, cowpea, groundnuts, and soya bean. Livestock such as cattle, sheep, goats, pigs, and poultry are reared, and fishing is also done in the Black Volta River by communities settled along it (LDA, 2015).

The municipality has about 39.5 hectares of protected area with overall perimeter of 5.2 km out of the total of 127 hectares of forest reserves. Human activities, such as felling of trees for fuel wood and charcoal production, bush burning, inappropriate farming practices, and over grazing of livestock, have resulted in environmental degradation. This has affected the vegetative cover and soil fertility (GSS, 2014b).

4.3 Research Methodology

Research methodology is central to the overall success of every research to be conducted. It shows the systematic steps and procedures taken by the researcher to scientifically address the research problem in a study (Kothari, 2004). According to Dawson (2002:15), every methodology has its associated strengths and weaknesses and that "different methodologies become popular at different social, political, historical and cultural times". Therefore, the researcher takes cognisance of these weaknesses and strengths that may come up with respect to the research design adopted for this study by building on the strengths and improving on the weaknesses.

4.3.1 Research Design and Approach

Research design is seen as the "overall strategy that is chosen to integrate the different components of a study in a coherent and logical manner to ensure that the research problem is addressed effectively" (Indu & Vidhukumar, 2019:64). It is described as "a master plan that specifies the methods and procedures for collecting and analysing the needed information"

(Zikmund, Babin, Carr & Griffin, 2009:66). According to Choy (2014), a research design involves decision making in relation to the type of case to study, sample selection, measuring of factors and the techniques to employ for gathering, analysis and interpreting data. Creswell (2014) noted that the overall decision in research design has to do with the selection of the appropriate approach for the study topic by the researcher. This basically also depends on the nature of the problem the research seeks to address, the study audience and personal experiences (Creswell, 2014). Three main approaches namely quantitative, qualitative, and mixed methods approaches are commonly identified by scholars (Rahman & Shiddike, 2020; Sileyew, 2019; Timans, Wouters & Heilbron, 2019; Creswell & Creswell, 2018; Schoonenboom & Johnson, 2017; Almalki, 2016; Creswell, 2014).

This study sought to examine changes, understanding, behaviours, experiences, and practices among different groups of the study population (smallholder farmers) over time in relation to the application of scientific, indigenous, and local knowledge systems for explaining and understanding climate change and for adapting agriculture to climatic impacts. Since there are two seasons in a year in northern Ghana, it was essential for a study like this to collect data and observe farm practices among farmers during the farming season (rainy season) and the off-farm season (dry season) in order to truly ascertain: (1) the trends of the changing weather conditions over the years and how smallholder farmers were assessing climatic risk and agricultural vulnerability through local and indigenous knowledge; (2) the dynamics of interfacing the application of scientific, local and indigenous knowledge and farm practices employed in promoting climate compatible agriculture over the rainy and dry seasons; (3) the awareness and knowledge of farmers about climate compatible farming practices and; (4) what factors influence farmers in adopting various farming practices and technologies through indigenous and local knowledge.

To achieve this, the study therefore adopted the mixed methods approach to have a combination of quantitative and qualitative research approaches in detailing the description of the methods of data collection, analysis, and interpretation (Creswell, 2009). Thus, the mixed methods approach allows for qualitative and quantitative methods to be used during data collection and analysis and allowed for data triangulation. The approach involves the collection of both quantitative and qualitative data in an integrated but distinct manner based on philosophical assumptions and theoretical frameworks (Creswell, 2014). That is, the combination of both quantitative and qualitative approaches in data collection, analysis, interpretation, and reporting gives a comprehensive understanding of the research problem than a single qualitative or quantitative approach (Creswell, 2014; Guest & Fleming, 2014). According to Guest and Fleming (2014), the mixed methods research approach is not new and has, over the years, expanded and become popular among researchers in many other fields both theoretically and in practice. However, Creswell (2014) and Denscombe (2010) are of the view that the mixed methods research approach maybe relatively new among researchers compared to the quantitative approach. According to Creswell (2014), the mixed methods approach gained prominence in the latter half of the 20th Century when the idea of integration of different research designs emerged among researchers. This followed the growing interest in the use of qualitative research approach against quantitative approach, and by the early 1990s, a systematic convergence of qualitative and quantitative databases was sought through the mixed methods approach. Consequently, the mixed methods approach has become increasingly utilised common tool for addressing complex research questions among researchers in various fields of study (Guest & Fleming, 2014). It addresses the biases and weaknesses associated with qualitative and quantitative data through triangulation (Creswell, 2014).

According to Creswell et al. (2011), mixed methods researchers assume the pragmatic perspective of research to bridge the dialectical stance of postpositivist and social constructivist worldviews of quantitative and qualitative researchers, respectively. Thus, the pragmatic perspective of the approach "allows it to bring together methods drawn from 'paradigms' of research conventionally regarded as incompatible" (Denscombe, 2010:139). Therefore, the mixed methods approach offered the researcher the opportunity to draw on diverse perspectives in an integrated manner to establish what worked for the research during the study. This was achieved by focusing the research questions on lived experiences, contextual understandings, multi-level perspectives, and cultural influences; utilising different methods in the collection, analysis, and interpretation of data as well as triangulating to draw on the strengths of each of the methods to compensate the weaknesses of others (Creswell et al., 2011; Denscombe, 2010).

Further, the mixed methods design allowed for detailed examination and understanding of the subject matter of the research which enhanced generalisation of the findings than the use of a single approach (qualitative or quantitative approach) (Roller, 2018; Creswell, 2014). It also allowed for triangulation, thus, the combination of different methods in the study of the same phenomenon (Yeasmin & Rahman, 2012). These authors noted that social realities are inherently complex to be captured in its entirety by a single method or technique of data collection. Triangulation, thus, aims to compensate weaknesses associated with other methods in the research process. The use of triangulation helped the researcher to minimise the limitations and biases by making comparison and complementarities from the perspectives of both qualitative and quantitative approaches (Choy, 2014). To this end, it verified and increased the credibility and validity of the study data and information through the combination of several viewpoints and methods such as different types of sampling and methods of data collection and analysis (Kielmann, Cataldo & Seeley, 2012).

The mixed method has three main procedures namely: sequential, concurrent, and transformative mixed method procedures (Creswell, 2009). The study employed the concurrent mixed method procedure, which involved collecting both qualitative and quantitative data at the same time and integrating the information for the interpretation of the overall results (Creswell, 2009). The quantitative and qualitative aspects as in the mixed methods approach are discussed in the following sub-sections.

The quantitative approach adopts a deductive approach to conducting research, where researchers hold the view that objective reality can be achieved in research (Stockemer, 2019; Almalki, 2016). Thus, the approach allows for statistical and numerical description of phenomena as well as determining and establishing empirical relationships between and among two or more variables (Stockemer, 2019; Tyagi, Varshney & Chandramouli, 2013). This approach therefore helped the researcher to minimise bias, offer alternative explanations, and allowed for the findings of the research to be generalised and replicated (Creswell, 2014). According to Rajasekar et al. (2013), the main distinguishing features of the quantitative research approach include the fact that the approach uses statistics and produces numerical values, presents results in graphs and tables, and it is conclusive rather than exploratory. It is associated mostly with large-scale surveys where statistical data are generated with closed-ended questionnaires and analysed using statistical tools such as SPSS, Microsoft Excel, and other statistical tools (Sileyew, 2019; Dawson, 2002).

To this end, the quantitative aspect of the study came from the administration of a closed-ended questionnaire (structured questionnaire) with predetermined options from which respondents choose from. The questions were structured according to the themes built from the research objectives. The quantitative aspect of the study also has to do with the secondary data from the Ghana Meteorological Agency (GMet) on rainfall and temperature gathered over the period 1960-2018 in the Sissala East and Lawra Municipalities. This aspect was very relevant in making comparison of farmers' perceptions with the recorded data on rainfall and temperature from the GMet. This also helped in establishing the relationships between indigenous and scientific systems for studying climatic changes. It helped the researcher to confirm or otherwise of farmers' perceptions of changes in the two climatic variables (rainfall and temperature) in the study areas. Thus, the quantitative approach aspect of the study complemented the understanding of some aspects of the study that were difficult or impossible to capture qualitatively (Kielmann et al., 2012). It helped to improve upon the design and interpretation of the household survey as well as gave a better understanding and extensive exploration of the subject matter of the study since, to the best of my knowledge, much of the subject matter has not been explored in North-western Ghana (Mohajan, 2018).

The qualitative aspect of the study, on the other hand, explored in-depth attitudes, practices, and experiences through such methods as interviews, focus group discussions and observations. These broadened and/or deepened the understanding of how local practices and experiences came to be relevant in smallholder agriculture, and for promoting agricultural sustainability in northern Ghana over the years (Hancock, Windridge & Ockleford, 2007). This approach draws on diverse strategies of inquiry as well as methods of data collection and analysis (Creswell, 2009) for explaining the value and role of different knowledge systems like scientific, indigenous, and local knowledge within the context of climate change adaptation and mitigation planning and sustainable agriculture in northern Ghana. It, therefore, provided the researcher with an opportunity to explore and better understand the complexity of the subject matter of the study with a focus on why people think, behave and act and/or respond in certain ways at household and community levels in relation to climate change and variability (Mohajan, 2018). Thus, it emphasises on people's perceptions, lived experiences, and activities, rather than numbers, in a manner that simplifies and manages data on a complex phenomenon within its natural context (Ibid.).

The qualitative research approach is basically used for exploratory research that examines the meanings, opinions, behaviour, and motivations that individuals hold about a specific phenomenon (Indu & Vidhukumar, 2019; Stockemer, 2019; Tyagi et al., 2013) and are expressed in the form of stories, words, pictures, audio, and observations (Sarstedt & Mooi, 2019). According to Sarstedt and Mooi (2019:31), qualitative data are very rich because of the "potential to offer detailed insights into respondents' perceptions, attitudes, and intentions". It is however subjective in its data interpretation; hence coding of qualitative research data is suggested for reducing the level of subjectivity (Sarstedt & Mooi, 2019; Tyagi et al., 2013). To this end, the researcher coded all data collected through face-to-face interviews and groups discussions so they can easily to be identified accordingly during data interpretation to reduce the level of risk of subjectivity. Thus, qualitative aspect of the study was appropriate and legitimately preferred approach because it extensively explored the attitudes, behaviour, and experiences of the research participants in relation to the aim of the study to attain in-depth views of research participants using such methods as (in-depth) interviews and focus group discussions (Dawson, 2002; Greene, Caracelli & Graham 1989).

According to Creswell (2014), it is through this approach that the meanings that individuals and groups attach to social and human issues are better explored and understood by researchers. The author further notes that the qualitative research process involves emergence of questions and procedures, collection of data through participatory processes, inductive data analysis where themes are built from particulars to general, and interpretations made by researcher based on the meanings derived from the data collected and analysed (Creswell, 2014). The qualitative approach investigates issues from a specific context to make meanings within the context of experiences and opinions of individual participants (Almalki, 2016). Thus, it generates data within the context of specific problem which basically reflects the experiences of the research participants and how the meanings drawn are shaped by those experiences (Matangira, 2017).

Therefore, the mixed methods approach was operationalised by collecting data through the administration of questionnaire in household survey, face-to-face interviews with key informants, FGDs and field observation of farm practices and other practices. Also, secondary data from the GMet was analysed to support the field data gathered on rainfall and temperature elements in the two study municipalities.

4.3.2 Sampling Design

A sampling design denotes the procedures and techniques for the selection of a study sample. It represents “a definite plan for obtaining a sample from a given population” (Kothari, 2004:55). According to Kothari (2004), a good sampling design is representative, controls and minimises sampling errors, and presents an appreciable level of confidence. According to Denscombe (2010:23), sampling is premised on the basic principle that a researcher can “produce accurate findings without the need to collect data from each and every member of a survey population”. This saves the time and money of the researcher as it reduces the amount of data needed to be collected by the researcher without compromising the accuracy of the research findings.

The study employed both probability and non-probability sampling techniques in the selection of the study participants and hence adopted the multi (stage) sampling technique/approach in the sampling process. Probability sampling uses the principle of random selection, and it is applied in large-scale surveys (Mooi et al., 2018). The techniques employed under probability sampling included simple random, cluster and multi-stage sampling techniques. These techniques were employed in the selection of respondents for the household survey which produced quantitative data for the study. Simple random sampling is a technique where every element or respondent in the population has the same equal and independent chance of being selected for the study (Creswell & Creswell, 2018). There is no personal influence of the researcher in the selection process and hence minimises bias in sample selection (Kumar, 2011). The cluster sampling was applied in selecting samples from large populations (all smallholder farmers in the communities) where it was difficult and relatively expensive for the researcher to individually identify the sampling units (Kumar, 2011). Therefore, the study communities were divided into clusters based on identifiable features and household respondents were selected through the simple random sampling technique.

Non-probability sampling, on the other hand, is applied in situations where selection of participants cannot be done based on chances. It is useful for conducting small-scale surveys and saves cost because the sampling decision is much dependent on the researcher's discretion and interest (Denscombe, 2010). Non-probability sampling procedures are less expensive and are easy to execute compared to probability sampling procedures (Mooi et al., 2018). Samples are, however, not representative as with probability sampling techniques. To this end, the researcher tried as much as possible to minimise any bias by strictly basing the reason for sampling of participants for engagements on depth of understanding, experience, and in-depth knowledge on the subject matter of the study (Kumar, 2011). The purposive sampling technique was employed under this design in selecting the study region, municipalities, and participants for face-to-face interviews and FGDs, which produced the qualitative data for the study. As part of the qualitative data collection process, the study employed purposive sampling technique in selecting participants for both face-to-face interviews and focus group discussions. The purposive sampling technique involves deliberate selection of respondents based on their known attributes. Thus, the respondents are hand-picked by the researcher because of their in-depth knowledge and experience on the subject matter of the study (Denscombe, 2010). It can produce quality and valuable information and insights on the subject matter of the study. Representation can be ensured by selecting from a range of the study population categories such as demographic characteristics. According to Dawson (2002), the purposive sampling technique is ideal for situations where the research seeks to unpack the everyday subjective experiences of the study participants.

The multi-stage sampling technique involves the principle of simple random sampling but involves sampling at various stages where samples are drawn from previous level of selected samples in sequence manner (Denscombe, 2010). The technique is useful when resources of researchers are limited to cover large samples. The multi-stage sampling technique is associated with cluster sampling except that the multi-stage sampling selects a sample from a cluster while cluster involves everybody or everything in the cluster (Ibid.). It involves multiple stages of sampling where the sampling is carried out in stages using smaller sampling units at each stage (Nyasulu, 2014). Therefore, the multi-stage sampling technique was applied in the selection process of the study municipalities, study communities and household heads. Multi-stage sampling was preferred because of its flexibility in the choice of sampling units and methods of selection at different stages as well as cost considerations (Nyasulu, 2014). This technique was also appropriate because the study adopted a mixed method approach for data collection and analysis – a combination of qualitative and quantitative data collection and analysis. Therefore, the technique allowed the researcher to use both probability and non-probability sampling techniques such as simple random and cluster sampling, and purposive sampling, respectively. The simple random sampling technique was used in selecting respondents for the household survey which resulted in quantitative data, while purposive sampling was used in selecting respondents for face-to-face interviews and FGDs which also resulted in qualitative data at different stages in the research process (Opoku, Ahmed & Akotia, 2016). The technique provided an opportunity to select samples at different stages which were more comprehensive and representative of the population, which took into account the primary and secondary sample units of the study population (Pandey & Pandey, 2015). It can, however, be a difficult and complex method of sampling too. Therefore, the researcher was conscious not to consider only the primary units in the stages of sampling which overcome any possible errors and complexities (Ibid.).

4.3.3 Sampling procedure

At the first stage, purposive sampling technique was employed in selecting the Upper West Region out of the then three regions (namely Northern, Upper East and Upper West Regions) of northern Ghana. However, two regions namely North-East and Savannah Regions were carved out of the Northern Region, and thus, has increased the number of regions in northern Ghana to five regions. The selection criteria for the study region were based on the researcher's judgment (Babbie, 2007). The Upper West Region was selected because, even though the region falls within the same agro-ecological zone (Guinea Savanah zone), it has wide variations and differences in local climatic and topographical conditions including agricultural land and activities across the 11 administrative districts and municipalities (Ayanlade et al., 2017). It is also because of resources constraint in covering all the then three and the now five regions of northern Ghana (Elum et al., 2017). The purposive sampling technique was useful because the study sought to construct a historical reality about climatic elements (particularly temperature and rainfall), describe and develop the interface in the application of scientific, local and indigenous knowledge for exploring climate compatible agriculture which, only a little is known (Kumar, 2011) in the Upper West Region of northern Ghana. Therefore, since purposive sampling technique was more suitable and associated with the collection of qualitative data, the researcher validated the responses with quantitative data from the household survey and the meteorological data on rainfall and temperature. This enhanced data triangulation of the findings of the study.

At the second stage, two municipalities (namely Sissala East and Lawra Municipalities) in the Upper West Region were purposively selected for the study. These municipalities are predominantly farming areas but with different characteristics in terms of land, vegetation, soil suitability, farming practices and other features although they all fall under one agro-ecological zone. It was also seen as a good representation of the Upper West Region in that the Sissala East Municipality represented the eastern part of the region while the Lawra Municipality represented the western part of the region. Thirdly, three farming communities were selected from each of the two municipalities using simple random sampling technique. The communities include Dolibizon, Nabugubelle and Walembelle in Sissala East Municipal, and Babile, Kalsagri and Eremon communities in Lawra Municipal.

Fourthly, 305 farming households (152 and 153 farming households from the Sissala East and Lawra Municipalities respectively) were selected through the cluster sampling technique. Thus, the study communities were each put into clusters of five, comprising of compounds as it pertains in northern Ghana. From the five clusters, 10 compounds which comprised of many households, were randomly selected. Then a household was also randomly selected from each of the 10 compounds, and a questionnaire administered to the head of the selected household by a field research assistant. In terms of composition of the selected household heads, 50 household heads were randomly selected from Dolibizon, and 51 respondents each from Nabugubelle and Walembelle communities for Sissala East Municipality. In Lawra Municipal, 51 household respondents were also randomly selected from each community (51 from Babile, 51 from Kalsagri and 51 from Eremon). The unit of analysis was the household (Alam, Alam & Mushtaq, 2017).

There were two (2) field research assistants for each municipality who were trained by the principal investigator. They were very fluent in the respective local languages (Sisaali and Dagaare languages in Sissala East and Lawra municipalities respectively). After the training, they conducted a pilot study using the approved instrument on 30 randomly selected farming household heads at Bamahu community in the Wa Municipality.

The cluster sampling technique was applied at the stages of the selection of study communities and household heads for engagement in the survey. The two municipalities were each divided into three clusters of farming communities and then a simple random sampling was used to select one community from each cluster for the study. Thus, Lawra Municipality was divided into three clusters and the study communities namely Babile, Kalsagri and Eremon were randomly selected from their respective clusters. In Sissala East Municipality, the same approach was used to randomly select Dolibizon, Nabugubelle and Walembelle communities for the study.

Participants for the face-to-face interviews and focus group discussions (FGDs) were purposively selected for the study. In purposive sampling, the selection of respondents is done on the basis of their knowledge and willingness to provide the required information on the subject matter of the study. The selection criteria were, thus, based on the judgment of the researcher about the participants' knowledge, experience, ability and willingness to provide the needed information (Babbie, 2007). Therefore, respondents included key informants such as community elders, chiefs, queen mothers, earth priests (locally called *Jantina/Tindaana*), traditional chief farmers, other opinion leaders including women group leaders, youth leaders, and other relevant stakeholders. Characteristic of dominant qualitative research, the exact number of face-to-face interviews and number of FGDs conducted was determined during the data collection process (Dawson, 2002) once the saturation point was reached. The saturation point is when the interviews and other processes yield no additional insights into the data and research process.

Table 4. 1: Summary of respondents selected

Community	Household respondents (n=305)	Focus group (n=18)	Face-to-face interviews (n=90)
Dolibizon	50	3	15
Nabugubelle	51	3	15
Walembelle	51	3	15
Babile	51	3	15
Kalsagri	51	3	15
Eremon	51	3	15

Source: Author's construct, 2021

4.3.4 Sample size determination

According to Mooi, Sarstedt and Mooi-Reci (2018), accurately selecting a sample size is more important than the size of the sample because relatively small sample sizes could be more precise. The authors further argue that, even though larger samples enhance precision, "the required sample size has very little relation to the population size" (Mooi, Sarstedt & Mooi-Reci, 2018:47). To this end, the sample size for the research was determined from the overall target population of smallholder farmers by using the Yamane (1967) formula as stated below: $n= N/1+N(e)^2$, where, n= sample size, N= population, e= level of precision

The total number of households in the six communities was arrived at through a local census of compounds and households by the researcher using field officers recruited in each community. Two persons were recruited in each community by the researcher and trained on what was expected of them. These persons were natives of the respective communities, and this made the work simple and easy since they were very much familiar with the dynamics of their respective communities in terms of sections, compounds, and households. There was also maximum cooperation from the community members, and they delivered good outcome.

Using the above formula, a sample size of 305 household heads was obtained from a total of 1,291 households from the six study communities in the two municipalities. A sample of 50 household heads were randomly selected from Dolibizon community and 51 household heads each from Nabugubelle, Walembelle, Babile, Kalsagri and Eremon communities. That is, the sample size of 305 was divided by the number of selected communities to obtain the average sample size for each study community. Since Dolibizon was with the least sample size, 50 was maintained and 51 respondents for each of the rest of the five (5) communities.

4.3.5 Sources of data for the study

The study collected data from two sources, namely primary and secondary sources (Mooi, Sarstedt & Mooi-Reci, 2018). Primary data refer to data "collected from first-hand-experience" (Kabir, 2016:204). It is an unpublished data which makes a research work very reliable, credible authentic, objective, and valid (Ibid.). Sources of primary data include surveys, focus group discussions, questionnaires administration, interviews, observations, and experiments (Mooi et al., 2018; Kabir, 2016). Primary data are basically collected for a specific research work through two major means namely by asking (face-to-face interviews, surveys, focus groups) and observation (Mooi et al., 2018). For this study, the primary data were collected principally through questionnaire administration, face-to-face interviews (in-depth/key informants), FGDs and through direct observations in the field.

The secondary source of data came from the Ghana Meteorological Agency (GMet) where recorded data for rainfall and temperature were sourced over 1960-2018. Also, literature from journal articles, seminar/conferences presentation documents, textbooks, websites of institutions and organisations, theses, and dissertations were sourced and reviewed for writing this study. Secondary data on rainfall and temperature recorded over the period 1960-2018 was collected from the GMet for the two municipalities. A request letter was sent to the Director-General at the national Headquarters, Accra, as a procedure. The required information was provided in softcopy form to the researcher. However, there were some incomplete data where recorded data for some months and years were not available. This challenge was made known to the researcher by officials of GMet before the data was given. To this end, the research did data cleaning where all years with no and/or incomplete data were not included in the computation and analysis of the mean annual values on rainfall and temperature.

4.3.6 Main Data Collection Methods

Data collection in every research is important because it provides the primary data which is analysed, interpreted, and reported to address the research objectives. Therefore, the right methods (techniques and instruments) must be employed in data collection process to ensure accuracy, credibility, and integrity of the results of the study because each technique has its strengths and weaknesses in the research (Kabir, 2016). Leading from this, the study employed four main data collection methods namely interviews, FGDs, survey and observation. the data gathering was conducted in two phases; the first phase involved the collection of quantitative data via a household survey using the questionnaire method while the second phase dealt with the collection of qualitative data through face-to-face interviews, FGDs and observation. These data gathering methods are discussed below.

Interviews

The interviews were conducted on the field in forms that suited the kind of data or information being solicited for from respondents (Pavan & Kulkarni, 2014). These interviews mostly involved a face-to-face interaction between the researcher and the interviewee (s). Face-to-face interviews with key informants formed the basis of the data collection since they allowed the researcher to delve into details by probing further on certain issues during interactions on issues of climate change and climate compatible agriculture in relation to interfacing scientific and local knowledge system by smallholder farmers in North-western Ghana (Walliman, 2011). Thus, the face-to-face interviews provided the researcher the opportunity to ask and probe for detailed and rich data as well as explored complex and unknown issues from the respondents (Kabir, 2016). This process also allowed the participants to express their views freely about what they thought and knew about the subject matter of the study. According to Collumbien, Busza, Cleland and Campbell (2012:54), “key informants are people in the community who are knowledgeable about the topic of interest and/or about local cultural beliefs”.

Therefore, the key informants for the study were participants with significant years of farming experience, understanding, knowledge of the issues as well as were willing to be engaged in the study. The key informants included community elders including retired farmers, chiefs, queen mothers (known locally as *Hakuoru* and *Pognaa* in Dagaare and Sisaali respectively), earth priests (locally called *Jantina/Tindaana*), traditional chief farmers, other opinion leaders including women group leaders, youth leaders, and officers from the municipal assemblies (municipal planning officer, municipal budget officers, Municipal Director of Agriculture, and extension officers). The interviews took the form of conversations between the researcher and the key informants and established a form of rapport that allowed the interviewees to express their views freely on the subject matter (Collumbien, Busza, Cleland & Campbell, 2012). During the interviews, the researcher had less control but only guided the discourse of the conversations to cover all the topics of interest in the study and probed into new issues that emerged during the interviews (Kennedy & Montgomery, 2018).

These face-to-face interviews were conducted using interview schedule/guide (Ifeanyi-Obi, Togun, Lamboll, Adesope & Arokoyu, 2017). The principal investigator (the PhD candidate) conducted and moderated all face-to-face interviews with some support from research assistants. This is because face-to-face interviews require an in-depth understanding of the objectives and purpose of the study in order to ask questions that will give the researcher accurate and reliable data (Collumbien et al., 2012). As suggested by Magna, Ofori and Ojo (2018), the researcher engaged two trained research assistants in the translation of the conversations in Babile, Kalsagri and Eremon communities in the Lawra Municipality because the principal investigator was not fluent in the Dagaare language. They also made notes where appropriate to augment the notes and recordings made by the principal researcher. Before engagements, the researcher asked for the consent of interviewees before audio and video recordings were done as well as photos were taken on the field. These face-to-face interviews were, however, time-consuming, as interview sessions lasted for 45 minutes and, in some instances, lasted for one hour. To this end, the researcher only asked questions and made further enquiries on issues relevant to the subject matter of the study. Also, the conversations with informants were guided by the researcher using interviews guides to avoid participants from digressing into irrelevant matters (Mohajan, 2018). Three different interviews were used for three set of key informants, the study communities, department of agriculture, and municipal assembly officers (budget and planning officers).

Household survey

A household survey was conducted using a structured questionnaire to obtain primary data from various household heads that were sampled for the study. According to Panneerselvam (2011:23), "a questionnaire consists of a set of well-formulated questions to probe and obtain responses from respondents". Questionnaires are instruments that consist of a set of questions mostly designed for gathering and analysing statistical data from respondents (Kabir, 2016). The use of questionnaire was appropriate because the study covered a considerable large number of households (305 households in total) in the study sites (Pavan & Kulkarni, 2014). This study, therefore, adopted a structured (closed-ended) form of a questionnaire for conducting the household survey, where respondents were required to select their responses from alternatives provided. The use of the structured questionnaires generated statistical data, and consequently evoked statistical analyses (Walliman, 2011; Dawson, 2002). The structured questions provided greater uniformity and were also easy to process using statistical tools (Babbie, 2007). As noted by Panneerselvam (2011), these questionnaires took two major formats, that is, there were questions with multiple responses, and there were questions with a rating scale with discrete responses or continuous range for respondents to select their responses from. With the multiple response options, respondents were required to select by ticking two or more of the responses provided in the questionnaire while the Likert scale mostly provided opposing responses of strongly disagree and strongly agree, very high to very low and other Likert scale responses. Questions were kept short, clear, and unambiguous for easy understanding by respondents (Babbie, 2007).

The researcher recruited and trained four research assistants (two from each municipality) who assisted in the administration of the questionnaires to respondents. This was because most smallholder farmers in the study communities have no and/or low level of formal education and could not be able to complete the questionnaires by themselves (Derbile et al., 2019; Agula et al., 2018; Dumenu & Obeng, 2016). The training translated in reduction in the level of bias that would have been associated with the instrument (Peersman, 2014). Research assistants had a minimum of first-degree qualifications with knowledge and experience in research work. Each of the research assistants had previously participated in at least two data collection exercises using a questionnaire. The questionnaire was pre-tested in a pilot survey to identify some shortcomings relating to sampling; questions asked, etc. for redress (Igwenagu, 2016). Consequently, the questionnaire was improved upon after pretesting it which enhanced adaptation to the local context of the study areas and the respondents (Peersman, 2014).

Focus Group Discussions

Focus group discussions (FGDs) were held separately with different respondents using checklists. FGDs are flexible and responsive and therefore provide an opportunity for the researcher to probe and question participants in detail on issues that will emerge from face-to-face interviews (Arthur & Nazroo, 2003). An FGD is described as "an in-depth field method that brings together a small homogeneous group (usually six to twelve persons) to discuss topics on a study agenda" (Kabir, 2016:221). The purpose of FGDs goes beyond 'questions and answers' interactions to include obtaining an "in-depth information on concepts, perceptions, and ideas of the group" (Ibid:222). According to Asamoah (2012:157), FGD "is a group of interacting individuals having some common interest or characteristics brought together by a moderator who uses the group and its interaction as a way to gain information on a specific issue". The researcher as a moderator "introduces the topic, asks specific questions, controls digressions and stops break-away conversations" (Dawson, 2002:30). FGDs involve collecting data through the process of group interactions and discussions where members of the group share common interest, characteristics, experience, views, and knowledge on a topic that reflect their socio-cultural norms (Kielmann et al., 2012).

To this end, FDGs were relevant for this study because the subject matter of the study was relatively new (in the Upper West Region), and the research also adopted a mixed method approach to explore a variety of the opinions, feelings, and perceptions of participants where a wide range of local terms and expressions were also used by participants to aid explanation and understanding of the subject matter of the study. They provided the researcher with an opportunity to learn more through self-disclosure by participants about the attitudes, practices, experiences, and opinions of the groups of people as well as how they thought and felt about the subject matter under discussion (Kennedy & Montgomery, 2018). The FGDs were conducted separately with different smallholder farmers with similar socio-economic characteristics such as land ownership, type of farming, farming practices, farm sizes, types of crops cultivated and livestock reared, understanding and application of LIK in their respective communities and household levels in response to changing weather elements. This provided further information and clarity on the farming practices by smallholder farmers, awareness, and adoption decisions of climate compatible agriculture practices, how LIK was applied in response to climatic shocks at household and community levels, the dynamics, and trade-offs in the application of LIK as well as interfacing scientific and LIK systems as applied to agriculture.

The researcher facilitated the discussions to avoid unnecessary digressions and 'one-man show' of discussions (Dawson, 2002). Membership of the groups ranged between 6 and 10 participants to allow effective discussions (Kabir, 2016; Bhattacherjee, 2012) and sessions lasted between 45 minutes as least and 90 minutes maximum. Mostly, participants for FGDs were selected based on basis of traits such as age, sex, occupation, socio-economic status, and other characteristics to stimulate free expressions and contributions by members without fear of being judged differently by their colleagues. Therefore, participants were purposefully selected based on their socio-economic characteristics such as gender, age, education, economic as well as their knowledge, awareness and experiences on climate change, responses to climate change, agricultural practices, and technologies (Magna et al., 2018). Tape (audio and video) recordings were made by seeking permission from discussants. Discussions were done in the local languages (*Sisaali and Dagaare*). The field research assistants were used for translation in Dagaare spoken communities.

The researcher conducted three discussions in each community among three categories of people namely, men, women, and youth. Discussions were done separately to allow for detail and free expression of views by participants since women and youth in northern Ghana mostly do not actively dominate discussions in the mist of elderly men in the community. The challenge with the FGDs was that it was difficult for ensuring anonymity and confidentiality among participants as acknowledged by Kabir (2016). Therefore, the researcher usually informed the participants about the lack of anonymity and confidentiality and thus, encouraged all participants to as much as possible keep contributions made by individuals confidential. The researcher did not record any names of participants as a way of enhancing anonymity and confidentiality (Peersman, 2014).

Field Observation

The researcher also observed the farming practices and technologies adopted by farmers and how they were applied on their farms (Muyambo, Bahta & Jordaan, 2017). According to Collumbien et al. (2012:61), “observation involves systematically watching people and events to find out about behaviour and interaction in natural environments”. Direct observation involves observing the phenomenon in its natural setting on the field and recording it for analysis and interpretation (Kabir, 2016). It is systematic, well planned, and selective in what is being observed. With direct observation, the researcher personally studies events and behaviours of what is being observed directly without necessarily engaging an intermediary (Kumar, 2011). Kennedy and Montgomery (2018) suggested that emphasis should be placed on the role of the researcher during observation because the researcher is inextricably connected with the data, he/she collects (Kennedy & Montgomery, 2018). An observation schedule was used, and the issues observed by the researcher were mostly check listed in a field notebook.

This method was very useful as it provided the researcher with insights for understanding "what people are doing rather than why they are doing it" (Mooi et al. (2018:62). It helped to understand some situations which could not be expressed in words by participants during the study. Such observations were recorded in the form pictures. It provided a significant level of precision and reliability of information that was free from researcher bias since the phenomena observed could not be influenced in any way by the researcher.

4.3.7 Data Analysis and Presentation

Data analysis "entails coding the data, creating thematic categories, dimensionalising the thematic categories into variables, conducting statistical analysis, and creating a storyline by recontextualising the results" (Guetterman, Molina-Azorin & Fetters, 2020:432). The data collected from focus group discussions and face-to-face interviews were edited and analysed after every session to identify emerging issues that could be built upon in the next discussion sessions (Asamoah, 2012). Conversations during face-to-face interviews and FGDs were audio recorded and some major issues written in field notebook of the researcher. The data collected was edited both at the field and at home. The researcher edited the raw data on the field after every interview and group discussions sessions to "identify technical omissions, check legibility, and clarify responses that are logically and conceptually inconsistent" with what the subject matter of the study seeks (Kabir, 2016:278). The issues identified and the emerging issues were addressed and improved upon in the next interview and discussions sessions. Data collected were also edited by the researcher at the night of the same day to ensure consistency, uniformity, accuracy, and completeness. It also afforded the researcher the ability to identify emerging issues and uncovered areas that were to be interrogated and explored in the following days' interviews. The audio recordings were transcribed and used for the presentation and discussions of results and findings.

Analysis and presentation of results was done through detail descriptions, transcriptions, direct quoting and paraphrasing of information given by the respondents (Rakotobe et al., 2017). The results of the study were analysed using content analysis and presented under themes and sub-themes built from the research objectives (Tirivangasi, 2018). This helped the researcher to identify, analyse and present under themes, among other things, the trends, and patterns of the use of LIK practices and technologies in adapting to climate change, the factors influencing farmers' decisions to adopt climate compatible practices, and the level of awareness of climate compatible practices in the study communities (Mugambiwa, 2018).

The quantitative data collected from the household survey were entered into SPSS (version 20) at the end of each day that questionnaires were administered. This was done after every day's engagements to avoid a carry forward entries and mixture of information which could affect accuracy of the data collected about the household head respondents. This enhanced categorisation and entry into the SPSS software. Descriptive analyses were conducted where raw data were converted into figures and tables for easy understanding and interpretation (Kabir, 2016). This, according to Babbie (2007), helps researchers to summarise the primary data by reducing the amount of data collected into manageable forms to establish a measure of association between and/or among variables. The descriptive statistical analysis helped in describing the characteristics of the data in relation to the research questions and objectives by presenting them in the form of graphs, charts, and tables for easy interpretation. This offered clear and useful information of the set of data gathered on the subject matter of the study.

The SPSS analyses were exported to Microsoft Excel (Microsoft Office 365) to generate the tables, charts, and graphs for this study. This was because the Microsoft office generated tables and graphs were easy to be edited and were also more appealing to the researcher. The results were linked to and discussed under the themes built from the qualitative data within the context of the study objectives (Daniel, 2018).

The secondary data obtained from the Ghana Meteorological Agency on rainfall and temperature recorded from the period 1960-2018 was analysed trend and time series analyses conducted against local perceptions. The data on both temperature and rainfall were not complete as data for some months and years were missing. Therefore, the data were cleaned by the researcher where all the years with incomplete monthly data for the two climatic variables were taken off and were excluded from the analysis. One sample t-test was conducted to determine if the mean annual rainfall from 1960 to 2014 were significantly different. The normality of the data was verified based on K-S and Shapiro-Wilk normality test.

To ensure the validity and reliability of the quantitative aspect of the study, the researcher took into consideration the following:

1. The issues of internal and external validity of the research design: With the use of the mixed research approach, issues of internal and external validity were addressed through triangulation. Creswell (2009) noted that the mixed method approach has three major procedures namely: sequential, concurrent, and transformative mixed method procedures. The study employed the concurrent mixed method procedure, where the researcher collected both qualitative and quantitative data over the same period and integrated the information for the interpretation of the overall results. With the concurrent mixed method procedure, the researcher adopted the concurrent triangulation strategy where both quantitative and qualitative data were concurrently collected in two phases – quantitative data was collected through a household survey in the first phase and the qualitative data in the second phase. The results were compared to determine if there were differences, convergence, or a combination of both (Creswell, 2009). According to Terrell (2012), the concurrent triangulation of the data and results of both the quantitative and qualitative data ensures confirmation (or disconfirmation), corroboration and cross-validation in a single study. Therefore, the researcher compared the quantitative data with the qualitative data to support or disconfirm the results to ensure accuracy and validity of data of the overall results of the study.
2. The issues of validity and reliability of the data gathering instruments (questionnaire and interview guides): The use of concurrent mixed method procedures and the concurrent triangulation strategy allowed for comparison of both the quantitative and qualitative instruments prepared by the researcher before data collection. Thus, the questionnaire for the survey was compared with the guides for face-to-face interviews and FGDs to ensure consistency (reliability) and accuracy (validity) in addressing the objectives of the study (Creswell, 2014). Besides, the instrument was pre-tested through a pilot study in the Bamahu community in the Wa Municipality to ensure that the questionnaire was

consistent with the information it sought to gather (reliability) as well as focusing on exactly what it sets out to achieve according to the objectives of the study (validity) (Asamoah, 2012). Also, the data collected from both sides were compared by the researcher and integrated for presentation and discussions of the findings.

4.4 Pilot study

A pilot study was conducted to test the instruments for the data collection to ensure the effectiveness and efficacy of the tools as indicated by Kaur, Figueiredo, Bouchard, Moriello1, and Mayo (2017). According to Dźwigoł (2020), pilot studies form an important the research process because pilot studies direct the research process in a manner that positively impact on the research outcome. Pilot studies mostly seek to verify the research problem, the research methods and tools including the procedures for sample selection and questioning of respondents.

The questionnaire for the survey was therefore piloted among 30 randomly selected farming household heads in Bamahu community in the Wa Municipality. This provided an opportunity for the research to assess the effectiveness and usefulness of the instruments in terms of the coherence of the questions, the interpretation of some terms such as climate change, scientific knowledge and practices, indigenous knowledge and practices, climate compatible agricultural practices and other similar terminologies relating to the topic under study. Thus, the pilot study provided the researchers with preliminary knowledge about the research problem to be investigated (Mutz & Müller, 2016). The piloting also offered opportunity for the researcher to know the amount of time needed to complete a questionnaire with a respondent. After the pilot, the researcher reviewed some aspects of the questionnaire instrument by editing out some portions which were repetitive and others that were not directly relevant to any of the objectives.

The interview and focus group discussion guides were also pretested to assess their effectiveness in providing the necessary information that they were prepared to achieve. After the pre-test, the interview guide was maintained while the guide for the focus group discussion was edited. Some topics were identified to be repetitive and were edited out by the researcher including other aspects that were not very direct to the study.

4.5 Trustworthy and Authenticity of the Qualitative aspect of the Study

Trustworthiness and authenticity, according to Creswell and Miller (2000) looks at the validity or how accurate research findings are to the researcher, the participants, and the readers of the research. To ensure trustworthiness and/or authenticity of the qualitative aspect of the study, the researcher took into consideration the following measures:

The researcher examined participants' experiences as well as the socio-political implications of the research on the people in the study communities and municipalities (James, 2008) by exhibiting a high level of fairness (Guba & Lincoln, 2005) among participants. The researcher also avoided marginalisation and being bias towards participants by providing equal access to participants to the research process where the views, concerns, and perspectives of participants were fairly captured and represented (James, 2008).

On the other hand, the researcher considered the credibility, transferability, dependability, and conformability of the research findings to ensure trustworthiness of the qualitative research (Given & Saumure, 2008).

1. Credibility: The researcher used direct quotes of participants to support statements made in the analysis and presentation of results of the study. The researcher used multiple data-gathering and analysis techniques and triangulated the data from different sources for integration. The researcher always cross check the data to ensure accuracy and consistency of results during the data analysis process (Creswell, 2009).
2. Transferability: For the qualitative findings of the study to be generalised or transferable, the researcher provided full and purposeful account of the context, participants, and research design to readers, thus, through thick description. The researcher also employed purposeful sampling in the selection of participants for face-to-face interviews and FGDs. The selected participants were key and experienced members of their respective communities, and hence linked participants to the context of the study. In addition, the

researcher provided full understanding of the study within the context of the research questions and objectives to the overall purpose of the study (Jensen, 2008a). Interview and focus group discussion schedules were used to guide interactions for accuracy and consistency which enhanced transferability.

3. Dependability: To ensure dependability, the researcher clearly outlined the methodology of the study in simple terms which allowed for easy replication of the results. The results of the study were linked to the data gathered to ensure consistency of the findings as the accurate expression of the meanings intended by the participants (Jensen, 2008b).
4. Confirmability: This was achieved by verifying two basic goals of (1) understanding the phenomenon of climate change, and local and indigenous knowledge application from the perspective of the research participants and (2) understanding the meanings people give to their experiences (Jensen, 2008c:112). The researcher interpreted the narrations (data) from participants and presented the findings that mirrored the perceptions and expressions of participants and not that of the researcher.

4.6 Limitations/challenges of the study

During the study, the researcher encountered some challenges which included delayed responses from gatekeepers, limited resources including finance, means of transport, etc., the coronavirus (COVID-19) pandemic, and others. These are discussed below.

There were delayed responses/replies from some gatekeepers during the ethical clearance application process. The researcher had to make several follow-ups to those institutions, particularly the municipal assemblies before they could their consent forms. The Sissala East Municipal consent form took many months to be completed after several follow-ups, which came with high cost of transportation and risk of traveling on long and bad road from the regional capital, Wa, where the researcher resides.

Also, the training of field research assistants for the study came with a cost to the researcher, considering the fact that the research was self-financing his studies. Research assistant lived in different places and so the researcher brought all of them together for the training which lasted for almost one week. So, the feeding, accommodation and transport costs were borne by the researcher. It is however important to mention that the bursaries awarded the researcher under the UNISA Master and Doctoral Bursary in 2019 and 2020 were very helpful in this direction.

The COVID-19 pandemic was the greatest of all the challenges as it significantly affected the data collection process by causing a long suspension of all field activities when it was recorded in Ghana. The pandemic resulted in partial lockdown of some parts of the country and a nationwide travel restriction imposed by the Government of Ghana. The data collection that was billed to start in March 2020 eventually started in July 2020 and went into 2021. Data collection during the era of the novel COVID-19 came with extra and unplanned cost to the researcher in that the researcher had to procure personal protective equipment (PPE), as well as train field research assistants on the COVID-19 safety protocols. Some of the PPEs purchased for use on the field included hand sanitizers, face masks and liquid soap for handwashing. The wearing of face masks, use of hand sanitizers, frequent handwashing, social distancing, and other safety protocols were strictly adhered to by both researchers and the participants. The research team carried extra sanitizers and nose masks and where a participant did not have a nose mask, he/she was given one to wear before engagements. Engagements were done by observing social/physical distancing and avoiding personal contacts. There was regular use of hand sanitizers and handwashing as communities had handwashing facilities provided them by some stakeholder such as Members of Parliament, NGOs, Municipal Assemblies, and other stakeholders.

Another challenge during the study was the timing of the data collection. The months of July, August and September represent the peak of the rainy season in northern Ghana and hence there were sometimes that rains disrupted engagements. Field researchers were sometimes beaten by rains either on their way to or from the communities. The face-to-face interviews and FGDs were conducted during the period that farmers were also busy with harvesting and related activities to avoid destruction by bushfires. Consequently, the researcher had agreement and schedule for meetings with key informants and FGD participants was drawn. Some special days and times such as Fridays, Sundays, and market days of the respective communities were agreed on as meeting days. These days where participants which were mostly smallholder farmers could be available for a considerable time of the day after their respective prayers. Communities in Sissala East where the people were predominantly Muslims were met on Fridays and Sundays for communities in Lawra. These were days they offer prayers. Market days were also ideal for the engagements particularly participants for the FGDs. On market days, discussions were held in the mornings between 7.30am and 10am to enable participants go for their market activities. Face-to-face interviews were also scheduled and conducted among key informants and groups mostly at different times morning, afternoon, and evening) in different communities. These arrangements were done in consultation with the participants. Although, this arrangement enhanced smooth engagements in all the communities, it thus slowed the pace for the data collection.

The last but the least challenge was the cost of transportation for the researcher. The data collection involved frequent movement over long distances, with risks and threats of road accidents, cost of maintenance and fuelling of the means of transport (car and motor bikes). These brought financial burden to the researcher since the study was self-financing.

4.7 Ethical Considerations

According to Kielmann et al. (2012), the primary data collection process in the field raises ethical issues of concern that should be key to the researcher. Therefore, the researcher was highly conscious of the ethical issues that abound mixed method approach to data collection for the study (Creswell, Klassen, Clark & Smith, 2011). That is, the researcher was conscious of the “implications of manipulating conditions experienced by participants” associated with the quantitative aspect of the study, on one hand, and the “implications of gathering personal information through audio-recordings that could identify a participant” in the qualitative research procedures on the other hand (Ibid.:23).

The National Committee for Research Ethics in the Social Sciences and Humanities (NESH, 2006:5) defines the concept of research ethics as "a complex set of values, standards and institutional schemes that help constitute and regulate scientific activity". It noted that research is often intertwined with other activities including academic activities that scholars engage in, which may result in scientific publications, graduates' contributions to the formation of public opinion, improvements for users and well-functioning institutions such as universities and research institutes. Hence, it is critical to focus on the interface between studies, communication, specialist activities and the management of institutions during the research process (Ibid.).

In this study, the researcher was cognisant of and adhered to such ethical principles as informed consent, anonymity, confidentiality, respect for participants, trustworthy and honesty throughout the research process (Bhattacherjee, 2012). Informed consent means that, the researcher sought the permission of the potential respondents in order for them to participate in the research process by explaining to their understanding, the purpose and procedures of the study. The activities and the kind of information being sought for, as well as potential risks, and benefits involved in the study were also explained to participants' understanding as suggested by Terrell (2012).

Participants were made to understand that their decision to participate in the research was purely voluntary and as such, they were free to either accept to participate or decline to participate. They were also free to withdraw their participation at any time during the research process. A consent form was prepared, indicating participant's choice to participate, not to participate and right to withdraw in the process of engagement which were given to every participant who agreed to participate in the study to sign and/or thumbprint (Kielmann et al., 2012).

The researcher also ensured the anonymity of participants at all stages, particularly during the data collection and analysis stage of the research. Thus, the identities of participants were not disclosed against any findings of the study nor disclosed to any individual or group. In addition to anonymity, the researcher also assured participants of confidentiality of any information that they provided. As a result, field notebooks, video, and audio recordings, completed questionnaires and field photos have been kept in secured places and are accessible only to the researcher (Bhattacherjee, 2012). Participants were made to understand that the data gathered were only to be used for academic purposes. The researcher usually showed the ethical clearance letter obtained from the University of South Africa (UNISA) to participants prior to engagements. The researcher respected the privacy of participants and as such, avoided actions that could intrude into the privacy of participants and/or cause embarrassment to any participant. The socio-cultural values, beliefs, and norms of participants in their respective communities and private lives were respected by the researcher and his team (research assistants).

The researcher also respected the contributions and views of all participants in the data collection and reporting processes without any bias. Accuracy of participants' contributions and opinions were ensured in order to establish trust with participants. The researcher further demonstrated a great level of honesty with participants by avoiding the tendency of manipulating data and information collected from participants (Kielmann et al., 2012).

Also, all secondary information sourced and used in this study were duly cited and acknowledged by the researcher in the thesis. The researcher is responsible for any shortfall in this study. In line with UNISA Research Ethics Policy, the research proposal leading to this thesis was submitted, through the researcher's Supervisor, to the appropriate Ethics Committee of the University for consideration for the issuance of ethical clearance before the commencement of data collection (Chapter 7 of UNISA Procedures for Masters and Doctoral Degrees).

4.8 General introduction on demographic characteristics of respondents

This section presents the demographic characteristics of the study respondents who were smallholder farmers from six communities across Sissala East and Lawra Municipalities.

The study results show that an overwhelming majority of 94% of the participants were basically engaged in farming as their main livelihood activity while six percent indicated farming was not their main occupation, as seen in Table 4.2. The results also show that the respondents were farming household heads who were within various age groups, with most of them found within the 50-59, representing 46% and followed by 60-69 age groups which constituted 25%. According to the results, the majority of the respondents (75%) were males while 25% were females as indicated in the table. In terms of the level of education of the respondents, the results show that 46% of the of the respondents did not have any formal education, 20% had primary education, 13% had junior high school education, 11% had senior high school education while seven percent and three percent had vocational education and tertiary education, respectively. Therefore, those who did not have any formal education were the majority.

The results further show that 83% of the household respondents were married, four percent were single, six percent were divorced persons while seven percent of the respondents were widows and widowers. The households with membership of seven and more constituted 40% of the total respondents, representing the majority, as shown in Table 4.2. It was found that the participants were predominantly from Sissala and Dagaaba ethnic groups with some few participants belonging to the Brifoh and Waala ethnic groups in the Lawra Municipality. The results show that all the respondents in Sissala East were Sissala unlike in Lawra Municipality where there was a combination of respondents from different ethnic groups such as Dagaaba, Brifoh and Waala, as shown in the table. This could be attributed to the fact Babile is border town and so has people of ethnic extraction living there.

Table 4. 2: Demographic characteristics of the respondents

VARIABLE		
Age	Frequency	Percent
30-39	10	3
40-49	49	16
50-59	140	46
60-69	76	25
70+	30	10
Total	**305**	**100**
Gender	Frequency	Percent
Male	230	75
Female	75	25
Total	305	100

Level of education		
No formal education	141	46
Primary	61	20
Junior High School	39	13
Vocational School	22	7
Senior High school	34	11
Tertiary	8	3
Total	**305**	**100**
Marital status		
Married	254	83
Single	13	4
Divorced	18	6
Widowed	20	7
Total	**305**	**100**
Ethnicity		
Sissala	152	50
Dagaaba	102	33
Waala	28	9
Brifoh	23	8
Total	**305**	**100**
Household size		
1-2	33	11
3-4	66	22
5-6	84	27
7+	122	40
Total	**305**	**100**
No. of years lived in community		
16-20	11	3.6
21-25	21	6.9
26-30	29	9.5
31-35	53	17.4
36-40	68	22.3
41+	123	40.3
Total	**305**	**100**
Farming as major occupation		
Yes	287	94
No	18	6
Total	**305**	**100**
Farming experience		
11-15	2	1
16-20	16	5
21-25	19	6
26-30	30	10

31-35	43	14
36-40	62	20
41+	133	44
Total	**305**	**100**
Average size of farm (acres)		
1-2	86	28.2
3-4	76	24.9
5-6	52	17.0
7-8	25	8.2
9-10	25	8.2
11+	41	13.4
Total	**305**	**100**
Farmland acquisition		
Family	232	76.1
Gifted	55	18.0
Temporal farmland	18	5.9
Total	**305**	**100**

Source: Field Survey, 2020

As seen in Table 4.2, most of the respondents indicated that they have lived in their respective communities for more than 40 years. Generally, the results show that 89% of the respondents have lived in their communities for more than 30 years which suggests that respondents have better understanding of the changes in climatic patterns in their respective communities.

In terms of years of farming experience, the results show that 78% of the respondents had more than 30 years of farming experience while 22% had between 11 to 30 years of experience. Also, the results show that 53.1% of the respondents had farm sizes of less than five acres, with the rest having five or more acres. This shows that households were predominantly smallholder farmers. Farmlands were mostly acquired through family inheritance where majority (76%) of the respondents indicated that they were cultivating on their family lands while 18% were gifted lands and six percent were cultivating on temporary acquired lands. Sharecropping, renting and bought lands were not means of acquiring farmlands in the study communities.

4.9 Conclusion

The chapter presented the brief profiles of the two study municipalities namely Sissala East and Lawra which showed that the inhabitants of both municipalities were predominantly subsistence farmers. It then presented the methodological framework for the study. It presented the research design and approach of the study, which is the mixed methods where quantitative and qualitative data collection and analysis methods were employed. Data for their study were collected through household survey using a structured questionnaire, interviews and focus group discussions using interview and FGD guides respectively, and field-based observation. The sampling design and techniques were also discussed. Both probability and non-probability techniques were used in the selection of the study areas, participants of the interviews and FGDs, and respondents for the household survey. The chapter also outlined how the study dealt with the ethical issues such as the confidentiality and anonymity of participants in relation to the protocols that were adhered to by the researcher and his team of research assistants in engaging participants. The challenges encountered during the study were also outlined. The COVID-19 pandemic was greatest of all the challenges because it affected every part of the data collection plan and budget. Lastly, the chapter also presented the demographic characteristics of the household survey respondents.

CHAPTER 5: CLIMATE CHANGE TRENDS AND SMALLHOLDER FARMERS' ASSESSMENT OF CLIMATIC RISKS AND AGRICULTURAL VULNERABILITY

5.1 Introduction

This chapter presents and discusses the results on the perceptions of smallholder farmers on the changes in climatic elements of rainfall and temperature in North-western Ghana. It also assesses the risk of climate change and the vulnerability of agricultural systems to the impacts of climate change through the lens of local and indigenous knowledge of smallholder farmers.

5.2 Trends in changes in rainfall and temperature in North-western Ghana

It emerged from face-to-face interviews and focus group discussions that climate change was perceived by smallholder farmers mostly in terms of changes in rainfall and temperature. These changes were usually observed over considerable long periods and within the context of the impacts on agricultural livelihoods, which is the major livelihood activity in addition to other daily activities. It is within this perspective that smallholder farmers make meaning about the causes and response mechanisms over a shorter or longer duration (Mafongoya & Ajayi, 2017; Kupika et al., 2019). The study found that, in addition to rainfall and temperature, farmers observed changes in other weather elements such as sunshine, wind and some non-climatic elements to confirm changes in the climate and environment. These farmers observed the behaviour of certain plants, animals, insects, clouds, stars, and other phenomena around their immediate environments. They were also able to detect changes by comparing the trends of the changes in rainfall and temperature in terms of the onset, time of cessation, intensity, frequency of occurrences, timing of occurrence/onset, duration of occurrence, distribution/coverage, and amount/quantity/magnitude experienced over decades. Similar findings have been reported by other scholars (Kupika et al., 2019; Selato, 2017).

General changes in rainfall and temperature elements were largely acknowledged by the participants of the study. Smallholder farmers associated the occurrences of recurrent floods and droughts (dry spells), extreme temperatures, pests and diseases, and bushfires to climate change. The impacts of these hazards were revealed to be very severe on livelihoods including agricultural production, household food security, health, and the general wellbeing of respondents over the years. These observed changes represented the individual and collective perceptions (understanding and experiences) of smallholder farmers on how rainfall and temperature have transitioned over the decades and how it has imposed significant negative consequences on the people in North-western Ghana as related by Arbuckle et al. (2015). These changes were observed and reported to have been transitioned from generation to generation in a gradually deteriorating manner over the decades (File & Derbile, 2020). The account of farmers on changes in rainfall and temperature suggested that the conditions during the past generation were better than the conditions experienced by the present generation. According to a participant from an interview undertaken in Eremon, *"the changes we experienced today are severer compared to the time of our parents and grandparents. The changes in rainfall and temperature were not so devastating when we were teenagers as today"* (Excerpt from In-depth interview, Eremon, 2021). This suggested that the changes in rainfall and temperatures have drastically become adverse and this has not favoured smallholder agriculture over the years. Moreover, the results of the household survey show that all the respondents (100%, n=305) indicated as having noticed some changes in rainfall and temperature over the past years in their practice as smallholder farmers. This finding corroborates with Dapilah et al. (2019) who reported of smallholder farmers in North-western Ghana as having observed and experienced changes in climatic elements over the past 30 years. Other studies have also suggested that there have been general changes in rainfall and temperature in northern Ghana over the past years (Guodaar, Bardsley and Suh, 2021; Derbile et al., 2019).

Having established that there were changes in the climatic elements over the decades, the study proceeds to present and discuss the perceived changes in rainfall over the years in North-western Ghana.

5.3 Perceptions in changes in the pattern and trend of rainfall in North-western Ghana

Precipitation was generally measured in terms of the amount of rainfall received and the amount of moisture in the soil. Changes in rainfall were measured in terms of changes in the amount of rainfall, frequency of rainfall, intensity of rainfall, duration of rainfall, time of onset of rainfall, time of cessation of rainfall, and coverage and/or distribution of rainfall among geographical areas over the past years. These serve as indicators for determining changes in rainfall and precipitation by smallholder farmers in their local communities using their local knowledge systems. From the respondents of the survey, total rainfall over the years has been variable, demonstrating a significant level of uncertainty and unpredictability. It emerged that rainfall has been erratic and the timing of it was uncertain and unpredictable in recent years than in the past. As shown in Figure 5.1, the results generally reveal that the majority of the respondents perceived a variable and decreasing rainfall pattern over the decades, a situation which makes farmers unable to accurately plan their agricultural activities in contemporary times. Thus, there were significant changes in rainfall over the years as perceived by smallholder farmers. This confirms the findings of Iddi et al. (2018) who indicated that smallholder farmers in northern Ghana are often affected by various dimensions of rainfall variability. Derbile et al. (2016) also described it as an exposure of smallholder farmers in northern Ghana including North-western Ghana to the double tragedy of rainfall variability. Guodaar et al. (2021) also reveal the increasing threats posed by the decreasing trend in rainfall pattern to smallholder agriculture in North-western Ghana. The dimensions of rainfall variability were measured in different forms as indicated earlier to include changes in annual total rainfall, differences in the distribution/coverage of rainfall, changes in the onset and cessation of rainfall as well as the changes in certainty and predictability of rainfall pattern over the years. These are presented in the figure (Figure 5.1) below.

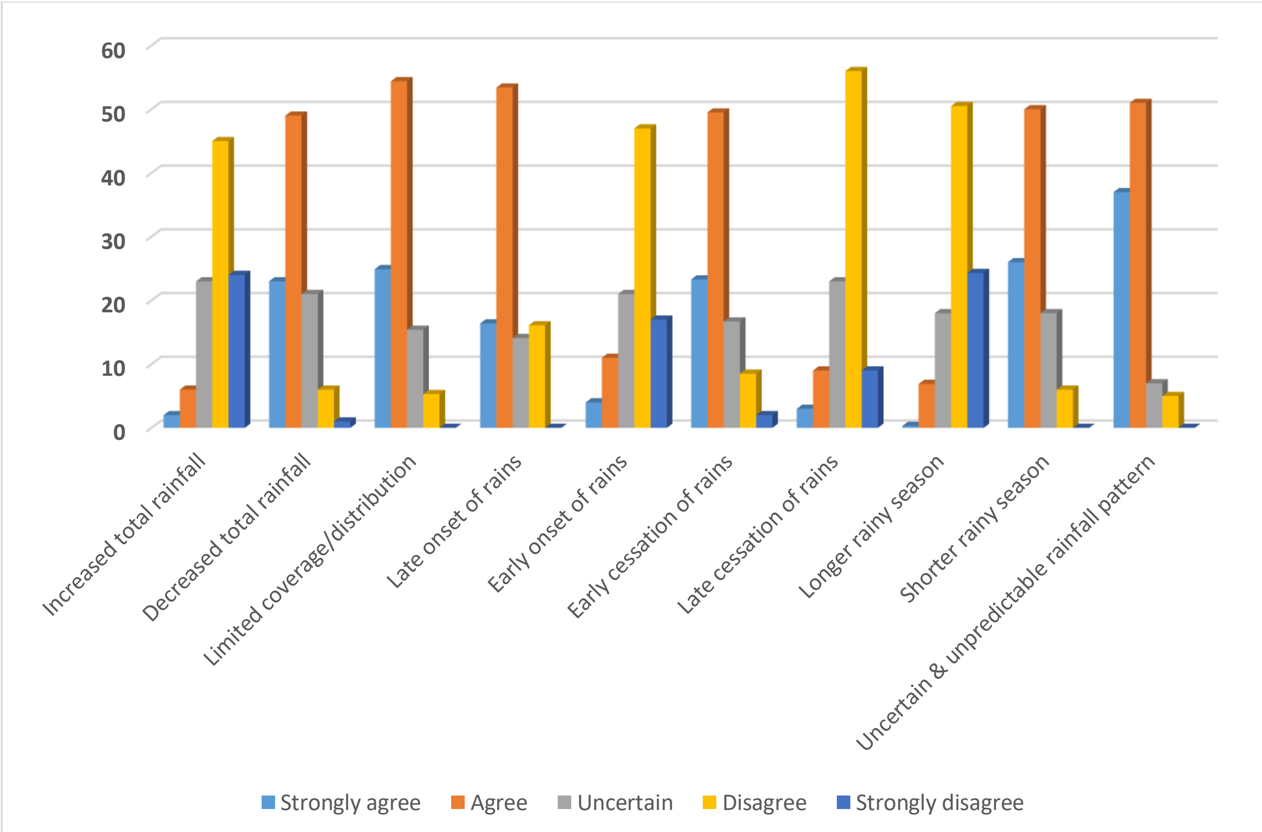


Figure 5. 1: Perceptions on rainfall variability/characteristics (n = 305)

Source: Field survey, 2020

As shown in the figure above, 10 dimensions of rainfall variability were identified, and respondents indicated their levels of agreement or otherwise on each of the dimensions. These are presented and discussed below.

5.3.1 Variability in total rainfall

Over the years, the pattern of rainfall has been variable with some years recording higher annual rainfall while other years also recorded low annual total rainfall. Yearly total amount of rainfall in North-western Ghana has been identified to be declining in a manner that poses significant threats to smallholder farming. To this end, respondents were asked to indicate whether they strongly agree, agree, are uncertain, disagree and strongly disagree with the assertion that annual total rainfall over the years has increased on one hand, or decreased on another hand in North-western Ghana. The responses of the respondents are presented in Figure 5.1. From the figure, the survey shows that 45% of the respondents disagreed with the assertion that total rainfall had increased over the years; 24% strongly disagreed 23% were uncertain while six percent and two percent agreed and strongly agreed respectively. Thus, the findings show that 69% of the respondents disagreed that rainfall had increased over the years, while only about eight percent of the household respondents agreed. On the other hand, 49% of the respondents, thus, agreed that total rainfall had decreased; 23% strongly agreed; 21% were uncertain, while about six percent disagreed, and less than one percent strongly disagreed that total rainfall has decreased over the years. It therefore emerged that the majority (72%) of the respondents were of the view that total rainfall has decreased over the past years. In this regard, the findings generally suggested that there were perceived decreasing trends in annual total rainfall among smallholder farmers over the years. Other scholars have reported of similar findings in North-western Ghana (Napogbong et al., 2021; Dapilah et al., 2019; Derbile et al., 2019; Dakurah, 2018, Abdulai, Ziemah & Akaabre, 2017). Decreasing rainfall pattern poses severe threats to smallholder rain-fed agriculture in North-western Ghana as crop farming is the major livelihood activity of the people and their households. Also, farming is predominantly and solely dependent on the natural rainfall since there was a lack of alternatives such as irrigation facilities for farmers. Few cases of irrigation only related to small facilities and manpower and hand-dug wells where some farmers in some of the study communities engaged in dry season vegetable cultivation to supplement household food supply.

The perception of the respondents in the survey were compared with the meteorological data on recorded rainfall for the Sissala East and Lawra Municipalities from the Ghana Meteorological Agency, to establish the differences and similarities in the perceptions of smallholder farmers in North-western Ghana. The findings show that farmers' perceptions about decreasing rainfall over the years were consistent with the meteorological data as shown in Figure 5.2.

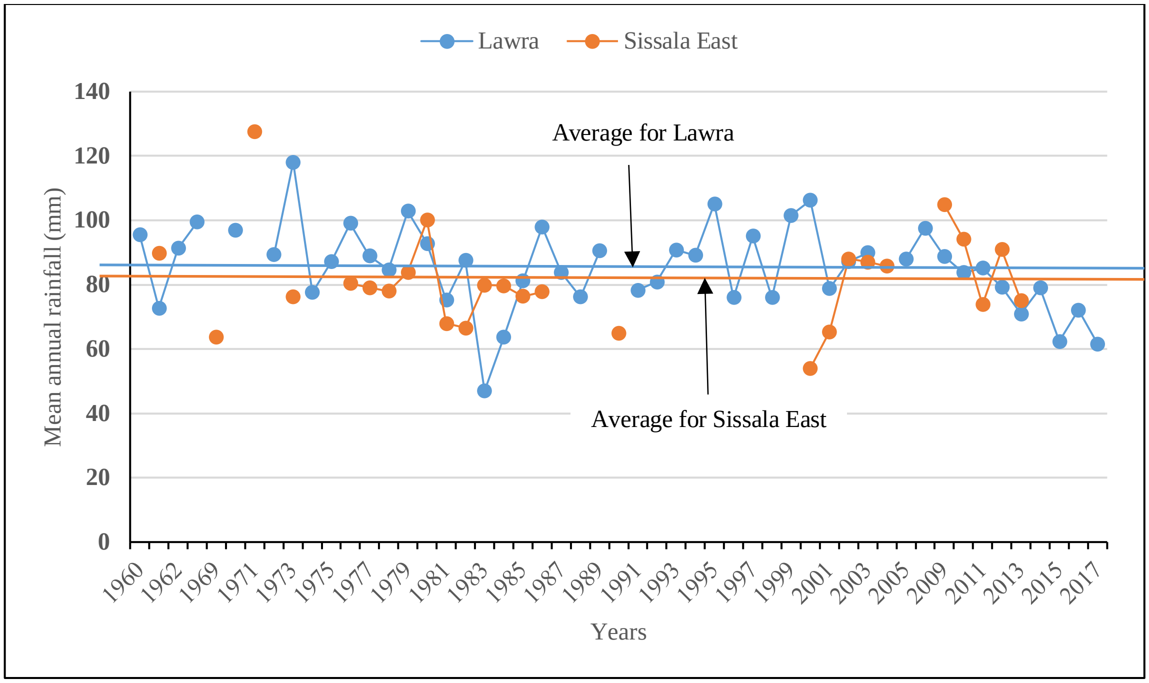


Figure 5. 2: Mean annual rainfall for Sissala East and Lawra Municipalities (1960-2018)

Source: Field Work 2021 (data from Ghana Meteorological Agency, 2020).

From Figure 5.2, it emerges that annual total rainfall over the period of 58 years from 1960-2018 have significant levels of variability in the two study municipalities. The mean average annual rainfall for the Sissala East Municipality was 81mm, while that of the Lawra Municipality was 85mm. These figures show that Lawra Municipality experienced more rainfall than Sissala East. The findings further show that the annual rainfall for most of the years were below the annual average for Sissala East Municipality, having experienced rainfall below the annual average of 81mm for 16 years out of 26 years of data employed for the study. The rainfall pattern for the municipality demonstrated a high significant level of variability; it recorded its highest annual rainfall of 127mm in 1971 and its lowest of 54mm in the year 2000 as depicted in Figure 5.2. Therefore, total annual rainfall has been decreasing at a decreasing rate over the years, which confirms the general perceptions of smallholder farmers in the study communities.

On the other hand, many of the years over the period recorded above the annual average rainfall in the Lawra Municipality. Out of the 47 years of the data used, 22 years recorded below the annual average, indicating that Lawra experienced a better pattern, albeit high variability, than in Sissala East. In 1973, Lawra Municipality recorded its highest annual rainfall of 118mm and its lowest annual rainfall amount of 54mm in 1983.This suggests a decadal change in the annual amount of rainfall in the area. The annual rainfall pattern in Lawra Municipality also demonstrated a significant level of variability where total annual rainfall shows decreases and increases over the years. However, annual rainfall has been decreasing over the years. Total annual rainfall has shown a consistent decrease since 2006, with adverse implications for water availability and soil moisture for smallholder crop farming.

It further emerged from face-to-face interviews and FGDs that total rainfall in North-western Ghana has decreased in terms of amount, intensity, and frequency. A participant, during the FGD in Nabugubelle stated that the amount and intensity of rainfall experienced in the past 30 years were significantly higher than what they were currently experiencing. The participant made these remarks:

> *"There was more rainfall in the past than now; they came so heavy that they could usually cause rivers and streams to overflow their banks. The rains came with very high intensity and were also very regular. We cannot compare the rains in recent years to the past. Rainfall has decreased over the years. They [rains] are not enough for us [farmers] to plan agricultural activities adequately and effectively"* (Excerpt from FGD, Nabugubelle, 2021).

The variability in rainfall has been detrimental to agricultural planning, especially in the case of smallholder farmers who mostly do not have access to formal extension services that guide them on the right time for planting. These farmers who relied on the pattern of rainfall and other observed phenomena to undertake farming activities are mostly left in a dilemma regarding the right time to plant. This has the potential of exacerbating poverty levels among farming households in North-western Ghana since late planting affects the yield levels of many crops. This is particular of concern since the rainy season has become shortened in recent years.

5.3.2 Predictability and certainty of rainfall pattern

The results (Figure 5.1) reveal that there was a level of uncertainty and unpredictability of the rainfall pattern in North-western Ghana. This affects smallholder farmers' decisions on agriculture and related activities. The survey shows that 37% of the respondents strongly agreed that the rainfall pattern was uncertain and unpredictable; 51% agreed, seven percent were uncertain about their decisions while only five percent disagreed that the rainfall pattern was uncertain and unpredictable. Hence, about 88% of the respondents indicated that the rainfall pattern over the decades has been very uncertain and unpredictable for smallholder farming. The high uncertainty and unpredictability of the rainfall pattern generally affect the traditional agriculture calendar of smallholder farmers in northern Ghana (Jarawura, 2021). Mutegi et al. (2018) also revealed that the rainfall pattern in SSA generally exhibits characteristics of high variability and unpredictability, thereby exposing farmers to further threats of extreme events of recurrent floods and droughts over the farming seasons.

5.3.3 Changes in onset and cessation of rainfall

Northern Ghana experiences single maximum rainy season, which in recent years, usually starts from April to September or early October every year with the rest of the year being the dry season. The peak of the season is experienced in the months of August to early September, while the rest of the season is the dry season. In the past, the onset of the rainy season used to start in March and ended in October with the months of July to September being the peak of the rainy season. There has been a general shift in the onset of the rainy season causing the season to be shorter than it used to be. The results show that most of the respondents (70%) agreed that the onset of the rainy season was always late; 14% were uncertain while 16% disagreed that there was late onset of rains over the past years. Similar findings were reported by Akrofi-Atitianti et al. (2018). The delayed commencement of the rainy season has had adverse impact on crop farming particularly indigenous crops that require a relatively longer time to mature. Similarly, the findings reveal that the majority of respondents (73%) also agreed that the rainy season ceases abruptly and/or earlier than anticipated. The rains usually cease prematurely during the season when farm crops have not fully matured leaving room for damages and poor yields of major staple crops such as maize, sorghum, millet, yam, rice, etc. The late onset of the rainy season at beginning of the farming season and early cessation are a contradiction to the farming and rainy seasons in North-western Ghana. This places smallholder farmers in northern Ghana in a double exposure to the late start of the rainy season which translates into late planting and early cessation of the rains thereby causing poor yields of crops over the same season (Derbile et al., 2016; Akudugu et al., 2012).

As indicated, the rainy season in the past used to begin in March and by April, farmers began early planting of some crops such as cowpea, sorghum, and other crops. However, the study reveals that the rainy season mostly begin in mid to late April in recent years and on a low and irregular pattern which may not be sufficient for any significant farm activity. Early planting in most instances has recently tended to be in the month of May instead of April, which is often characterised by irregular and intermittent rains. This mostly results in delays in ploughing of farm fields and in planting characterised by poor germination of crops. A participant in Babile community revealed that

> *"Growing up we knew the month of March was the beginning of the rainy season and April was for the planting. The rains never failed us, and planting was done in almost a uniform manner everywhere, because the rains start in March and by April majority of farmers have planted many of their crops. In the past, the month of May was for planting millet and groundnuts. Millet was mostly planted on cowpea fields after they [cowpea] were harvested. These days, the rains start in late April in an erratic manner, which many farmers are unable to plough their fields early for planting. Therefore, many farmers tend to plough and plant crops in the month of May which extend up to July. Many of these crops planted in late July do not yield well because the rains usually stop in the 9th month [September] when the crops have not yet matured. Here [in Babile], the rains have been on and off on yearly basis. The rains may start early some years, and in some years, they start too late. In this community, some farmers may have their crops germinated while in other places [of the Municipality], farmers may not have completed preparing their lands due to the late onset of rains in those communities"* (Excerpt from In-depth interview, Babile 2020).

There have been drastic changes in the pattern of rainfall, which culminate into changes in the farming calendar for smallholder farmers. This makes smallholder agriculture more vulnerable owing to its dependence on natural rainfall. It is therefore crucial for the government and non-governmental institutions to invest in the provision of irrigation facilities to augment rainfall for farming in North-western Ghana and northern Ghana in general.

Rainfall coverage and/or distribution in North-western Ghana was also reported to be limited and uneven in most places and communities. There was increasing belief that the amount of rainfall experienced differs from community to community, resulting in high differential amount and intensity of rainfall received over communities in North-western Ghana. The survey results indicate that 79.3% of the respondents agreed that rainfall usually reach few geographical locations (communities), and that the distribution was also uneven across communities, with 15.4% of respondents being uncertain while 5.3% disagreed with the assertion that rainfall distribution was uneven with limited coverage. The rainfall pattern over the years has demonstrated significant level of uneven distribution and coverage where many communities may not experience rainfall within the same period. The amounts of rainfall received equally vary from one community to the other which accordingly have varying effects on crop development and yields among smallholder farmers. The rainfall pattern in Lawra Municipality varies from that of Sissala East Municipality which might be attributed to the differences in vegetation and topography. It is important to note that the Lawra Municipality is bounded to the west by the Black Volta River which runs through many communities and might have influence on rainfall. This corroborates the findings of Akudugu et al. (2012) who reported that rainfall distribution and coverage in northern Ghana were limited. Alam et al. (2017) also reported of similar changes in the distribution of rainfall.

In Walembelle community in the Sissala East Municipality, a participant indicated that rainfall coverage and distribution was limited and uneven in recent years than in the past. There were disparities in the rainfall amount and the number of communities covered whenever it rained. This participant related that:

> *"The rainfall these days does not reach all places [neighbourhood communities] unlike when we were children. In many of the years, we usually experience rains earlier than other communities. We sometimes experience rains while Nmanduanu, Bichemboi and other surrounding communities will be dry. Sometimes, it may just drizzle in those communities. So, we usually start planting before our colleagues in the other communities. Some years too other communities will record rains early than us. The rainfall these days does not reach all places [neighbourhood communities] unlike when we were children. There have been many instances where it could rain at home but will not reach our farms, and sometimes too, it may rain on some farms but will not rain at home. So, even if you see the weather threatening to rain, it is not a guarantee that it will reach all communities".* (Excerpt from FGD, Walembelle, 2020).

Consequently, different communities have different planting calendars with those communities which experience early rains planting early, while those which experience late and low rainfall plant late within the same municipality. Thus, farmers from the same community who farm in different geographical locations under this circumstance may experience different planting dates. Rainfall has been noted as a major issue SSA (Kupika et al., 2019; Buah et al., 2017; Elum et al., 2017).

Conclusively, the foregoing changes and variations in the rainfall pattern have, over the years, translated into changes in planting dates and other farming activities with dire implications for agriculture production and household food security in North-western Ghana. Although, smallholder farmers have also changed and varied their planting dates of farm crops over the years to align with shifts in the seasons, the effect has always been adverse for crop yields and household food security. It emerged from the survey that 82.6% of the respondents indicated that there were significant changes in planting dates in recent years compared to the past 30 or more years. Also, 13.8% of the respondents indicated uncertainty concerning changes in planting dates while 3.6% believed there were no changes in planting dates. The consequent adjustment of smallholder farmers to match with contracted growing seasons comes with the adoption of the cultivation of short (early) maturity crops and drought-favourable crops to sustain food crop production and household food supply. This has been reported as a common phenomenon experienced by smallholder farmers across SSA and other vulnerable regions globally (Davies et al., 2019; Menike & Arachchi, 2016). This has caused farming households to abandon many indigenous crop varieties because of the longevity in maturing. In this regard, the acquisition of early maturing and other improved crop varieties come with extra production cost to smallholder farmers, thereby exacerbating the burden of low adaptive capacities of farming households. The acquisition and application of inputs such as fertilizer, pesticides, herbicides, and tractor services have also intensified among rural farmers in North-western Ghana due to the burden of a shorter farming season placed on them by climate change. Thus, smallholder farming is becoming more expensive among households which is a recipe for household food insecurity and increased household poverty among rural households in North-western Ghana.

Generally, there is growing emphasis on rainfall variability with a decreasing trend in total annual rainfall over the years which has been adversely affecting smallholder crop production in North-western Ghana. A female discussant in Walembelle remarked in Sisaali that *"bisi hang duonu bi sia kene"* which literary means that "these years, the rains are not reliable". Since agriculture in northern Ghana is predominantly rainfed, predictability, certainty, and an ideal distribution in terms of coverage, frequency and intensity are important for planning smallholder agricultural activities. Any inability of smallholder households to predict the rainfall pattern will result in severe consequences for food production and livelihood sustainability. A participant in Dolibizon believes that

> *"These days we are always in dilemma about the certainty of the rainfall pattern for the farming season. We cannot tell when the rains will come for us to begin farming and when it will stop; we cannot tell whether the rains will be adequate for us or not; we cannot tell if the rains will be frequent and will take us up to the end of gbanchang chana [September] or it will stop early than that. We are always not sure of what yields we will get from our farms because we are not sure of how the rainfall pattern will be like. This was never the case when we were young. Those days the rains were highly certain, and one could predict the pattern of it. We knew the months that the rains would begin and the months that the rains would stop. These days the rains start late but end too early. It is a difficult situation for us as farmers. Things have completely changed today"* (Excerpt from In-depth interview, Dolibizon, 2020).

Climate change has promulgated a situation of significant uncertainty into smallholder agriculture which needs serious multi-stakeholder approach to sustain rural agriculture as the major livelihood activity among rural people. The need to make climate services accessible to rural farmers is becoming a compelling necessity considering the extent of variability in climatic elements such as rainfall.

In Kalsagri community in the Lawra Municipality, the earth priest (known as *Tendana* in Dagaare language) shared similar views about the variability and changes in the rainfall pattern over the past decades and how this may affect the efficacy of traditional forecasting and coping mechanisms.

> *"The rains have changed these days. The rainfall pattern is not like what it was during our time [youth days]. In recent years we [earth priests and other fortune tellers] are unable to accurately forecast the rains for our farmers to prepare themselves for the season. The rains mostly come late with destructive rainstorms, and they do not last up to the 10th month [October] of the year. Even the rains are scarce during the peak of the rainy season in recent years. Well, we [human beings] have caused it for ourselves because we no longer adhere to traditions, as compared to our days and that of the days of our fathers. It has become difficult for the rainmakers to call the rains during the*

farming season when farmers need rain. Although we are still doing our part in trying to forecast the season every year through [spiritual] consultations, things are not getting better for us." (Excerpt from In-depth interview, Kalsagri, 2020).

There is growing threat to the accuracy of traditional forecasting systems and sustainability of smallholder farming in North-western Ghana. This calls for capacity development of smallholder farmers in terms of accessibility to agriculture extension services since many smallholder farmers rely on indigenous knowledge for farming activities. Most smallholder farmers have low education, low access to improve agricultural services, inadequate access to credit and climate information which affect their planning and response systems to climate change and variability. Their ability to adjust, drawing on these factors, is highly limited; hence, their levels of vulnerability become compounded with adverse implications for food production and household food security.

5.4 Impact of Rainfall Variability on Smallholder Agriculture in North-western Ghana

Changes and variability in rainfall over the years have, generally, had adverse consequences and impacts on smallholder farming in northern Ghana. It has often resulted in recurrent occurrences of flood and dry spells (drought) and related incidents such as pest and diseases among crops and livestock. There have been growing adverse effects of these on crop and livestock farming and household food security in North-western Ghana. These effects vary from place to place and for different crops and livestock. As indicated by Ifeanyi-Obi et al. (2017), the impacts of droughts and floods are becoming very intense for smallholder farmers in SSA including Ghana. The occurrences of these rainfall related hazards were examined within the context of smallholder farmers' knowledge and experiences over the past decades. Consequently, farmers mostly rely on observed phenomena and historical events including changes in political regimes to demonstrate the changes in the trend of occurrences of floods in their respective communities. The frequency of occurrences of floods over the past decades has demonstrated a high level of variability.

5.4.1 Floods and their impacts on smallholder farming in North-western Ghana

Smallholder farmers are affected by floods almost every year, particularly farmers whose farms are located near rivers, streams and on lowland areas. Such farms are usually inundated by excess water due to heavy rainfall and waterlogging in many lowland farms. The increased intensity of rainfall usually results in excess water and saturation of lowland areas which result in flooding and waterlogging. The implications of these incidents on smallholder agriculture are adverse as most farm crops inundated with water and consequently change colour and perish. Affected farmers experience crop failure and hardly get yields that can feed their households. However, the frequency of floods over the past years was generally perceived to be declining as shown in the Figure 5.3).

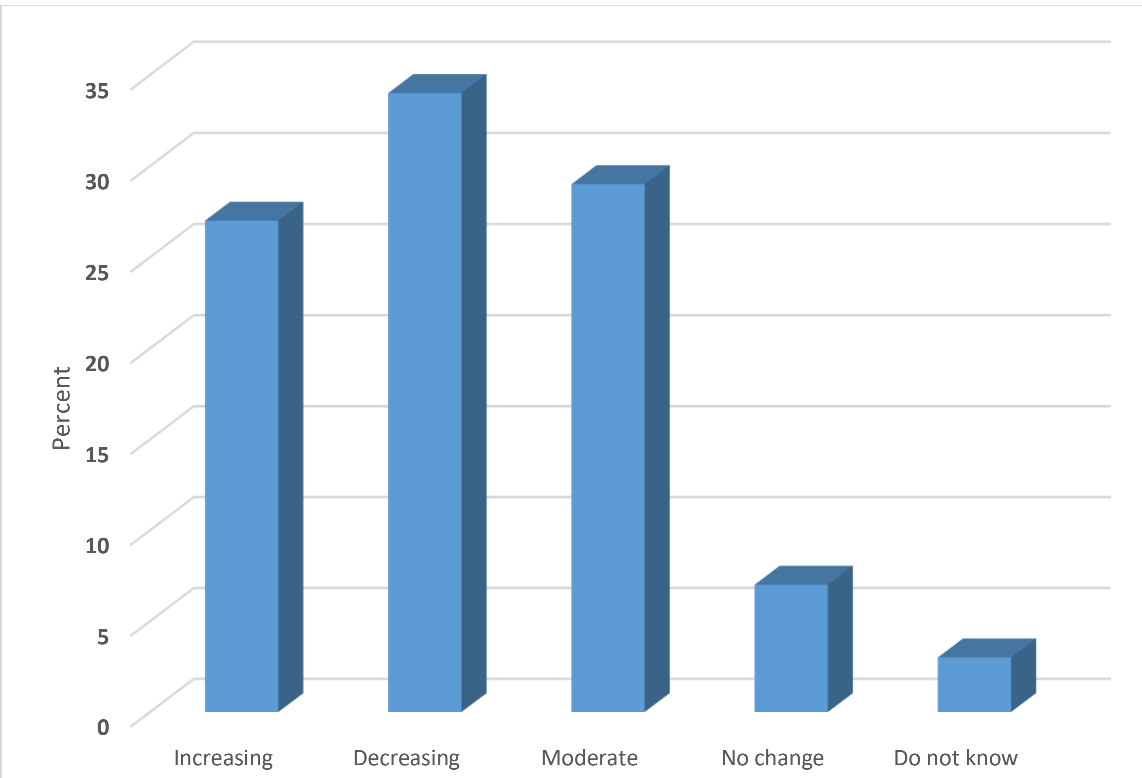


Figure 5. 3: Frequency of occurrence of floods in North-western Ghana (n = 305)

Source: Field survey, 2020

There were mixed perceptions of households on the frequency of occurrences of floods in North-western Ghana lately with 26.9% of the respondents believing that the occurrences of floods have been increasing in recent years while 34.1% indicated floods were decreasing. It also emerged that 29.9% of the survey respondents believed the occurrences of floods were moderate while 6.9% realised no change with 2.8% indicating they were oblivious. These varied perceptions about the frequency of occurrence of floods resonates with the findings of Derbile et al. (2021) who reported that the frequency of flooding in North-western Ghana was perceived to be irregular than an annual one. This is contrary to the findings of Guodaar, Bardsley and Suh (2021) who suggested an increasing phenomenon of occurrences of floods across northern Ghana. It also disagrees with the findings of Mulwa et al. (2017) who reported of consistent increases in the frequency of occurrence of flooding.

The impacts of perennial flooding in northern Ghana have generally been devastating over the years with smallholder farmers bearing much of the brunt. From the results of the survey, it emerged that 53% of the respondents attributed poor crop yields to the occurrences of floods while 34% were of the belief that floods impact moderately on crop yields. However, 11% of the respondents held a contrary view that farmers experience improved crop yields during years that floods occur. Meanwhile, two percent also indicated that floods have no impact on crop yields. Despite the varied opinions, the impacts of floods on smallholder food crop production have mostly been negative and pose severe threats to household food security in North-western Ghana. This has been echoed by Derbile et al. (2021) that the occurrences of floods in North-western Ghana adversely affect crops growth and yields.

It was revealed that farms which are usually located on lowlands, valleys, riverbanks, and other low-lying areas are mostly affected by overflow due to excess water and surface and ground water saturation. Farm crops and lands are usually washed off and eroded thereby causing soil erosion and degradation. Farm crops were forced to die prematurely due to stagnant waters and excessive precipitation. Many of the crops cultivated by farmers were highly vulnerable to excessive precipitation and usually did not yield well when farm fields become inundated with water. Leguminous and cereal crops, except rice, were highly vulnerable to flooding and excessive precipitation. Thus, crops such as maize, sorghum, groundnuts, beans, millet, and other crops which are not water receptive/resistant are usually cultivated on uplands; however, intensive and continuous rains could cause fields to be water saturated and waterlogged. When this happens, crops change colour and begin to shed leaves to a point where they die off.

The findings further indicate that rice is a water receptive crop. Therefore, the impacts on yields were mostly positive to rice farmers except those who had their fields washed off by flash flood waters. Yam crops which became submerged in flood waters for more than five days could usually be negatively affected. However, when yam mounds are raised above human knee-level, the impacts of floods on yields of yam are projected to be minimal. Therefore, in most cases, yam mounds are raised high on lowland areas compared to upland areas. Generally, the impacts of floods were severe for farmers who cultivated on lowland and waterlogged areas than farmers who cultivate on uplands. A discussant in Eremon community in Lawra Municipal indicated that:

> *"Flood waters can wash away the crops on your farm if the farm is located on a water way or along a river. Sometimes the flood waters could stay on the farm for some days, and this can cause the crops to turn yellow and eventually die off when they are not water loving. In that case, what will you get from such farm? It is only rice that can do well provided they are not washed off. What is worrying is that, in most of the years we are affected by floods and droughts interchangeably; the droughts come after planting and the floods follow at the stage of crop maturity. As if that is not enough, the rains stop suddenly, and the crops are affected by dry conditions. In this case, the yields of all farm crops are negatively affected. This has been our situation in recent years.".* (Excerpt from FGD, Eremon 2020).

Similarly, in the Walembelle community in the Sissala East Municipality, a participant emphasised that maize, millet, sorghum, beans, groundnuts, and soya beans which are major cultivable crops among farmers were more vulnerable to floods. According to the participant,

> *"Floods, although not very frequent as in our time [in the past], are highly disastrous. You can have your whole farm destroyed by floods leading to a total crop failure. Maize, beans, sorghum, and other non-water loving crops, are severely affected. Last two years ago (2018), I lost my sorghum and maize crops to floods following intensive and continuous rains which caused the land to become waterlogged. The crops turned yellow and brownish colour and consequently die off. I got virtually nothing from my farm. But I had good harvest from my rice farm which I cultivated in the valley"* (Excerpt from In-depth interview, Walembelle 2020).

There is also the incidence of recurrent floods and drought conditions that are inimical to crop production and household food security in North-western Ghana and northern Ghana in general. This makes smallholder agriculture highly vulnerable with undue pressure on household food security systems as indicated by Morton et al. (2017).

From the foregoing, the impacts of floods on crop farming are imminent and disastrous to household food security and poverty reduction in North-western Ghana. The impacts are experienced in the form of low crop yields, poor crop growth and development. The impacts of floods on smallholder agriculture have been articulated by other scholars in Ghana and SSA in general (Abdulai et al., 2017; Rojas-Downing et al., 2017; Derbile et al., 2016; Dumenu & Obeng, 2016).

5.4.2 Drought/Dry Spells and their impacts on smallholder farming

The terminologies drought and dry spells have been used interchangeably in this study to refer to the absence of rains or moisture for a reasonable period that will have any negative effect on the development of farm crops. The local understanding of drought mirrors a situation of lack/inadequate rainfall and moisture during the farming season which spans over three weeks to three months. This mostly culminates in severe consequences such as poor germination, wilting, and dying of farm crops. The local terminologies, *'hiling'* in Sissali and *'saa wier'* in Dagaare languages in Sissala East and Lawra Municipalities respectively, are used for drought and/or dry spells. Mostly, the emphasis is placed on agricultural drought which is the temporary absence and/or inadequate rainfall leading to declining soil moisture for a relatively short period capable of compromising crop growth and yield (Udmale et al., 2014). It emerged that extreme droughts were experienced in Ghana in the early 1980s which necessitated international humanitarian interventions. No incident of drought of such magnitude has been experienced in the country except intermittent droughts (agricultural droughts).

A discussant narrated his experience as follows:

> *"What happened during the early years of JJ [Rawlings] regime was very terrible for us. We have not experienced such conditions since then, and we do not pray for it. Those years were very difficult for every Ghanaian farmer, we could not farm because there were no rains. This resulted in serious hunger and water crisis in our homes and communities. JJ [Rawlings] and his government had to supply us with wheat, sorghum,*

and oil to feed our families for more than a year. Maybe you were not born by then, or you might have been a child then [referring to the interviewer (researcher)]. We do not pray to see that again, and it should not happen again to any of our generations. …What we are experiencing these days are short and intermittent dry conditions which occur frequently every year during the cropping season. These dry conditions occur mostly during and after the sowing season and do not last for more than three months" (Excerpt from FGD, Dolibizon community).

The political regime of the Provisional National Defence Council (PNDC) military rule under former president of Ghana, Flt Lt. Jerry John Rawlings was mostly the reference point of the early 1980s drought disaster in Ghana. Participants were familiar with this detail. It was a historic drought disaster in Ghana that many household members who experienced it could still recall the impacts in the form of acute food and water shortage due to an almost one year of lack of rainfall. Farmers could not grow crops due to the prolong lack of rains which also caused severe water crisis in the country especially in northern Ghana where ground wells, streams, and rivers were the major sources of water for many communities. It has been noted that the issues of climate change, which manifests in droughts and related dry conditions pose severe threats to water availability and water resources in Africa (Muchuru & Nhamo, 2019b).

As shown in Table 5.1, the majority of the respondents (66%) indicated that the frequency of occurrences of dry spells in recent years was increasing compared to the past decades. Also, 19% of the respondents believed the occurrences of drought/dry spells were moderate over the years while 10% have a contrary view concerning the decreasing trend in the occurrence of dry spells in North-western Ghana.

Table 5. 1: Observed changes in the frequency of dry spells (n = 305)

Variable	**Frequency**	**Percent**
Increasing	201	66
Decreasing	30	10
Moderate	58	19
No change	16	5
Total	**305**	**100**

Source: Field survey, 2020

From Table 5.1, it is suggestive that there is an increasing trend in the frequency of occurrences of dry spells over the years. This has negative implication for smallholder agriculture as the tendency of poor yields and low productivity are eminent outcomes for smallholder farmers. Household food and income security are also threatened by the danger of worsening poverty and access to quality health and educational services in North-western Ghana. The GNCCP (2013) expressed grave concerns about eminent consequences of continuous decreasing pattern of rainfall and increasing incidents of drought conditions on rural livelihoods, particularly agriculture, in Ghana.

There were similar views among respondents in the Lawra and Sissala East Municipalities on the frequency of occurrences of dry spells. In both areas, there was the belief among smallholder farmers that the incidents of dry spells have been increasing over the years with implications for crop production, household food security and poverty levels in rural North-western Ghana as indicated in Figure 5.4.

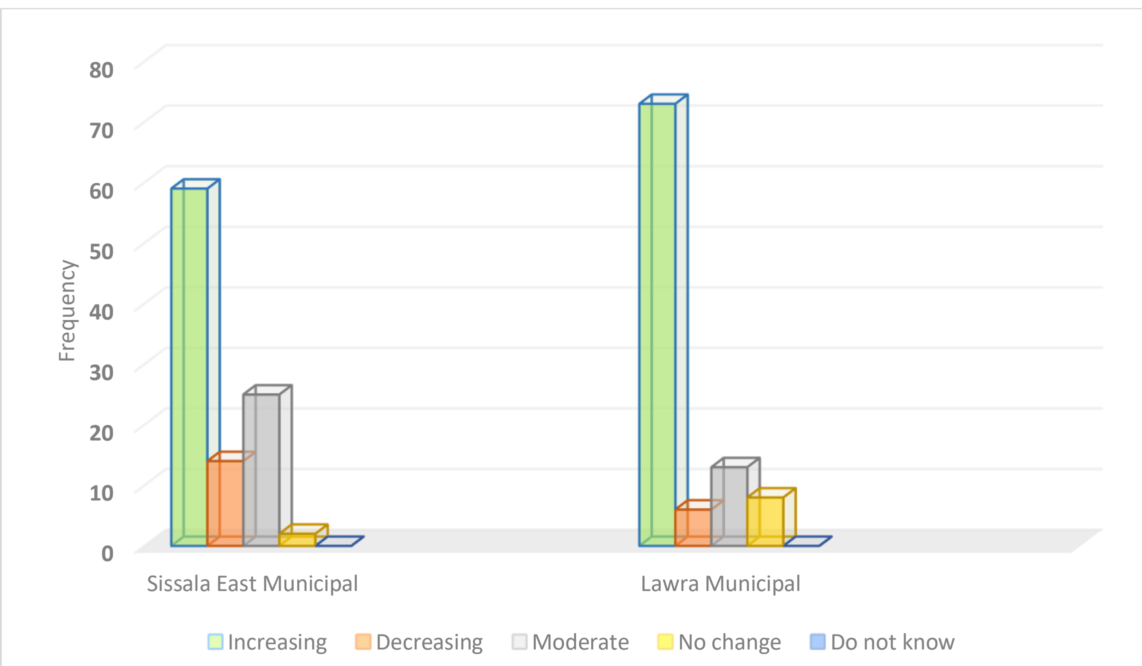


Figure 5. 4: Incidents of dry spells in recent years in Sissala East (n = 152) and Lawra (n = 153)

Source: Field survey, 2020

The results show that there has been a general common perception among smallholder farmers from both municipalities about the occurrences of dry spells. However, the majority of respondents in Lawra Municipal (73%) perceived increasing frequency of dry spells than respondents in Sissala East Municipal (59%). This is consistent with the findings of Abdulai et al. (2017) who indicated that the planting season in the Lawra Municipality is mostly dominated by frequent intermittent dry spells. This could be attributed to the differences in the topographies of the two municipalities. While the topography of Sissala East Municipal offers relatively loose and rich soil and vegetation, that of Lawra Municipal is mostly rocky in nature and easily becomes dry. This is further given credence by the fact that many of the respondents in Sissala East Municipal believed dry spells were moderate compared to those in Lawra Municipal. Therefore, the vegetative and the landscape conditions of both municipalities might have influenced the responses of the respondents, as Menike & Arachchi (2016) suggested that farmers' perceptions are largely influenced by agro-ecological factors.

It was elaborated that the occurrences of dry spells in North-western Ghana have adverse effects on crop farming which jeopardises household food security and poverty levels. Smallholder crop farming has been a major source of household food supply and income to rural households in northern Ghana. Being predominantly rainfed, it is vulnerable to climate change which manifests in dry conditions and other related events which negatively impact crop yields. In Kalsagri community (Lawra Municipal), a participant indicated that dry spells affect germination, yields and growth of farm crops. According to the participant droughts have been very devastating and exacerbate household poverty levels:

> *"Droughts are very common these days than in the past. Every year we [farmers] are affected by droughts, particularly during and after planting. These [droughts] usually delay sowing, and result in poor germination. Some crops also wilt due to the dry conditions. Last year [2019], I lost my cowpea crops to droughts. The rains were not coming at the time they were flowering, which badly affected the yield. They wilted and dried up".* (Excerpt from FGD, Kalsagri 2020).

The survey shows that, 69% of the respondents attributed poor crop yields to the increasing incident of intermittent droughts during the planting season. There were other views that claim farmer experience moderates crop yields (26%); two percent indicated dry spells have 'no impact' on crop yields while three percent were unaware. These have cascading effects on food production, household food security and the income of smallholder farmers and consequently their ability to access quality health and educational services for their household members. According to Jarawura (2021), droughts in northern Ghana have significantly reduced crop yields which has compromised household food supply. This consequently causes smallholder farmers to embark on seasonal migration to urban and other places to look for alternative livelihood portfolios. Similarly, Udmale et al. (2014) reported that increasing droughts have been responsible for declining production of major cereal crops such as maize, wheat and rice in Maharashtra, India.

The results of FGDs and face-to-face interviews further emphasised the vulnerability and exposure of smallholder farmers in North-western Ghana to recurrent droughts and floods within the farming season as indicated by Derbile et al. (2016). The findings further show that farmers experienced frequent intermittent dry spells during and after the planting season as the first phase and immediately after the abrupt cessation of the rains in the month of September.

A participant in Nabugubelle community recounted how farmers were affected by the double tragedy rainfall variability in the following narrative:

> *"We [farmers] are confused now because we really do not know what to prepare for. Should we prepare for droughts or floods? These years the rains usually start late, causing us to plant late, and after planting, the rains will not come, making us to experience weeks of intermittent dry conditions which affect crop germination, fertilizer application, and plant growth. Then, the rains will open in August, and farmlands get saturated with water and become waterlogged, causing crops to change colour prematurely. As if this is not enough, the rains cut off and we begin to experience dry conditions before the end of the 9th month (September) when many of our crops are still to mature. This is the situation we find ourselves now. This was not what we experienced when we were young"* (Excerpt from FGD, Nabugubelle, 2020).

Smallholder farmers are exposed to two phases of drought conditions over the farming season; the first phase is experienced after sowing of farm crops from May-July and the second phase mostly occurs in September. The impacts during the first phase relate to poor germination, poor growth and development while the impacts during the second phase relate to poor yields and poor development of seeds. Thus, the impacts of dry spells on crop farming manifest in poor crop germination and growth, wilting, poor seed formation, and general poor yields which pose daunting threats to household food and income security in North-western Ghana.

5.4.3 Hailstorms and their occurrences

Hailstorms are usually considered as signs of good and heavy rains depending on how frequent they fall any time it is raining. Frequent falling of hailstones at the beginning of the rainy season is perceived among smallholder farmers as a sign of good rainfall pattern for the year. It is a signal that the year may likely experience an intensive, a frequent and a prolonged rainy season which may cause flooding of farmlands, particularly farms on lowlands and riverbanks.

It was found that the frequency of occurrences of hailstorms in North-western Ghana over the past years has been decreasing. The incidents of hailstones during rainy days were rarely felt in the study communities unlike what others experienced in about three to four decades ago. It was suggested that hailstones were frequently experienced during the beginning and peak of the rainy seasons, and that what was being experienced presently was a sign of a changing climate. It emerged that the majority of the respondents (74.4%) believed that the frequency of occurrence of hailstorms has drastically been decreasing over the years. It was further found that 18.4% of the respondents observed the occurrence of hailstones to be moderate in recent years while 5.9% indicated there was no change. As shown in Figure 5.5, one percent of the respondents had a different view that they were experiencing more hailstones in recent years than in the past while less than one percent had no idea. The decreasing trend in the occurrence of hailstones implies that the rainfall patten has changed and become worse since hailstones signify a good pattern of rainfall over the farming season.

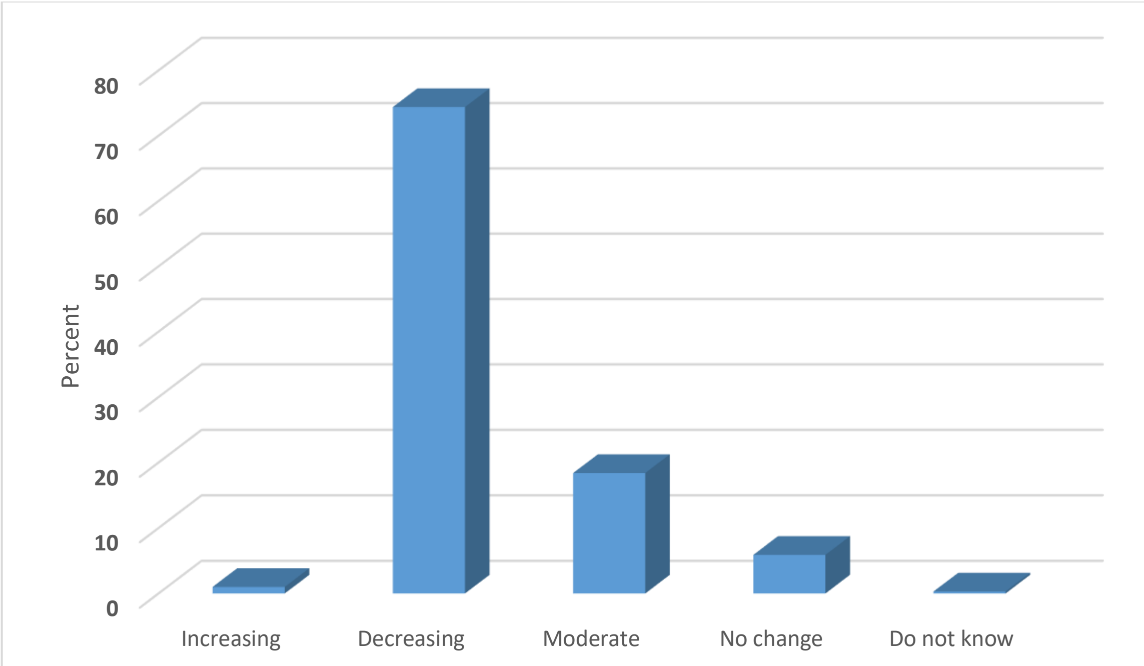


Figure 5. 5: Observed changes in the frequency of occurrences of hailstones (n = 305)

Source: Field survey, 2020.

It was observed through interactions that the communities rarely experience the occurrences of hailstones. This implies that future generations may lose the value of hailstones as a local predictor of the rainy season and the relevance for smallholder agricultural planning. It was suggested that several young people have not witnessed/experienced heavy falls of hailstones and might not be aware that hailstones could damage farm crops. A participant in Babile community doubted if numerous young people particularly children know hailstones, considering the near absence of the occurrence of hailstones in the community in recent years. The people have not experienced hailstones in the community for some years. This participant opined that:

> *"These days our children do not know hailstones because hailstones rarely fall during the rainy season. For more than five years now I have never seen hailstones fall in this community. So, how can my small girl of seven years know hailstones? Many of the young boys and girls in this community have never experienced the occurrence of hailstones for more than two times over the rainy season"* (Excerpt from FGD, Babile, 2020).

In both municipalities, it was discovered that respondents expressed common views about the changes in the occurrence of hailstones as can be seen in Figure 5.6. Thus, respondents in both areas believed hailstones have significantly decreased. This could be attributed to climate change which has caused changes in rainfall pattern and other climatic variables.

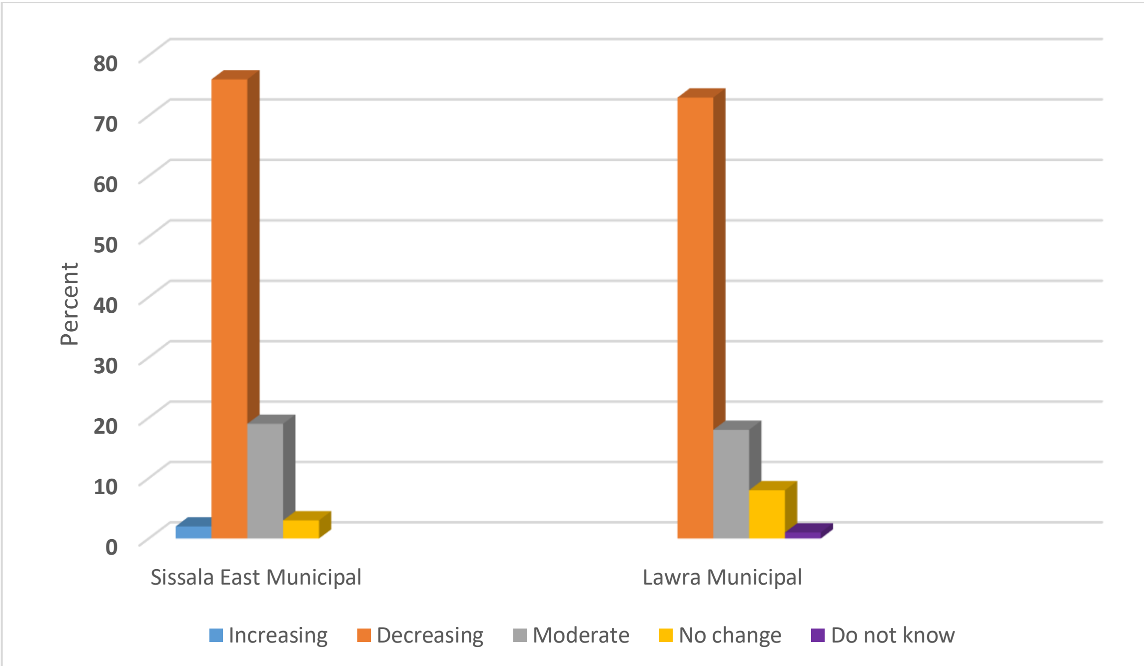


Figure 5. 6: Perceptions on changes in frequency of hailstones in Sissala East (n = 152) and Lawra (n = 153)

Source: Field survey, 2020.

From Figure 5.6, it emerged that about 76% and 73% of the total respondents in Sissala East and in Lawra Municipalities respectively indicated a decreasing trend in the occurrence of hailstones over the years.

In Walembelle community, a female participant related that she only got alarmed by one incident of a hailstorm in the year 2016, which occurred in one community in Sissala West District where farm crops were destroyed by heavy fall of hailstones to which her brother was a victim (Figure 5.7).

Figure 5. 7: A maize farm destroyed by hailstones in 2016

Source: Photo from a participant in Walembelle Community

It was suggested that such an incident was a rare case that many people have never experienced or heard for many decades and that it had spiritual connotations. An interview with the *Paare-nyimmah* (traditional chief farmer) of Dolibizon community in the Sissala East Municipality elaborated that there has been drastic decrease in the occurrences of hailstones which have been the means of measuring changes in rainfall pattern in North-western Ghana and northern Ghana. He noted that:

> *"Hailstones were one of the ways of predicting the pattern of rainfall during our time (time as active farmers). They were very frequent during the beginning of the rains and during the peak of the rainy season. You could see children picking them during rains and swallowing them. The story is not the same as today. For the past five years or more, I have never seen hailstones occurred in this community for more than two times during the rainy season. In fact, for many of years they never occurred not even once. I can remember, it was on one occasion that few hailstones fell for the whole of the rainy season last year [2019]. For this year (2020), I am yet to see any hailstones for the season"* (Excerpt from In-depth interview, Dolibizon, 2020).

This further emphasises the claim that climate change could pose severe threats to the efficacy of traditional and indigenous ways of forecasting rainfall in SSA.

5.4.4 Rainfall variability and rearing of livestock and poultry

Rearing is an important activity which is undertaken concurrently with food crop farming by traditional households in northern Ghana including North-western Ghana. Just as crop farming, livestock and poultry rearing are also affected by rainfall variability. Different livestock require different rainfall conditions. Therefore, the variability in rainfall could be positive or negative depending on the kind of animals and birds reared. The rainfall conditions under which the various types of livestock and poultry require for healthy living and reproduction were assessed in the household survey. As shown in Figure 5.8, moderate rainfall mostly provides a conducive atmosphere for rearing ruminants such as cattle (66%), sheep (78%), and goats (65%). It can be observed from the figure that high to moderate rainfall patterns are suitable for cattle production, while moderate to low rainfall conditions are favourable for the rearing of small ruminants (sheep and goats). Generally, moderate rainfall conditions turn to be suitable for the rearing of ruminants (cattle, sheep, and goats) in North-western Ghana. This suggests that extreme low and high rainfall are threats to ruminant production. Mostly, extreme rainfall results in extreme precipitation which provides favourable conditions for water-related pests and diseases that affect animals' health and reproduction. Small ruminants such as goats and sheep are very vulnerable to extreme precipitation related diseases such as foot and mouth rot, pneumonia, etc. Many farmers have reported of losing much of their flocks to pests and diseases during years of extreme rainfall and precipitation. Cattle are also affected by these extreme conditions and related diseases. The findings agree with other scholars who indicated that livestock farming requires a moderate rainfall pattern, as a low rainfall pattern presents severe threats to livestock rearing in SSA (Ayanlade et al., 2017; Rojas-Downing et al., 2017). However, high to moderate rainfall conditions were suitable for pig farming because pigs naturally like water and moisturised conditions. A participant indicated that extreme rainfall poses adverse risk of diseases and death among livestock with high mortality among small ruminants.

> *"Too much rainfall exposes animals to diseases which cause their deaths. Sheep and goats are mostly affected by heavy rains because they are mostly vulnerable to water and moisture related diseases. Cattle, although affected, do not die like sheep and goats*

do. We usually lose many of our goats and sheep to diseases after every rainy season every year. It is worst in years that the rainfall is high" (Excerpt from In-depth interview, Walembelle, 2020).

Ruminants particularly small ruminants are more susceptible to extreme rainfall and precipitation conditions while such conditions favour pigs.

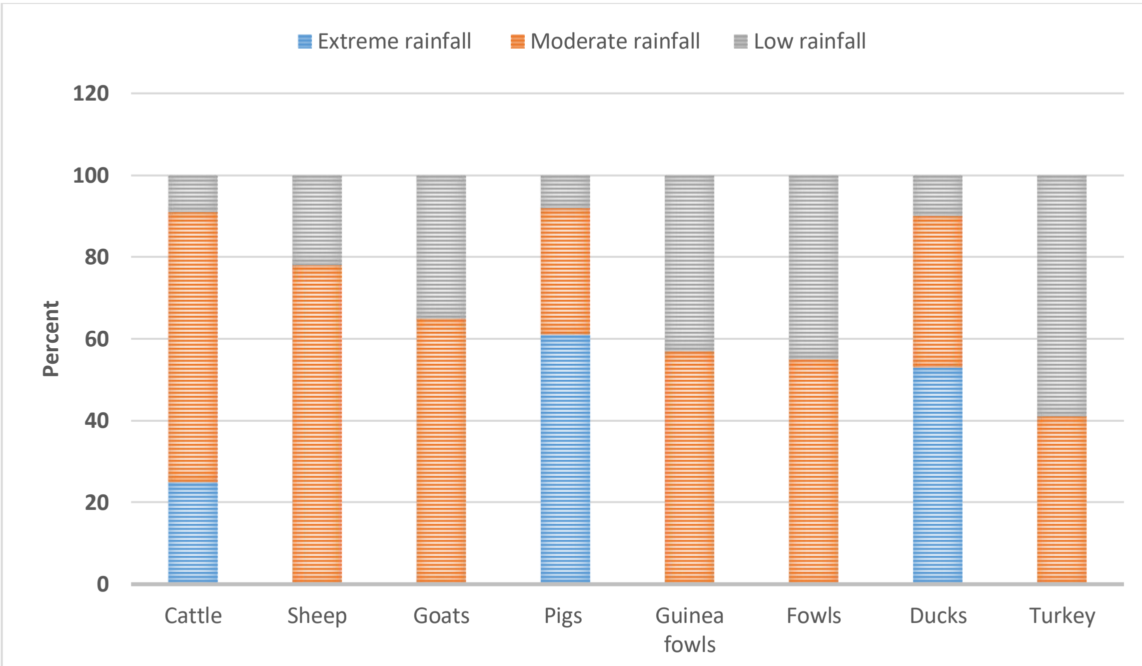


Figure 5. 8: Conditions of rainfall favourable for rearing (n = 305)

Source: Field survey, 2020.

From the figure, the findings show that most of the respondents (90%) indicated high to moderate rainfall conditions were suitable for the rearing of ducks which are water-loving birds. Besides, the results indicated that moderate conditions were most suitable for the rearing of guineafowls (57%) and fowls (55%) while 43% and 45% of the respondents indicated that low rainfall pattern was suitable for rearing guinea fowls and fowls respectively. Many of the respondents also indicated that low (59%) to moderate (41%) rainfall conditions were favourable for the rearing of turkeys. It is important to note that poultry such as fowls, guinea fowls, and turkeys are birds that require relatively dry conditions over extreme precipitation. Meanwhile ducks are water-receptive birds and so extreme precipitation conditions are suitable for their survival and reproduction. This mixture of dimensions of rainfall variability makes poultry and livestock farming in North-western Ghana highly vulnerable to climate change. This is because any changes in rainfall that will compromise fodder and grain production in North-western Ghana will eventually affect rearing adversely. It is within this context that Ayanlade et al. (2017) indicated that decreasing rainfall pattern poses severer consequences for poultry farming in SSA. Therefore, any variability in rainfall which negatively affects fodder and water availability for livestock and poultry will significantly cause a decline in production. These conditions will affect the growth, weight, size and reproduction of animals and birds, which will have a cascading impact on the market price and poverty reduction in North-western Ghana.

Thus, the impacts of rainfall variability on livestock and poultry production are manifested in the form of inadequate water and fodder for animals, pests and diseases, mortality of animals, low reproduction, low survival rate of newly born animals, and general changes in body size (fat and lean) of animals. Lactating animals cannot produce enough milk for adequate feeding and healthy growth of newly born ones due to inadequate feeding as result of fodder scarcity.

While high rainfall conditions mostly exposed animals to moisture-related pests and diseases such as ticks, mouth and foot rot diseases, and pneumonia, low rainfall conditions, on the other hand, result in water and fodder shortages for the animals. Interactions during FGDs revealed that mortality rates among small ruminants are usually high during years of high rainfall and extreme moisture conditions than years of low to moderate rainfall. It further emerged that while these conditions negatively impact sheep and goat production, they enhance reproduction and high survival rate of pigs and piglets. The mortality rate of piglets was usually lower during the rainy seasons and higher during the dry seasons. Conversely, the mortality rate of kids and lambs were noted to be higher during rainy seasons than during the dry seasons. Fodder and water for livestock have been a growing challenge in recent years in North-western Ghana particularly during the dry season. The period from January to April has always been a difficult time for livestock owners especially ruminant livestock which are grazed in the wild. Due to the perennial bushfires, the vegetation which provides natural fodder to livestock is destroyed and mostly looks bare to graze animals. In this regard, there is also the drying up of all natural water bodies. Since many of the communities do not have dams, farmers rely consistently on boreholes to provide water for the animals. Therefore, ruminants particularly cattle grow very lean with drastic loss in weight during the dry season due to inadequate feeding and drinking which affect the market price value. Many of them become weak and mostly die. This was particularly very common among the giant Fulani breed of cattle because the local breed of cattle was considerably resilient to these conditions.

It was observed that livestock and poultry were reared under the extensive system where the animals were left to roam and graze in the open environment. In Sissala East Municipal, cattle were taken care of by Fulani men while the small ruminants roam unguided in the communities. Pigs were also reared in the same manner in most instances. The exceptions were in the Lawra Municipality where some households have pens for their flocks. In Lawra Municipal, most households did not own herds of cattle and so family members usually graze them in the open including sheep and goats while pigs were mostly reared in pens. All livestock were tied in ropes to control their movement throughout the farming season to avoid destruction of farm crops since farmers in the Lawra Municipality were predominantly engaged in backyard farming. This was, however, not the case in Sissala East Municipality, where small ruminants and pigs roam freely and unguided, and mostly graze and destroyed backyard farm crops. As noted, cattle were herded by Fulani men who have contractual agreement with cattle owners. Many of these Fulani people also own cattle and therefore, this arrangement affords them the opportunity to settle in the communities and graze the cattle for free.

It was further observed that poultry rearing was also commonly done on the extensive and semi-extensive systems of rearing. Many of the birds especially the local breeds were left to feed on their own and roost in hen coops in the evening. Chickens were caged and fed for at least a month after hatching before allowing them to roam around. However, the foreign breed of poultry was reared in enclosed shelters and fed with processed chicken feeds made from grains and soya beans unlike the local breeds which were mostly fed with termites and raw grains. The local poultry and livestock were more resistant, than the foreign breeds, to local environmental conditions including pests and diseases. According to a participant, *"our local cattle do not get sick and die much like the Fulani cattle. Our goats and sheep are also stronger [resistant] than the 'Burkina' goats and sheep (exotic goats and sheep)"*. Therefore, the indigenous cattle, goats, sheep fowls and guineafowls were more preferred because of their resilience and adaptability to the changing climatic and environmental conditions in North-western Ghana.

5.5 Trend in temperature pattern and the impacts on smallholder agriculture

In North-western Ghana, smallholder farmers measure temperatures based on the warm and cold conditions they experience during the day and night, and the effects of these conditions on farm crops, livestock, and poultry. Temperatures in northern Ghana generally vary in terms of duration and intensity at different times of the year. These variations were observed among smallholder farmers through personal experiences about the timing, intensity and duration of night and day temperature conditions within their immediate environments. Usually, comparison is made between the past and current experiences of temperature conditions within their immediate environments.

There was a general perception of rising temperature conditions among smallholder farming households in North-western Ghana. It emerged from the survey that 60% of the respondents believed that temperatures had increased over the years, 18% indicated temperatures were moderate, while seven percent observed that the temperature had decreased. Meanwhile 12% indicated there were no changes in temperatures over the years. The foregoing findings show varied perceptions on changes in temperature although many of the respondents suggested that the temperatures were increasing over the past decades in North-western. Other studies have pointed to an increasing trend in daily and annual temperatures in Ghana and SSA over the years (Kupika et al., 2019; Antwi-Agyei et al., 2017; Buah et al. 2017) (see section 3.4). The findings confirmed the findings of File and Derbile (2020) who reported of rising perception of higher temperatures among farmers in North-western Ghana.

In Kalsagri community in the Lawra Municipal, a participant noted that

> *"The weather is becoming warmer every year. The heat during the day and night is warmer these days than during our youthful days. Even during the peak of the rainy season, one could be sweating when you are sleeping in the night. The heat season has become prolong and it starts from February through to May, which was not the case in the past. Then the 'gbancha' heat begins in late September instead of late October. These days, the cold conditions during the harmattan are not felt very much due to the*

increasing heat conditions. Why are we not setting fires in our rooms during the harmattan (cold) season as done in the past? Can we say the harmattan conditions we used to experience during the time of [Dr. Hilla Limann[1]] and JJ[2] [Rawlings] (referring to regimes of former Presidents of Ghana) are the same as today? No. The cold conditions during the harmattan period have reduced drastically these days" (Excerpt from FGD, Kalsagri 2020).

The historical and political regimes of former President Dr. Hilla Limann (1979-1981) and former President Flt-Lt. Jerry John Rawlings (1981-2001) were used to make comparison of the conditions of temperatures during those periods and the present. The comparison of temperatures during the late 1970s through to 2000 and currently tends to present a clear picture of the changes in temperature in the form of warm and cold conditions experienced among the people in North-western Ghana.

In a related opinion, a key informant indicated that much has changed in relation to temperatures over the years, of which the current generation might not be able to appreciate those changes because *"they were born into a warm regime"*. The participant further noted that

> *"During the time of our fathers through to our time, temperatures were low and moderate, and we could tell when the temperatures were expected to be high and when they were expected to be low. Usually, the peak of high temperatures was from March to April, just two months because the rains start in mid-March and get frequent in April for early planting. Then, we experienced the second warm season, which was even mild, in October when the rains were getting to an end. We call it 'gbanchang wulumung'. This period was usually characterised by intense sunshine and intermittent rains. The rains mostly come in a flash with sunshine which last less than five minutes. Then from November to February was the peak of the cold season [harmattan]. The cold conditions were very intense and severe that we usually set fires in our rooms to keep our bodies warm in the night. Men would usually be seen early mornings around fires in their various sections in the community. Do you see that happen these days? It was difficult to drink river water in the morning because the water was extremely cold. All these are absent today. Now much of the season is characterised by warm conditions, and that is why the young ones of today may not believe that there were times in the past we used to go to farm in the morning holding bundles of thatch lit with fire to keep us warm"* (Excerpt from in-depth interview, Dolibizon, 2020).

[1] Dr, Hilla Limann was president under the 3rd Republic of Ghana from 24th September 1979-31st December 1981. His presidency was toppled by JJ Rawlings in a coup

[2] Flt-Lt Jerry John Rawlings overthrew Limann's administration on 31 December 1981. His regime spanned from 1981-1991 of military rule and 1992-2000 of democratic rule.

Heat conditions may be increasing over the years and becoming consistent throughout the year in recent times. This results in decreased cold conditions in terms of intensity and duration during the year as indicated in Figure 5.9.

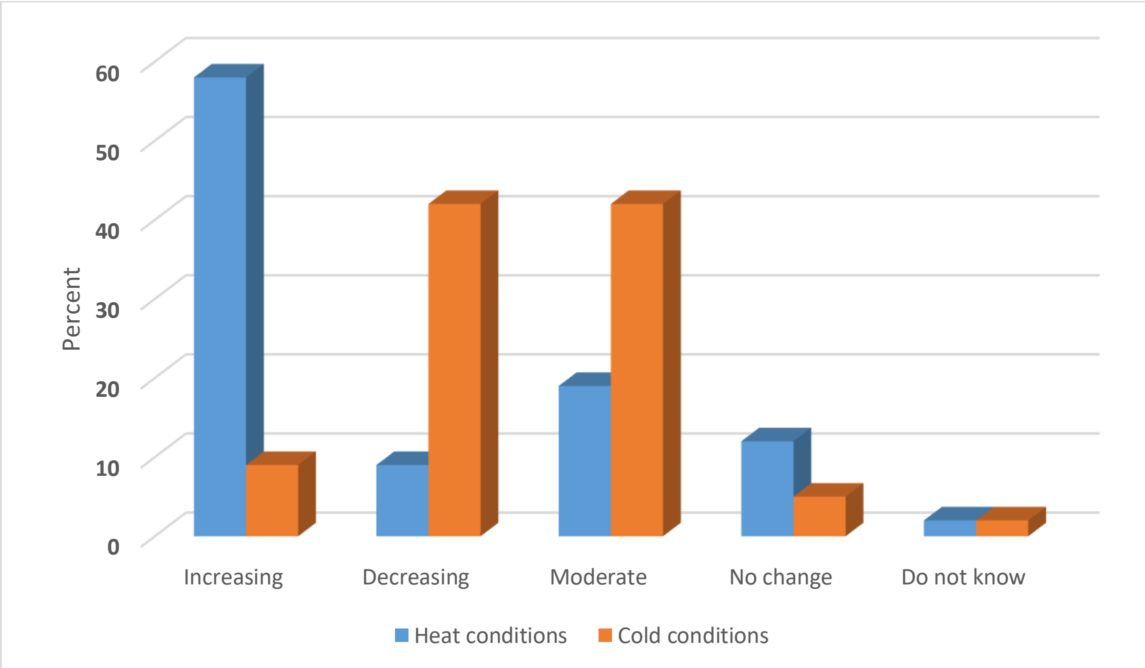


Figure 5. 9: Perception of general heat and cold conditions (n = 305)

Source: Field survey, 2020.

From Figure 5.9, it is evident that heat conditions were perceived by 58% of the respondents to be increasing, followed by those who thought heat conditions were moderate (19%,). 12% indicated there were no changes in heat conditions over the years. Meanwhile, nine per cent of the respondents were of the view that heat conditions were decreasing while about two per cent were unaware. On the other hand, 42% of the respondents indicated that cold (harmattan) conditions were decreasing while 41.6% indicated cold conditions were moderate. The results further show that 9.2% of the respondents believed cold conditions were increasing; 4.9% indicated there were no changes while 2.3% of the respondents indicated they were unaware. To this end, the findings show that heat conditions were increasing with decreasing to moderate cold and harmattan conditions over the years in North-western Ghana. A participant in Babile community in the Lawra Municipality noted that

> *"These days the heat is beyond our expectation. It has become more warmer both day and night than it used to be some years ago. Heat conditions were not as extreme as they are today. The heat season has now become longer than in the past. It now starts in mid-January and gets intensified in February through to May instead of starting in March to early April"* (Excerpt In-depth interview, Babile 2020).

Thus, the findings imply that warm seasons were increasing and becoming intensified and prolonged, thereby shortening the harmattan seasons in North-western Ghana. Similarly, in Zimbabwe, Kupika et al. (2019) found that temperatures were increasing with rising heat conditions and decreasing cold conditions over the years as indicated in chapter three (section 3.4).

There was the believe that high temperatures were gradually taking over the farming and rainy seasons which could severely jeopardise household food security and income in North-western Ghana. A participant indicated that the rising heat conditions in the Lawra Municipality were becoming predominant with health implications. Heat related diseases were said to have increased, making the municipality one of the hotspots for Cerebro-Spinal Meningitis (CSM) in the Upper West Region.

> *"I can tell you that we never experienced these levels of high temperatures during our youthful days in this community. Temperatures could only be extremely high from late February to end of March. But these days it starts in mid-January and lasts up to almost end of May, and even the rest of the season is mostly characterised by intermittent warm conditions. Do you know Lawra Municipal is one of the hotspots of CSM epidemic in the [Upper West] Region? It is because of the extreme temperatures and heat conditions we experience lately"* (Excerpt from In-depth interview, Eremon, 2020).

Thus, high temperatures do not only pose serious threats to crop and livestock farming, but also human health as indicated by Sahu and Mishra (2013).

It is important to notice that that northern Ghana is generally characterised by prolonged dry season which is dominated by extreme heat and harmattan conditions spanning from February to May and November to January respectively. The prolonged dry season has its associated level of temperatures where the heat season is characterised by extreme temperatures and warm conditions. The harmattan season, on the contrary, is dominated by relatively low temperatures, cold conditions, and dusty winds. The harmattan season mostly comes with extreme cold conditions during the night and early morning hours. It is also associated with dry, windy, and dusty conditions. As noted earlier, the harmattan conditions in recent years are not much pronounced, with reduced cold conditions. In the past, the harmattan season was always characterised by frequent covering of the sky with a smoke-like substance which trapped the sun rays and drastically reduced its intensity on the earth surface. This usually occurred from November to January in the following year. This provided farmers a conducive atmosphere to work long hours on their farms as reported by Gyampoh and Asante (2011). There have been drastic and sudden disappearance of this smoke-like substance, and a drastic reduction in the severity of cold conditions during the harmattan season in recent years.

In both study municipalities, there was a general perception of the increasing trend in heat conditions and the decreasing trend in cold conditions as shown in Figure 5.10.

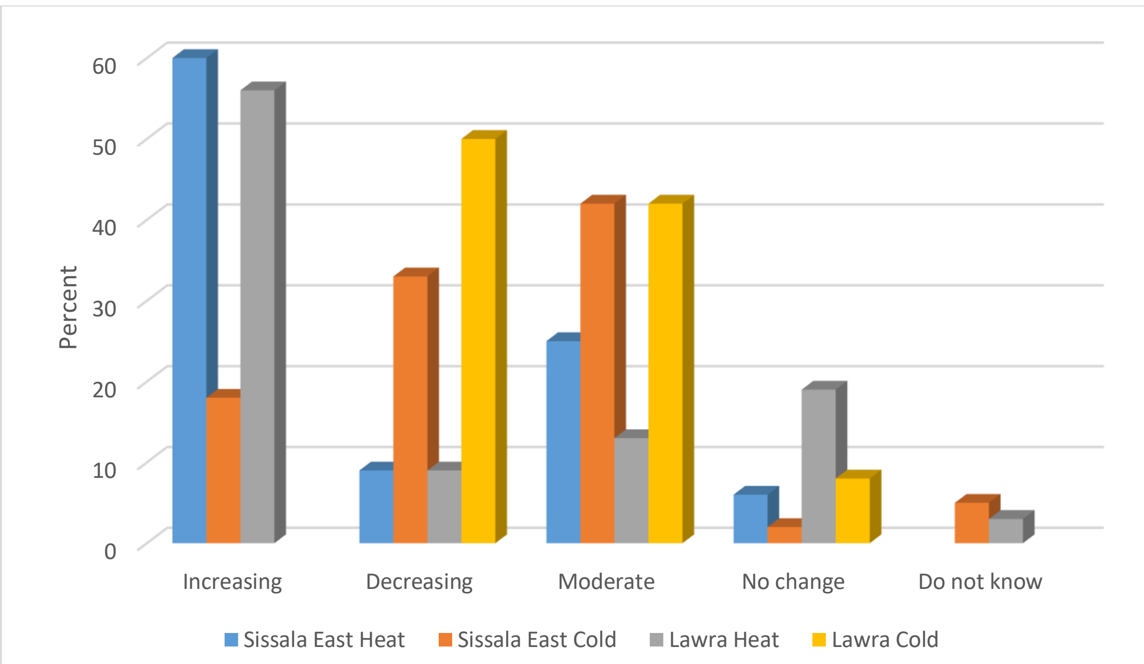


Figure 5. 10: Heat and cold conditions in Sissala East (n = 152) and Lawra Municipalities (n = 153)

Source: Field survey, 2020.

From the figure, cold conditions were perceived to have decreased more in Lawra Municipality than in Sissala East while there were equal respondents in both municipalities who otherwise thought cold conditions were moderate. This might be attributed to the fact that the Sissala East Municipality has a relatively forested environment than the Lawra Municipality. The landscape in Lawra Municipality is mostly rocky unlike in Sissala East where the land is gentle and undulating with thick tall grasses that cover the land surface.

Smallholder perceptions were similar when compared with meteorological data on temperature for the period of 1960-2018. Despite the unavailability of data for some months and years to make effective analyses, the results indicated that temperatures for both municipalities were increasing at a decreasing rate, and therefore confirmed smallholder farmers' perceptions that temperatures were generally increasing in North-western Ghana. This also corroborated Dakurah's (2018) assertion that smallholder farmers' perceptions were similar to scientific meteorological data on temperatures in North-western Ghana. Similarly, the general perceptions of local farmers in SSA have generally been similar to scientific climatic data on temperature (Kupika et al., 2019). As shown in Figure 5.10, temperature data for Sissala East was almost lacking thereby making it difficult to make comparative analyses between the two municipalities. Although the data for Lawra municipality were also incomplete, there was significant data to make analyses with.

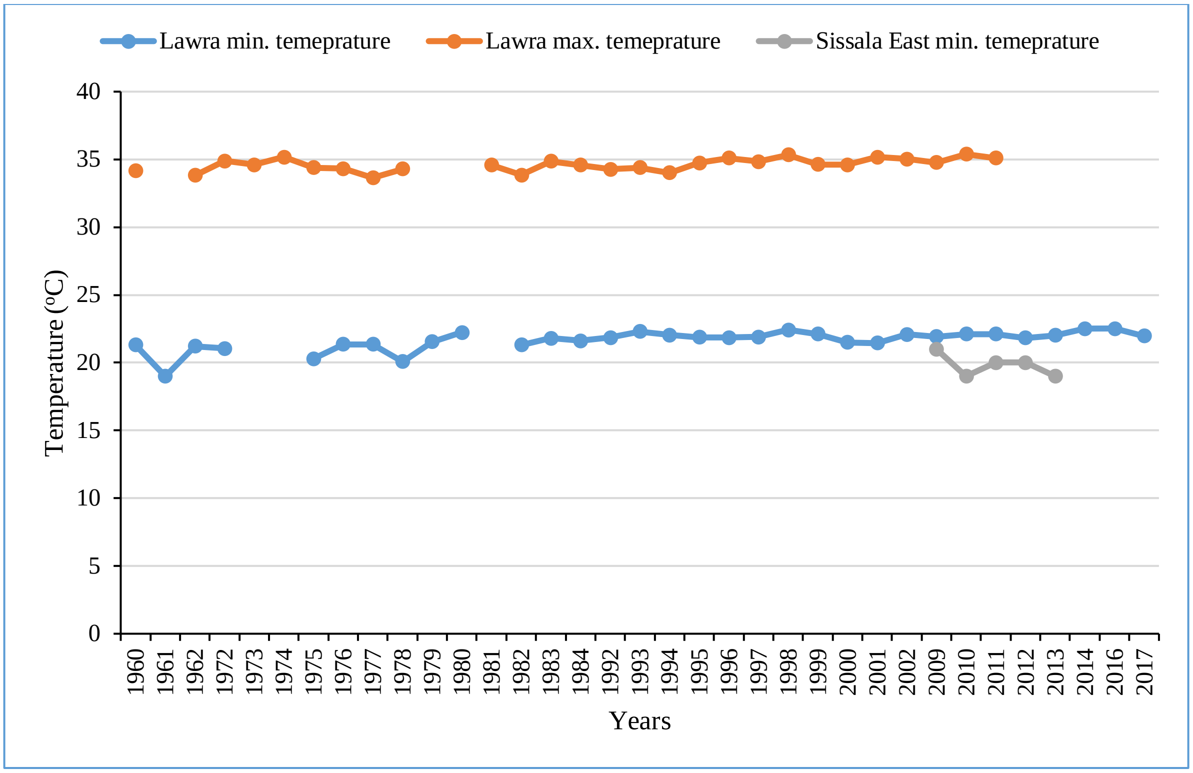


Figure 5. 11: Mean average temperatures for Lawra and Sissala East (1960-2018)

Source: Field Work 2021 (data from Ghana Meteorological Agency, 2020)

From Figure 5.11, it is revealed that the mean minimum temperature recordings for Sissala East were mostly unavailable except for 2009 to 2013. The five-year mean minimum temperature data recordings show fluctuations, having recorded high mean minimum temperature of 21^0C in 2009; This decreased to 19^0C in 2010. It thereafter increased to 20^0C in 2011 and 2012, and eventually decreased to 19^0C in 2013. This shows that temperatures were highly variable although data including mean maximum temperature data were unavailable. In Lawra Municipal on the other hand, mean minimum temperatures showed an increasing trend at a decreasing rate. Generally, between 1960 and 1980, mean minimum temperatures for Lawra mostly averaged 21^0C while the mean minimum temperature was about 22^0C for the period 1982 to 2017. This showed a marginal increase in mean minimum temperatures. Also, the mean maximum temperature recordings for Lawra Municipal showed that maximum temperatures were increasing at a decreasing rate over the period 1960 to 2017. The general trend showed that mean maximum temperatures for the period of 1960-1978 were largely 34^0C while it was mostly 35^0C between the period of 1982-2017. Both mean minimum and maximum temperatures were increasing and variable throughout the 58-year period in the study areas.

Generally, extreme temperatures adversely impact on food crop production in many ways with much impact on perishable crops. Extreme temperatures account for much of the post-harvest losses among roots, tubers, fruits, and vegetable crops which are perishable in nature. The farm produce such as yam, potatoes, tomatoes, cabbage, lettuce, watermelon, and other perishables were highly vulnerable to high temperatures. Many of these farm produces were caused to rot after harvesting due to heat conditions as result of higher temperatures since smallholder farmers usually lack appropriate storage facilities for them. This usually influences farmers to sell their produce at lower market prices to avert total losses, which does not improve their financial abilities. This particularly affects yam farmers mostly as they rush to sell their tubers at low prices immediately after harvesting to avoid the risk of them getting rotten. A yam farmer revealed that *"these days we rush to sell out our yam immediately after harvesting or else you risk losing them. They easily get rotten because of the high temperatures"* (Excerpt from FGD, Walembelle 2021). Similarly, vegetable farmers also indicated that high temperatures affect the prices of their vegetables because they are compelled to sell them at lower prices due to the perishable nature of the vegetables. Therefore, high temperatures adversely affect the market prices of farm produce particularly perishable goods and consequently put households in continuous poverty. Elum et al. (2017) reported of significant adverse impacts of high temperatures on vegetables and root crops in South Africa (see section 3.5 of Chapter three).

Extreme temperatures equally have significant adverse impacts on livestock production in North-western Ghana. The extreme heat conditions generated from high temperatures negatively affect the health and reproduction of livestock. It was revealed that farmers usually experience mass deaths of their poultry during the heat season on annual basis. It emerged that a whole community could lose all its poultry to the chicken pox disease which occurs every year during the heat season. There is also low reproduction of poultry because the heat conditions do not allow hens to sit on eggs for long hours to get them hatched. A participant noted that *"the heat does not allow hens to sit on the eggs regularly. It causes them [hens] to* *frequently abandon the eggs, and eventually the eggs will get spoilt and will not hatch. We experience good hatching during the harmattan and the rainy seasons"* (Excerpt from FGD, Nabugubelle 2020).

High temperatures (heat season) are usually experienced during the off-farm season where there is scarcity of fodder and water for animals to feed and drink. In many of the communities in North-western Ghana, there is always acute water shortage during the heat season leading to the death of ruminants particularly large ruminants like cattle. The animals mostly collapse and die after drinking much water when temperatures are extremely high. As a result, cattle were usually taken to drink at early mornings and late evenings when temperatures were relatively stable. The animals mostly appear weak during this season and many of them are unable to birth their young ones successfully. Many smallholder farmers do not have access to veterinary services to seek advice and care for their animals. Most of them cannot afford the services of mobile private veterinary services. Additionally, many of these veterinary officers were not licensed. In many of the communities, they rely consistently on Fulani men who they think have basic ideas on livestock rearing. State veterinary personnel and services were inadequate to provide services to smallholder livestock owners in North-western Ghana.

Cattle were exposed to heat related diseases such as skin rashes which is transmissible and can cause the death of the cattle. Cattle owners mostly incur extra costs during the heat season in treating their herds from this disease which was particularly common in Sissala East Municipal. High temperatures in SSA have been generally reported to have negatively affected livestock production directly and indirectly in the form of diseases, reduction in weight and body sizes, reduced quality and weight of meat, reduced production and quality of milk, eggs, and other products (Rojas-Downing et al. (2017). Similarly, Kupika et al. (2021) found that the occurrence of heat waves over the years in Zimbabwe has had significant effects on livelihoods of smallholder farmers. Therefore, moderate temperatures were indicated as favourable conditions for rearing of goats (75%), cattle (50%), guineafowls (56.7%), fowls (52.8%) and turkey (50%) while pigs (68%), ducks (72%) and sheep (55%) require low temperatures as indicated in Figure

5.12. Therefore, extreme temperatures are inimical to livestock and poultry production in SSA (see sections 2.2 and 3.4).

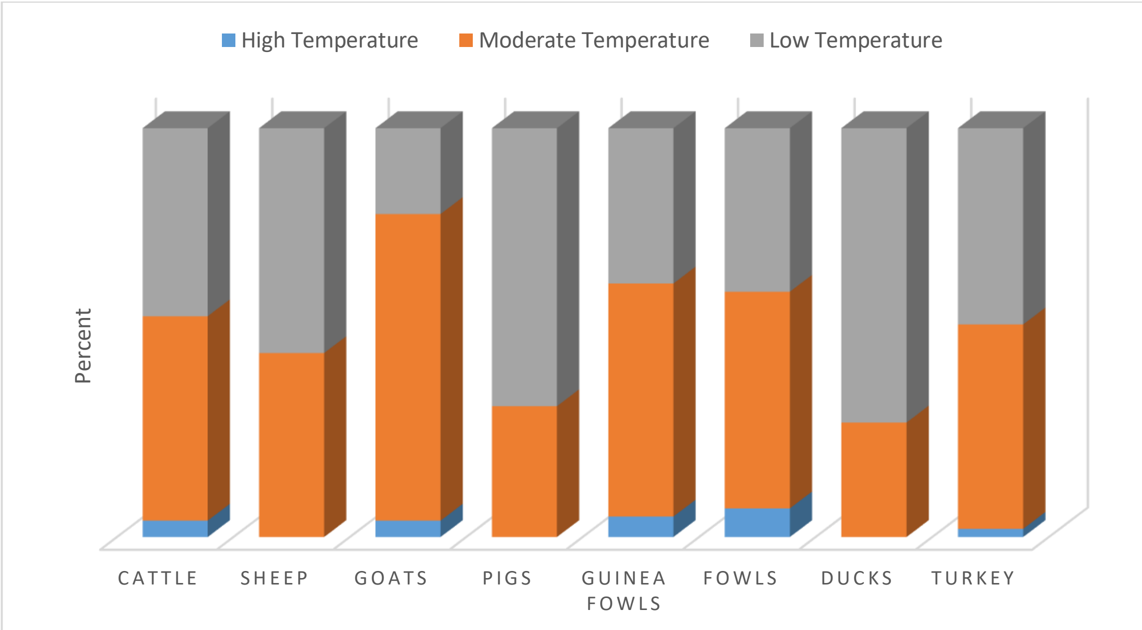


Figure 5. 12:Temperature Conditions Favourable for Livestock Rearing (n = 305)

Source: Field survey, 2020.

5.6 Conclusion

The observed general changes in rainfall and temperature have been presented and discussed within the perspectives of smallholder farmers' understanding at the household and community levels. These two elements were perceived to be highly variable over the past decades with severe implications for smallholder agriculture production and household food security. Total rainfall was found to be decreasing over the years with significant uncertainty and unpredictability about its onset and cessation. The rainy season has become short with reduced intensity and decreasing annual total rainfall over the years. The rainfall pattern has become highly intermittent, spanning from the planting season through to mid-September, which is often the end of the rainy season. The findings further show that rainfall has become irregular since the past 30 and more years. Temperatures were viewed to have increased over the years at a decreasing rate. Smallholder farmers' perceptions were found to be similar with meteorological recorded data on rainfall and temperature in the two study municipalities (Sissala East and

Lawra). The impact of these changes poses severe threats to smallholder agriculture production, household food security and poverty reduction in North-western Ghana.

CHAPTER 6: INTERFACING SCIENTIFIC, LOCAL, AND INDIGENOUS KNOWLEDGE SYSTEMS IN CLIMATE COMPATIBLE AGRICULTURE

6.1 Introduction

This chapter presents and discusses how smallholder farmers interface scientific and indigenous knowledge systems in promoting sustainable agriculture in North-western Ghana through climate compatible agricultural practices and technologies. It begins by looking at the preferences of smallholder farmers for the use of the two knowledge systems of scientific and LIK in their agricultural practices. The main sections include the following: interfacing scientific, local and indigenous knowledge for agriculture production; household adaptations strategies, and the conclusion of the chapter.

6.2 Interfacing scientific, local and indigenous knowledge for agriculture production

Smallholder farmers usually rely on both scientific and local and indigenous knowledge to undertake agricultural activities over the year in North-western Ghana and SSA generally. However, the difficulty in the accessibility and application of scientific knowledge, which mostly requires formal education and training make farmers predominantly resort to the employment of LIK in farming. LIK is a common pool source of knowledge to smallholder farmers, and it is transmitted from generations to generations through culture, oral traditions, and other traditional means, which do not require any scientific or formal education and training processes. For this reason, indigenous knowledge has become the primary source of farming information, practices, and technologies to smallholder farmers in North-western Ghana. The application and other matters relating to the utilisation of LIK are usually transferred to the present generation by the past generation through various means that include observation and field practice. Therefore, local knowledge as it is applied in agriculture is not only transmitted through culture and traditional means such as storytelling but also through (field) practice. Farmers have always observed the farm practices of their predecessors and how these practices and technologies are applied to succeed in farming. Indigenous knowledge application also dates to many years when agriculture began. This has become a part of the indigenes to which modern farming practices and technologies are recommended to blend with for adoption and sustainability purposes.

Scientific knowledge, on the other hand, is mostly acquired through formal education and training processes, and it is limited to a few individuals in society. The transmission of scientific knowledge among smallholder farmers mostly takes the form of formal teachings and learning through farmer training programmes/workshops, farmer-group meetings, radio discussions, community forums and field visits by agricultural extension agents and other expert initiatives. These platforms are not mostly accessible to smallholder farmers due to other factors such as the level of education and access to credit. Despite these challenges, smallholder farmers were found to have embraced some scientific-based farm practices, technologies, and methods to sustain farming under climate change.

Having brought this to the fore, the study proceeds to present and discuss how smallholder farmers have interfaced scientific and local knowledge in advancing sustainable farming practices in North-western Ghana.

6.2.1 Multiple farm ownership and locational characteristics

Smallholder farmers locate their farms based on vegetation, soil fertility and moisture-retention ability among other characteristics. It was observed that farms were located on uplands, lowlands, flatlands, waterlogged lands, flood plains and near rivers, for strategic reasons of adapting to different climatic shocks and stressors. In the survey, the respondents were asked to indicate all applicable locations of their farms. The results show that 69% of the respondents were farming on flatlands, 68% on uplands, 38% on lowlands, 20% on waterlogged lands, 29% on riverbanks, and seven percent on flood plains. Many households were found to be cultivating on flatlands, uplands, and lowlands. The choice for these different locations was mostly informed by the uncertainties and variability of the current pattern of rainfall and other climatic factors. Cultivating on different land areas with differences in vegetation, fertility and water-retention capacities enable farmers to adapt to recurrent floods and droughts (dry spells) as well as low soil fertility since locations such as flood plains and riverbanks are mostly perceived to be fertile due to accumulation of debris. These practices were common among both male and female farmers. However, female farmers mostly avoided siting their crop fields on waterlogged, riverbanks and lowland areas. On the other hand, Perez et al. (2015) found that female farmers site their farms near seasonal riverbanks while male farmers site crop fields close to permanent riverbanks in southern Ghana.

It was further discovered that a farmer may usually own two or more farmlands located in different or same geographical area(s) which have different land characteristics on one hand, and/or one farmland with two or more topographical characteristics on the other hand. As it was common to see a farmer cultivating different types of crops on his farmland, it was also a common practice among farmers to own two or more farmlands concurrently in different geographical locations that have different land and vegetative features. It was further observed that some farmers could own one farmland but with parts of it being upland, lowland, and flatland. On each of these lands, the farmer cultivated different crops respective to the suitability of the soils. This practice was more common among smallholder farmers in Sissala East Municipality where there was relatively available vast and arable land to farmers than communities in the Lawra Municipality which did not, comparatively, have adequate land for farming activities. By these practices, farmers were able to reduce their vulnerability to the different shocks and stressors of climate change. This is because the vulnerability of smallholder farmers in Ghana and SSA vary according to soil conditions and other resources on their farmlands (Perez et al., 2015). To this end, smallholder farmers make and take farming decisions based on the nature of the farmlands and the types of crops to cultivate to reduce vulnerability to climate events such as floods and droughts.

Relatedly, the locations were interfaced with the distances of farms from homes that depicted the availability, accessibility, and fertility of farmland to enhance crop yields and increase production within the context of growing impacts of climate change. Some farmers have their farms located near homes and others were located far from homes. There were three categories of farmers identified by the study in relation to the distance of farms from homes. The first category was backyard farmers who had their farms located near homes. These farmers were literally engaged in backyard farming where majority of them could not cultivate on large acres of land. Many of these farmers were cultivating on less than three acres of land size. Here, farmers mostly cultivated around and/or close to their settlements. The second category was farmers whose farms were located far from their settlements. Farms were usually located several kilometres away from home settlements and farmers would have to travel far distances to get to their farms. Due to the long distances involved, some farmers tend to stay on their farms during major farming activities such as sowing, application of fertilizer and harvesting of crops. Many of these farmers cultivated on large acres of farmlands. Lastly, the third category are farmers who owned both backyard farms and distant farms concurrently. Under this category, a farmer owns two or more farms concurrently and at different locations. At least, one farm is located near or far from settlements (homes).

For the purposes of this study, the first category of farms will be referred to as backyard (compound) farms and the second category of farms will be referred to as ‘bush farms’. This categorisation was also used by Derbile (2010) in his study of local adaptation strategies of smallholder farmers to environmental change in the Atakwidi Basin of North-eastern Ghana. This categorisation brings a clear distinction to the two concepts of farm ownership among smallholder farmers and how that has helped them to navigate the dynamics and complexities of climate change over the years in North-western Ghana. Moreover, this study considers farms located with a distance radius of two kilometres from human settlements as backyard farms and farms situated more than two kilometres from human settlements as bush farms. Thus, the results show an interface of bush and backyard farming systems/practices in a manner that created opportunities for engaging in different sustainable farming systems within households in North-western Ghana.

It was found that backyard farmers were tilted more towards organic farming practices than farmers whose farms were located far from homes. The use of agro-chemicals such as synthetic fertilizer, pesticides, herbicides, and insecticides was relatively moderate as compared to their application to bush farms. The use of manure (animal and poultry droppings) was particularly common among backyard farmers than farmers whose farms were far from homes. As there were opportunities for farmers who own bush farms to expand their fields, there were no opportunities for backyard farmers to expand their farmlands because of land restrictions by different families for settlement purposes. Thus, backyard farm owners were constrained with availability of land for farm expansion due to competing demand for settlement expansion to accommodate increasing family members. This makes it crucial to embrace agriculture intensification practices that conserve soil fertility for continuous farming and production within a limited land space. This could be the reason for backyard farmers' resort to the use of manure and moderate application of synthetic farm inputs. According to smallholder farmers, the droppings of livestock and other human waste generated (e.g., dumping refuse) onto the backyard farmlands make them fertile and mostly do not require much chemical fertilizer application. The use of pesticides and related chemicals were also regulated because of the potential harm they could cause to livestock and human health. Backyard farms were not mostly affected by floods and perennial bushfires that characterise northern Ghana.

According to the results of the household survey, 48% of the respondents were engaged in backyard farming, 41% had their farms located far in the bush while 11% of the respondents had both bush and backyard farms concurrently. Further analyses of the results show that backyard farming was very common among farmers in Lawra Municipal while bush farming was popular among farmers in Sissala East Municipal. From Table 6.2, 87% of the respondents in Lawra Municipal were engaged in backyard farming, nine percent were engaged in bush farming while four percent owned both backyard and bush farms. Thus, the majority of the households in the communities in Lawra Municipality were predominantly engaged in backyard farming. As indicated earlier, the topography including the landscape and vegetation in the Lawra Municipality presented inadequate arable land for crop farming unlike Sissala East Municipality.

In the Sissala East Municipal, 73% of the respondents were engaged in bush farming, nine percent were engaged in backyard farming while 18% were engaged in both backyard and bush farming. Thus, in Sissala East Municipality the majority of households had their farm far away from settlements and this has a direct relationship with the farming practices and technologies they adopt. Here, framers predominantly engaged in agricultural extensification practices which involve farm expansion through extensive clearing of forests and vegetation cover on annual basis. This activity coupled with perennial bush fires destroy forests and the general vegetative cover leading to depletion of soil nutrients, forest resources, land degradation and contamination of surface water bodies.

Table 6. 1: Distance of farmlands from home in Sissala East (n = 152) and Lawra (n = 153) Municipalities

Variable	**Sissala East Municipal**		**Lawra Municipal**	
	Frequency	**Percent**	**Frequency**	**Percent**
Near home (backyard)	13	9	133	87
Far from home (bush Farms)	111	73	14	9
Both (backyard and bush)	28	18	6	4
Total	**152**	**100**	**153**	**100**

Source: Field Survey, 2020

In Lawra Municipal where farmers were predominantly engaged in backyard farming, the findings show that arable land was scarce and land acquisition for farming was a difficult task due to the competing demand for residential purposes in families. The implication is that land for agricultural purposes in the communities in the Lawra Municipality is becoming limited due to population growth in families that require more settlement infrastructure. This requires that state departments and NGOs need to intensify education and training of smallholder farmers on climate compatible practices including ecological and sustainable agriculture intensification practices to sustain food production and security. There is also the need for investment in irrigation along the Black Volta River catchment to keep farmers in business all year round and ensure household food security.

In Sissala East Municipality, the findings show that farmers have access to vast arable land and that farmers can expand the sizes of their farmlands every year. They cultivate far away from their settlements for reasons that domestic animals do not destroy farm crops. Secondly, they cultivate far away from their settlements in search of more fertile lands (virgin lands) to cultivate to maximise yields. Families in Sissala East Municipality own vast pieces of land which can easily be acquired for farming purposes. It was observed that lands were released to friends and relatives, irrespective of which community they come from, for farming purposes without stiffer terms and conditions. The findings show that both male and female farmers had their farms located either far from their settlements (bush farms) or located at the backyard of their settlements (backyard farms) in the study communities. This departs from the findings of Perez et al. (2015) who had earlier found that female farmers within the Lawra-Jirapa area of North-western Ghana were engaged in backyard farming while male farmers were farming far away from homes. In all the three study communities in the Lawra Municipality, farms are located behind their settlements, a reason for the dispersed settlement pattern in the area. Land acquisition for farming in both municipalities was predominantly through family inheritance (76%). Land could also be gifted (18%) to friends and other relations while it could be temporarily (6%) released to friends and other people for farming purposes exclusively. Other means of acquiring farmlands such as sharecropping, renting, and purchased lands were not practised in the study communities.

6.2.2 Sources and access to weather and farming information

The study explored the sources of weather and farming information and how smallholder farmers in North-western Ghana access information on farming activities. Smallholder farmers access weather and general agricultural information from two major sources of knowledge namely scientific and indigenous knowledge. Farmers mostly combine both knowledge systems for weather and related information to undertake agricultural activities. It emerged that 70.5% of the respondents of the survey adopted the application of both local and scientific knowledge systems in their farming activities. Weather information on rainfall and the planting season are determined based on a combination of local and scientific means. This means that smallholder farmers are becoming aware of the increasing threats of climate change on the efficacies of both local and scientific knowledge and hence are becoming aware of the need to integrate knowledge systems for effective climate change adaptation. Furthermore, 28.5% of the respondents were relying solely on the application of LIK, while one percent relied absolutely on the application of scientific knowledge for farming. Thus, in promoting climate compatible agricultural practices and technologies in North-western Ghana, most smallholder farming households adopted both scientific and local knowledge systems in their agricultural activities. This combination is intended to improve the strengths of each of the knowledge systems as well as to compensate the weaknesses associated with each of them to enhance agricultural sustainability.

It also emerged that despite the fact that smallholder farmers receive weather and other extensions from community radio stations and extension agents, they complement these sources with traditional means such as observing the behaviour and activities of certain plants, insects, birds, clouds, stars, etc. A participant in Lawra Municipality noted that:

> *"We observe the behaviour of some birds and insects to crosscheck the information we sometimes receive from agricultural extension officers, and what we hear from the FM [radio] stations concerning rainfall pattern and farming. If the agricultural extension officers tell us that this year the rains will be plenty, we check by observing how weaver birds make their nests on trees at the banks of rivers. If the nests are high, then the rains will be plenty and if the nests are hung low to water level, then the rains will be low. We can also observe the positions of some known stars in the sky, and some insects. We do not want to fail in our farming activities because these days the systems for prediction are not much reliable and many times, we hear that the rains will start early but they never did"* (Excerpt from In-depth interview, Kalsagri community 2020).

Another participant in Sissala East Municipal revealed that the changes in climate and ecosystem features including disappearance of certain plants and living organism species in recent years were significant reasons for the need to support LIK with modern (scientific) knowledge systems.

> *"These days many of the organisms and plants we used to observe to predict the rainfall pattern and the likely effects on crop yields have disappeared due to our own [human] activities. We have jumped to the use of modern practices and technologies without understanding their proper usage and the repercussions of continuous usage. During the time of our fathers and our time, we did not know 'condemn' (herbicides) and we never used them. We did not use tractors, [chemical] fertilizer and pesticides on our farms as done today. Too much use of these things among farmers in recent years has killed many insects and other organisms that were instrumental in helping us to observe the weather pattern. This is why we rely both on what we observe from the environment and what we hear on radio and from agriculture extension officers for our farming activities. Even the whiteman's [scientific] ways of predicting the rains are failing us; and this makes it more important for us to blend the two"* (Excerpt from In-depth interview, Nabugubelle, 2020).

There were spiritual means of forecasting rainfall pattern mostly through deities such as the rain god and other smaller deities. Some sacrifices are usually made by the earth priests (*Tendana* and *Jantina* in Dagaare and Sisaali languages respectively) to the gods and ancestors as a form of a call to them for good rains and good farming season. The actions of the fowls slaughtered were used to determine the pattern of the rains for the farming season. Consultations with soothsayers were other means of forecasting the farming season and the types of crops to cultivate for the season. Thus, smallholder farmers in North-western Ghana still have demonstrable strong attachment to the application of indigenous knowledge on one hand and integrating scientific knowledge into LIK for accessing farming information.

Smallholder farmers are usually conscious of the increasing impact of climate change and hence are equally conscious of the approaches they adopt to respond and build resilient livelihoods systems. Therefore, they are not oblivious of the fact that relying on one source to access agricultural and weather information may be highly risky to agricultural planning as it may not provide accurate information to farmers. This implies that farmers employ both systems not only to provide relatively reliable and accurate information but to reduce the risk of failure of farming systems due to changes in weather elements such as rainfall. Therefore, smallholder farmers are not detached from the use of scientific and/or formal sources of weather information in addition to their own knowledge systems which they are convicted by and have employed for several decades in their farming history.

There is an increasing need for smallholder farmers to blend indigenous and scientific sources of information considering the growing threats of climate and environmental changes on local means of weather and related forecast for agriculture. The traditional means of predictions are increasingly threatened by the unsustainable actions of humans that result in the disappearance of some species of plants, shrubs, insects, and other organisms which play a significant role in indigenous forecast of weather events, particularly rainfall. Thus, the potency of traditional forecasting was threatened by the unsustainable practices of farmers, which contribute to climate and environmental change as indicated by Mutegi et al. (2018) and Angula and Kaundjua (2016). Unsustainable practices such as the indiscriminate and excessive use of the chemical inputs such as fertilizer, pesticides, herbicides, insecticides, as well as farm machineries have the tendency of exacerbating climate change through emissions of significant volumes of GHGs such as carbon dioxide, methane, and nitrogen oxide into the atmosphere as explained in Chapter Two (section 2.3). These actions also defeat the notion of smallholder farmers of being innovators, and knowledge generators known for their effective incorporation of traditional farming models into modern ones to sustain agricultural production as intimated by Falconnier et al. (2018).

Although, most farming households indicated a blend in the application of knowledge systems in agriculture, there were some households which relied solely on the use of indigenous knowledge for agricultural activities. This suggests that smallholder farmers in North-western Ghana were still inseparable from the use of indigenous knowledge in accessing agriculture and weather information at the household level. This is because the majority of smallholder farmers in North-western Ghana have low levels of education and therefore lack the basic understanding of modern agricultural practices, technologies and scientific forecast information. To this end, smallholder farmers tend to see scientific forecast information as mostly inaccessible, inconsistent, and unreliable within their context. This corroborates Davies et al. (2019) who found smallholder farmers in Namibia relied extensively on their traditional calendar dates for agricultural activities because of some perceived inconsistencies associated with scientific information. Moreover, Selato (2017) reported that farmers in Bobirwa sub-District in Botswana relied on indigenous forecast systems because they did not trust the accuracy and reliability of scientific forecast information. The various sources through which smallholder farmers access weather information for planning and making agricultural decisions are shown in Table 6.1. The respondents were asked to tick all applicable sources of weather information available to them.

Table 6. 2: Sources of weather information to farmers (n = 305)

Source	Frequency	Percent
Radio	274	90
Television	95	31
Agricultural extension officers	178	58
Observing behaviour and activities of birds, trees, insects, clouds, etc.	300	98
Mobile phones	30	10
Farmers group meetings	102	33
Friends	214	70
Family members	266	87
Social media	20	7

Source: Field survey, 2020.

As reflected in table 6.1, an overwhelming 98% of the respondents indicated that they observe the behaviour of trees, insects, animals, birds, etc. to gain insight on the weather pattern for their farming activities. Also, it was revealed that community radio stations (90%), family members (87%), friends (70%) and agricultural extension officers (58%) were major means for accessing weather and extension information among smallholder farmers in North-western Ghana. The utilisation of mobile phones (10%) and social media platforms (7%) such as WhatsApp groups, Facebook, Twitter, etc. were the least sources of gaining weather and other related information.

Smallholder farmers predominantly rely on the observation of changes in activities and behaviour of plants, insects, birds, animals, clouds, direction of winds, pattern of rains, positioning of stars in the sky at night to predict the weather for their farming activities. Generally, smallholder farmers in North-western Ghana and SSA are mostly disadvantaged in terms of accessibility to scientific meteorological forecast information as well as improved services due to their poor socio-economic backgrounds as earlier intimated in Chapter Three (see section 3.5). Thus, rainfall and temperature patterns in North-western Ghana are still predominantly predicted among farmers through observing the time certain plants shed leaves, flower, and fruit; the singing, appearance, disappearance and south-north movement of certain birds and insects. The position, movement, and direction of some weather elements such as clouds, stars, wind direction are also elements for prediction. It was revealed that the primary means by which farmers access information was by observing natural phenomena within their immediate environment. A participant noted that there were various means of accessing information within their context as individuals who lack adequate access to improved agricultural extension services.

> *"As farmers, we depend on many sources for information for our farming activities. Our primary source is to rely on what our grandparents and parents taught us, that is, to observe some trees, insects, activities of birds and animals as well as the clouds and stars in the sky to predict how the rainfall pattern for the year will be like. There are different species of trees that we observe to know whether the rains will be too much, or too little. The flowering, shedding of leaves and fruiting of some trees tell us the pattern of the rainfall, and the phases of farm activities on our farming calendar. When blackberries fruit plenty, then the year will record heavy rains. The shedding of leaves of rosewood is an indication of the end of the rainy season and late droughts, and what this means is that farmers who cultivate late will suffer yield loss. Also, yam farmers will have to be getting ready to raise yam mounds before their fields get dried. It also gets us prepared for the harmattan season and bushfires. Throughout my life as a farmer, I have observed these things to plan my farming activities, and I never failed in my farming history. I still advice my children on farming activities based on these observations. So, my children combine my advice and what they learn from friends and the agricultural extension workers to plan their farming activities. They have always believed and appreciated what I tell them. I remember, one of my sons telling me that he trusted what I tell them than what the extension officers sometimes tell them"* (Excerpt from In-depth interview, Dolibizon 2020).

Some smallholder farmers still trust their indigenous means of forecasting weather and farming information despite the threats posed by climate change and variability. Mase et al. (2017) indicated that smallholder farmers mostly rely on local and indigenous knowledge than scientific knowledge to understand, predict, interpret, and respond to climatic changes at the household and community levels. Arbuckle et al. (2015) also related that the ability of farmers to forecast and predict weather events is greatly hinged on the trust in their personal observations and experiences of the phenomena within the environment in which they live. In SSA and Africa in general, the observation of local phenomena such as clouds, trees, insects, birds, animals, wind direction, etc. for predicting and interpreting weather patterns (mainly rainfall and temperature) have been extensively discussed in Chapter Three (section 3.4), of which the findings of this study corroborated.

Community radio stations were found in the capital towns of the municipalities and served as significant means for disseminating information including weather and general agriculture information to smallholder farmers and the public in North-western Ghana. There were three community radios in the two municipalities at the time of this study was conducted: one in Tumu, the capital town of Sissala East Municipal and two in Lawra town, capital of Lawra Municipal. These radio stations had wide coverage in their respective municipalities and had thousands of listeners. The respective local languages namely *Sisaali* and *Dagaare* were predominantly used in the dissemination of information and discussions on most programmes at the stations. Many households owned radio sets for listening to local news, announcements, talk-shows including agricultural programmes on the radio stations in both municipalities.

Agriculture extension workers were obtaining weather forecast information and other extension services to farming households through community engagements and field visits where they engage smallholder farmers in the form of community durbars and farmer group meetings. These platforms were useful avenues for informing and educating farmers on new and sustainable farming practices such as the adoption of new crop varieties, when and how to plough farm fields and sow/plant based on meteorological forecast information, and proper use of farm inputs such as fertilizer, pesticides, herbicides, etc. Farmers were also sensitised and educated on improved farming practices by extension workers through field visits. An extension worker noted that *"we visit communities and farms within our respective jurisdictions to sensitise and educate farmers on best farming practices based on the forecast information we receive from the Ghana Meteorological Agency at the beginning of every farming season"* (Excerpt from In-depth interview, Lawra Municipal Assembly, 2021).

the study further reveals that, social functions such as funerals, festivals, markets, prayer grounds (mosques, churches, and shrines) serve as additional avenues where smallholder farmers obtain and share weather and farming information. A discussant had this to say:

> *"As farmers we share any information that relates to farming with our relatives and friends when we meet in occasions such as funerals, marketplaces, weddings, and prayer grounds. Many of us also listen to FM (radio) stations to get information about the rainfall pattern for the farming season. We listen to the extension officers any time they go to talk about farming on radio. Those who have television sets and understand English get weather information every day during news on television. The information is then shared with friends and relations. We do not keep information to ourselves as farmers when we get it"* (Excerpt from FGD, Nabugubelle 2020).

The fact that farmers share information among themselves can served as a window for achieving farmer capacity development through framer-field schools and other related platforms for training farmers on improved access to and use of meteorological information in North-western Ghana.

Low level of formal education among the majority of smallholder farmers in North-western Ghana has been a significant barrier to accessing weather information and other extension services through mobile phone platforms such as short messaging services (SMS) and related social media platforms such as Facebook, WhatsApp, Twitter, etc. They are unable to read messages on mobile phones and social media as well as use weather applications on android mobile phones and related devices for accessing weather information and alerts. Agula et al. (2018) observed that low level of education among smallholder farmers has been a major hindrance to accessing weather and related information in northern Ghana. This is particularly of grave concern because weather forecast information in Ghana is mostly communicated in the English Language on televisions and through press releases from Ghana Meteorological Agency. This makes it difficult for farmers to understand and utilise such information. Many households do not also own televisions because of inadequate household finances. Meanwhile, access to weather information is important for making farming decisions. According to Wood et al. (2014), smallholder farmers in SSA can make significant changes to farming practices if they have adequate access to weather information.

6.2.3 Hybridisation of crop and livestock production

Crop hybridisation and diversification

Smallholder households cultivated different types of crops such as cereals: maize, millet, sorghum, and rice; roots and tubers including yam, potatoes, and cassava; and leguminous crops such as groundnuts, beans, sesame, soya beans and bambara beans as shown in Table 6.3. It was found that these crops have different vulnerability and adaptive levels to climatic shocks and stressors. Therefore, diversifying the types of crops cultivated meant that smallholder farmers were indirectly and strategically reducing the levels of crop vulnerability and crop failure to climate change. They are also able to reduce crop vulnerability to floods and patches of droughts through the adoption of some improved crop varieties that were early maturing and friendly to intermittent dry conditions. That is, smallholders tend to hybridise crops cultivation by adopting improved varieties while maintaining some indigenous ones too. Different crops respond differently to different extreme events. Therefore, farmers are able to reduce the impacts of climate change and avoid crop failures through the cultivation of different varieties of crops. This enables farmers to sustain productivity to ensure household food security and income.

Table 6. 1: Types of crops cultivated by households (n = 305)

Crop	**Frequency**	**Percent**
Maize	300	98
Sorghum	167	55
Rice	66	22
Millet	61	20
Yam	140	46
Beans	134	44
Soya beans	92	30
Groundnuts	285	93
Potatoes	47	15
Cassava	43	14
Cotton	4	1
Bambara beans	176	58
Sesame	78	26

Source: Field survey, 2020.

The results in Table 6.3 were multiple responses from the respondents where they were asked to indicate all the applicable crops that they cultivate in their households. Among the cereal crops cultivated (in Table 6.3), maize was cultivated by an overwhelming majority of 98% of the respondents, followed by sorghum (55%), rice (22%), and millet (20%). In northern Ghana, *tuo zaafi* (popularly called T.Z) is the staple food of the people, which is eaten every day in traditional homes. T.Z. is prepared from maize. It is locally known as *kulung* in Sisaali and *sau* in Dagaare languages respectively. Although, it can be prepared from other cereals (such as millet and sorghum), maize has become the commonest cereal used for preparing it in households in recent times. This is similar to Saalu, Oriaso and Gyampoh (2020) who found that maize was used among the people of Abaluhya in Buyangu community of Kenya to prepare their local *Ugali* staple meal. According to Hengsdijk et al. (2015), maize cultivation is a major food crop activity among smallholder farmers in SSA. Also, Kupika et al. (2021) in their study found that 72% of smallholder farmers in communities within the transition zone of the Middle Zambezi Biosphere Reserve in northern Zimbabwe were engaged in maize farming.

Among the roots and tuber crops, the results show that yam (46%) was the most cultivated tuber crop among households than potatoes (15%) and cassava (14%) crops. Yam is eaten in different forms in households both at home and on the farm. Therefore, every household may aim to cultivate yam for this purpose as well as for sale to augment household income. With leguminous crops, 93% of the respondent households cultivated groundnuts, 58% cultivated bambara beans, 44% cultivated beans (white beans and cowpea), 30% cultivated soya beans, and 26% cultivated sesame. Groundnuts were the most cultivated leguminous crops among smallholder farming households in North-western Ghana. Except for the cultivation of yam, potatoes and sesame, women were actively involved in the cultivation of other food crops, most especially leguminous and vegetable crops for both household food supply and income. The cultivation of sesame crops was common among households in Sissala East Municipality, where it was mostly cultivated as a household cash crop. The produce was mostly sold at Leo market, a border community in neighbouring Burkina Faso. It was also sold to retail businessmen and women who export it to Burkina Faso for sale. Sesame production was an emerging income generating activity among farmers, particularly young farmers, in Sissala East Municipality due to its current good market price. Households also cultivated vegetables such as okro, pepper, garden eggs, tomatoes, cabbage, etc. for both household consumption and income.

From the foregoing analyses, it emerged that smallholder farmers cultivated a mixture of crops concurrently on their farms. This is corroborated by other scholars which indicated that smallholder farmers in Africa are mostly engaged in the cultivation of maize, yam, millet, sorghum, rice, tomatoes, cabbage, and potatoes for household food and income (Kupika et al., 2019; Ayanlade et al., 2017; Elum et al., 2017). The findings also corroborate Rawe et al. (2015) who indicated that smallholder farmers, including female farmers, in the northern Ghana are mostly engaged in the cultivation of a mixture of cereal crops such as millet, sorghum, and maize. Also, Saalu et al. (2020), reported the cultivation of maize, sugarcane, tomatoes, beans, sweet potatoes, cassava, cabbage, and some indigenous vegetables among smallholder farmers in Kenya.

There were some significant dynamics in interfacing LIK and scientific knowledge in the cultivation of crops among farming households. These dynamics reflected some commonalities and differences in cropping and practices among smallholder farmers within the context of climate change adaptation. Most smallholder farmers have shifted from the cultivation of some indigenous types of crops to the cultivation of improved seed crops as response to climate change and variability. It was observed that indigenous varieties of food crops were becoming less common among households, and some farming households had completely abandoned the cultivation of most indigenous staple food crops because the development, growth and yields of these crops were perceived to be poor under current climatic conditions. It emerged that 65% of the respondents indicated that as having changed and/or stopped the cultivation of at least one indigenous crop in their households because such crop varieties were not yielding well under current climatic conditions. The growing variability in rainfall, temperature and diminishing soil fertility were adversely affecting the growth and yields of many indigenous crops in North-western Ghana. Meanwhile, 35% of the respondents never ceased cultivating any indigenous crops due to climate change. It is important to mention that households interface the cultivation of improved crops with some indigenous crops such as groundnuts, millet, bambara beans, and red sorghum. These indigenous crops were noted for their resilience to dry spells, and pests and insects. However, the yields from these indigenous crops were relatively low and fluctuate on yearly basis. Although, the indigenous millet crop is known for its ability to withstand low rainfall conditions, yields have been poor compared to yields some decades ago. Consequently, households tend to adopt different crop varieties that are high yielding (91%), early maturing (82%), drought-resistant (41%), water loving (13%), and can withstand the impacts of pests and diseases (23%). These were strategies that were applicable to households in a multiple manner where some households could adopt two or more of the strategies.

Across the study communities in the two municipalities, the results in Figure 6.1 show that some households were no longer cultivating millet (53%), sorghum (43%), cowpea (54%), rice (43%), bambara beans (12%), yam (32%), and potatoes (31%) due to climate change. Here, the respondents indicated all the applicable crops that their households were no longer cultivating due to climate change impacts.

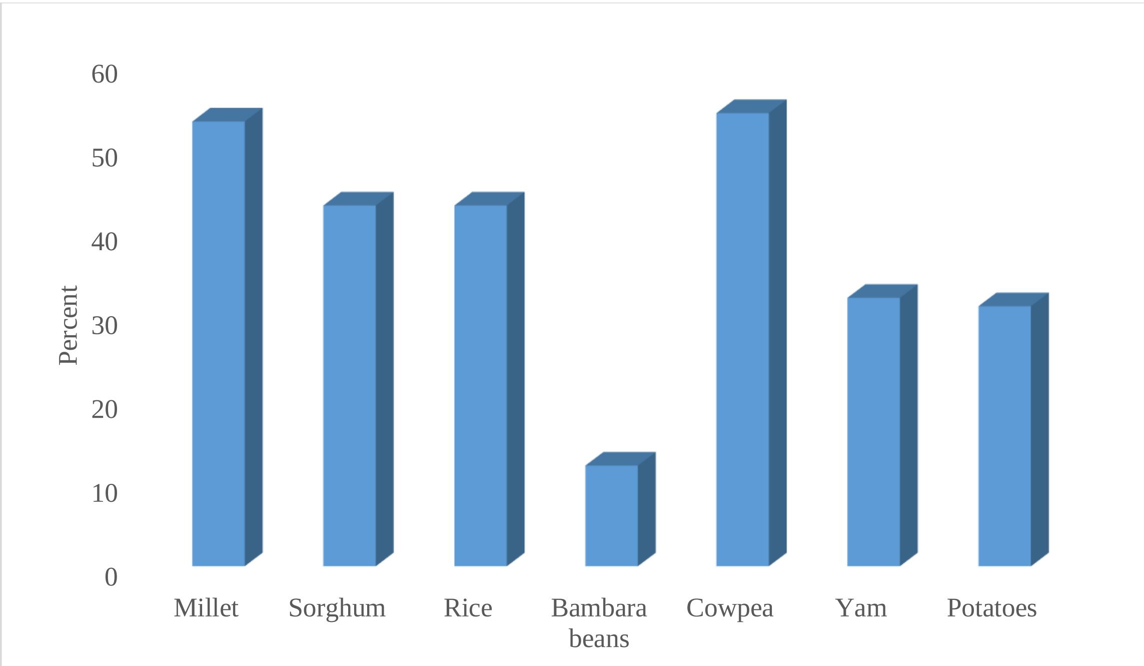


Figure 6. 1: Change in types of crops cultivated (n = 305)

Source: Field survey, 2020

It is however important to note that sorghum was a major staple crop cultivated in the Lawra Municipality. it was found that there were significant varying choices in the two study municipalities and no respondents in Lawra Municipality stopped the cultivation of sorghum and bambara beans unlike in Sissala East Municipality where 86% and 24% of the respondents indicated as having shifted away from the cultivation of sorghum and bambara beans respectively.

The differences can be attributed to differences in ecological, climatic, and socio-cultural factors. The ecological and climatic factors focus on the nature of the landscape, soil fertility, vegetation cover, rainfall, and temperature. As noted earlier, Lawra has inadequate arable land which generally is rocky with low soil fertility to promote all kinds of crops. The nature of the land also makes it more vulnerable to rainfall variability and consequent hazards such as dry spells and floods. The soil in Lawra is more suitable to produce sorghum, beans, and groundnuts than maize, rice, and yam. Particularly in Sissala East Municipal, the cultivation of millet, sorghum, and cowpea were very low although these crops were staple crops during the past four decades. Meanwhile, in Lawra Municipal sorghum farming was very common among farming households. It was observed that sorghum and beans were mostly used for preparing the favourite *pito* (locally brewed beer) and *kosie* (locally made bean cakes) by the people in Lawra Municipal and by extension the Dagaaba in North-western Ghana.

In Sissala East Municipal, all the household respondents (100%) indicated they stopped or changed the cultivation of at least one type of indigenous crop in their households due to changes in rainfall pattern and soil fertility which adversely affect their yields. Farmers, however, adopt the cultivation of a mixture of some indigenous and improved crop varieties. In Lawra, only 30% of household respondents indicated as having stopped the cultivation of at least one type of indigenous crops while the majority (70%) were cultivating indigenous crops with improved crops. Thus, households in both municipalities were interfacing the cultivation of indigenous crops with improved varieties to maximise productivity under climate change. Crops such as groundnuts, millet, bambara beans, and red sorghum (popularly called guinea corn) were mostly known to be indigenous crops which have not been modified into a new variety for smallholder farmers. These crops were more adaptable to the current rainfall regime as well as other climatic and non-climatic shocks and stressors. The indigenous cereal crops were mostly perceived to have a longer maturity rate, and low yielding crops but were known for their resilience to droughts and pests' attacks. There were no readily available improved varieties of these crops to farmers unlike maize, (white) sorghum and rice crops. There were different improved varieties of beans, soya beans, potatoes, and yam available to farmers which were high yielding, and early maturing.

Maize has many different improved varieties. Smallholder farmers could acquire these mostly through the out-grower model of farming. There were many varieties of maize cultivated by smallholder farmers particularly in Sissala East Municipality where maize cultivation has become the most cropping activity among farming households. These varieties were high yielding, drought resistant and mature within two-three months. The rise to prominence of maize farming in Sissala East was mostly attributed to the increasing availability and accessibility to improved varieties of maize, coupled with their suitability with the land and/or soil and climatic conditions in the area. According to an extension officer of the Department of Agriculture in the Sissala East Municipal Assembly

> *"Maize is a simple crop to cultivate unlike other cereals. It is easy for farmers to get new variety of maize crop from different sources; they can get them from us (MoFA), out-growers, and many other seed companies. Almost every year, new maize varieties are developed for framers. The most important thing is that the land here [Sissala East] is very good (fertile) for maize farming; with the new improved varieties coupled with little application of fertilizer, farmers get higher yields from their fields despite the variability in rainfall pattern"* (Excerpt from In-depth interview, Extension officer, Sissala East Municipal, 2021).

Similarly, the Municipal Development Planning Officer of Sissala East Municipal Assembly indicated that the Municipal Assembly through the Department of Agriculture has made available different maize and other crop varieties to smallholder farmers under the 'Planting for Food and Jobs' programme of the Government of Ghana. He further indicated that the activities and processes involved in the cultivation of maize were not so cumbersome, and thus, enhanced active participation of women in maize farming in the municipality. He noted that,

> *"The Sissala East Municipality has vast land suitable for food crop production. This municipality is the food basket of the Upper West Region and among the high food production areas in northern Ghana. Over the past years, maize production has increased because of the suitability of the land coupled with different varieties that match the current rainfall regime. This is the reason why many out-grower companies are found in this municipality in the [Upper West] Region. Also, the activities and processes involved in maize cultivation are not very difficult unlike millet and other cereal farming. Maize farming is as simple as groundnut farming. This is the reason why many women are doing well in maize farming in this municipality. In fact, the [Sissala East Municipal] assembly has prioritised women farmers under the Planting for food and Jobs programme where we [Sissala East Municipal Assembly] assist them with inputs such as the seeds, fertilizer, and extension services"* (Excerpt from In-depth interview, Municipal Development Planning Officer, Sissala East Municipal Assembly, 2021).

Maize farming has become a major source of household food supply as well as source of income to majority of smallholder farmers in Sissala East Municipality in particular. It has become partly commercialised by some private individuals and households which has increased the levels of production in the municipality. Sissala East Municipality has vast arable land which gives farmers good yields. This has the potential of boosting and sustaining household food security and income. There is the potential to reduce household poverty in the municipality through sustainable maize production. This has engaged many young men and women in farming to improve their lives over the years. However, the over concentration on maize farming has adversely affected the production of other cereal crops such as sorghum, millet, and rice in the Sissala East Municipality. Yam, cassava, potatoes, and other food crop production have declined due to the unbalanced preference of farmers for maize cultivation. This could become disastrous for the entire municipality should there be a significant failure in the yields of maize due to failure in rainfall and other production factors.

On the contrary, sorghum farming was a popular cropping activity among majority of the households in the Lawra Municipality. There was a popular improved variety of sorghum known locally as *kampaala* and otherwise referred to as *dorado* which was cultivated in addition to the indigenous variety known as guinea corn. The cultivation of maize and millet were significantly low among households compared to sorghum in the Lawra Municipality. Millet farmers were still using the indigenous variety which has an extended maturity period and relatively low yielding potential under current climatic conditions. Sorghum has been a single cereal crop that can yield significantly to feed their families without (chemical) fertilizer application. It is a crop that was suitable to the soil and climatic conditions in both municipalities except that, farmers in Sissala East concentrated on maize farming to the disadvantage of other cereal crops. Meanwhile, millet was the most cultivated crop by households in both municipalities in the 1990s. There was no known improved millet variety available to farmers in the study areas at the time of this study. This might have accounted for the low numbers of farmers who cultivated millet in recent years.

According to the Lawra Municipal Director of the Department of Agriculture, there has been the absence of a popular millet variety for farmers in comparison to other crops, and that there was only the indigenous millet available to farmers. It was revealed that sorghum has two known improved varieties in addition to the indigenous red sorghum (guinea corn) for farmers. The *kampaala* and *dorado* were white-seeds sorghum with short maturity period and with high yields potential for farmers. Sorghum is the major cereal mostly used for brewing of *pito* which is a common local beer to the Dagaaba people.

> *"Sorghum farming is more common among the farmers in this [Lawra] municipality than any cereal crop. Unlike in the Sissala area where the land is very fertile to produce all kinds of crops, the land here is not fertile enough. Maize farming is not taken seriously here. It is these years that farmers are even cultivating maize because of the inputs we [Department of Agriculture] give them under the planting for food and jobs programme. But this is not enough to turn farmer here to maize farming. Sorghum, groundnuts, and bambara beans are the major crops cultivated here because they do better with the soils here"* (Excerpt from In-depth interview, Municipal Director of Agriculture, Lawra Municipal Assembly).

Generally, smallholder farmers embrace the cultivation of a mixture of crops with much concentration for crops that adapt well to the current local environmental and climatic conditions. Traditional households cannot detach themselves from the cultivation of indigenous crops because of socio-cultural reasons. It was found that indigenous crops were used for performing socio-cultural and traditional functions such as funerals, sacrifices to deities, traditional marriages, naming ceremonies and other cultural activities in the household and community levels.

The differences can be attributed to differences in ecological, climatic, and socio-cultural factors. The ecological and climatic factors encompass the nature of the landscape, soil fertility, vegetation cover, rainfall, and temperature. As noted earlier, Lawra has inadequate arable land which generally is rocky with low soil fertility to promote all kinds of crops. The nature of the land also makes it more vulnerable to rainfall variability and consequence hazards such as dry spells and floods. The soil in Lawra is more suitable for the production of sorghum, beans, and groundnuts than maize, rice, and yam. Particularly in the Sissala East Municipal, the cultivation of millet, sorghum, and cowpea were very low although these crops were staple crops during the past four decades. Meanwhile, in Lawra Municipal sorghum farming was very common among farming households. It was observed that sorghum and beans were mostly used for preparing the favourite *pito* (locally brewed beer) and *kosie* (locally made bean cakes) by the people in Lawra Municipal and by extension the Dagaaba in North-western Ghana.

Livestock rearing

Farmers were also engaged in the rearing of livestock and poultry as complementary activity to food crop farming. Livestock rearing and crop farming were simultaneous livelihood activities that depicted more of a traditional activity than just an adaptation strategy. Indeed, the results of the study show that almost every household reared at least one type of bird such as fowls, guinea fowls, ducks, and turkeys and one type of an animal such as cattle, goats, and sheep. The rearing of non-ruminants such as pigs and donkeys in addition to food crop farming was also practiced. Households mostly prefer indigenous poultry and livestock for various reasons including the fact that indigenous livestock are more adaptable to local environmental conditions. Indigenous livestock are also used for cultural and traditional purposes. Table 6.4 shows the various livestock reared by smallholder households in the study communities. Note that the respondents were asked to indicate all applicable livestock that they rear in their households.

Table 6. 2: Livestock reared by Households (n = 305)

Livestock	**Frequency**	**Percent**
Cattle	181	59
Goats	243	80
Sheep	131	43
Donkeys	47	15
Pigs	115	38
Fowls	296	97
Ducks	43	14
Turkeys	16	5
Guinea fowls	168	55

Source: Field survey, 2020

From the table, the majority of the respondents (97%) were engaged in rearing of fowls, 55% were rearing guinea fowls, 14% were rearing ducks and five percent reared turkeys. In terms of rearing of ruminants, 59% of respondents reared cattle, 80% engaged in the rearing of goats, and 43% reared sheep. Also, 38% and 15% of the respondents were engaged in the rearing of pigs and donkeys, respectively as non-ruminants. It was observed that the rearing of pigs was common among households in Lawra Municipal than in Sissala East Municipal. This is because pork is a delicacy among the Dagaaba tribe which formed the majority of the respondents in Lawra Municipality.

Livestock and poultry were reared for several purposes including exchange for food items, sale for income, payment of dowries, performance of ceremonies including marriages, child naming, funerals, and festivals. It was also revealed that livestock was reared for purposes of prestige in the family and community as well as for purposes such as outdooring of chiefs and other traditional leaders, performing of sacrifices to gods and ancestors, among other purposes. Donkeys were reared for three major purposes: (1) for carrying goods (loads); (2) for sale for household income; and (3) for exchange (barter) for other animals and food stuff for household consumption. Donkeys were not reared for meat in North-western Ghana as practiced in some parts of northern Ghana.

To this end, smallholder farmers in North-western Ghana basically interfaced crop farming with livestock rearing concurrently to sustain agriculture and household food security. Guodaar et al. (2021) indicated that the integration of livestock and poultry rearing with crop farming is an important livelihood activity among households in northern Ghana. Households sell animals and poultry for income to provide for educational and health needs of family members. It was revealed that there were some traditional and cultural reasons for engaging in poultry and livestock rearing. Traditionally, poultry and livestock are used for making sacrifices to ancestors and smaller deities (gods) at the individual, family, and community levels. They are also used for performing rites such as marriages, funerals, naming ceremonies, outdooring of chiefs and other traditional leaders including earth priests and priestesses. Besides, during religious occasions such as Christmas and Easter by Christians, and Idul-Fitr and Idul-Adha by Muslims, some of the livestock are sacrificed for consumption and sharing among neighbours. It was further revealed that owning large kraals of cattle in rural communities was a sign of riches and a source of prestige to the household both within and outside of the community. These findings are similar with Davies et al. (2020) who in their study reported that livestock ownership in Namibia was a cultural practice and a source of prestige among smallholder farmers.

As indicated earlier, local breeds of livestock were more adaptable and resilient to the local climatic and environmental conditions, than exotic breeds. It was disclosed that the exotic breeds of sheep, goats, fowls, and cattle were very susceptible to local environmental conditions such as heat, heavy precipitation, pests, and diseases, among other conditions compared to the indigenous livestock. However, it was revealed that the exotic breeds were huge in growth and big in body size which attract good market prices over indigenous livestock. Consequently, most cattle owners in Sissala East mixed indigenous cattle with the Sahelian Fulani cattle to crossbreed. This resulted in most cattle in Sissala East communities being crossbreeds unlike in Lawra Municipal. The crossbreeds exhibit characteristics of both local and exotic breeds and are resilient and adaptable to local climatic conditions, pests, and diseases on one hand, and on another hand, have more weight and growth in body size to produce more meat and attract high market prices. On the other hand, indigenous small ruminants were preferred for reasons that they were resilient to local environmental and other hash conditions that the exotic sheep and goats cannot endure.

A farmer in Babile community in the Lawra Municipality revealed that,

> *"Our local sheep and goats do not easily fall sick as compared to the [exotic] ones that we buy from Burkina Faso. With those foreign ones, one can easily lose all your flock within a week or two. Our local livestock are more resistant to diseases, ticks, and snake bites. We spend a lot of money in vaccinating the foreign breeds to keep them healthy and alive. For our local ones [goats and sheep], many people vaccinate them once a year or they do not even vaccinate them at all. What some other people do is to buy the male ones [foreign breed] to crossbreed with our [local] female ones"* (In-depth interview, Babile 2020).

According to the participants, the meat of the local livestock was thicker and sweeter compared to the exotic breeds. It was also revealed that the exotic livestock including poultry could not be used for any traditional purposes such as sacrifices to deities and ancestors, funerals, and other traditional rites. However, there were few crossbreeds of goats and sheep in both municipalities with many households preferring the indigenous breeds to these small ruminants.

It was revealed during FGD that some NGOs in the past have tried to engage women in livestock rearing as an alternative livelihood venture through training and supply of exotic small ruminants (sheep and goats). However, these animals could not survive the local conditions, and many of the groups that were supplied lost their flocks. According to a female participant

> *"We [women] were given some giant sheep to rear as a group, but the animals could not survive the local conditions. They were frequently getting sick, and we invited veterinary officers to come and vaccinate them; yet many of them died. Later, we were*

> *supplied with local breeds of goats, and they survived. They reproduced and multiplied within three years which we sold some for income for our group activities. Later, thieves were stealing them, and we were compelled to sell them and used the money to open an account at Lawra Rural Bank for safe keeping"* (Excerpt from FGD, Eremon 2021).

Also, the local poultry was preferred because of their adaptability to local conditions as compared to foreign poultry. Another concern raised was the fact that it was very expensive rearing foreign poultry than local poultry. An important reason among many households was that the foreign poultry were not used for traditional activities such as performance of funeral rites, traditional marriage rites, sacrifices to deities and other traditional activities.

6.3 Household adaptation strategies to climate change and variability

There were various strategies by which smallholder farming households were adapting farming to climate change. Many of these adaptation strategies were mostly developed from the combination of LIKS and scientific knowledge systems. Farmers also adopted diverse strategies concurrently instead of adopting a single strategy in adapting to the growing impacts of climate change on smallholder farming. These adaptation strategies have been broadly categorised into two forms, namely farm-based and non-farm level-based strategies as shown in Table 6.5. This categorisation was also used by Aniah et al. (2019). Farm-based strategies are those that directly relate to farming activities while non-farm-based approaches are those that do not directly involve farming activities. It is important to note that respondents were asked to indicate all the applicable adaptation strategies to their households, and therefore, households could adopt more than one adaptation strategy.

Table 6. 3: Categorisation of adaptation strategies

s/n	Category	Strategies
1	Farm level-based strategies	Crop diversification, use of chemical fertilizer, mixed farming, use of improved seeds (early maturing and high yielding crops), crop rotation, mixed cropping, upland farming, flat ploughing, use of herbicides, use of pesticides and insecticides, ridging/mounding, use of compost/manure, multiple farm ownership, use of drought-resistant crops, farm rotation, agro-forestry, and dry season farming.
2	Non-farm level-based strategies	Seasonal migration, petty trading, reduction in the quantity and frequency in meals served in households per day, village savings and loans (VSLA), hunting, gathering of forest products

Source: Field Survey, 2020.

From the table above, the results of the survey show that the major non-farm level adaptation strategies were seasonal migration (75%) to other parts of the countries to engage in menial jobs, reduction in quantity and frequency of meals taken in the households (50.8%), petty trading (51%), village savings and loans (42%) and dry season gardening (39.7%). Agroforestry (21%) and gathering of forest products (28%) and hunting (13.8%) were also non-farm activities households embraced to adapt farming to climate change at the household level, as shown in Figure 6.2. Contrastingly, the farm-based adaptation strategies included crop diversification (100%), the use of chemical fertilizer (98%), mixed farming (99%), the use of improved seeds (97%) crop rotation (77%), mixed cropping (77%), upland farming (72%), flat ploughing (67%), lowland farming (36%) and the use of herbicides (65%) were some of the popular strategies among farming households in North-western Ghana. Others include the use of pesticides and insecticides (49.5%), ridging/mounding (47%), the use of compost/manure (43%), multiple farm ownership (45%), multiple farming (45%) and farm rotation (40%). Harvesting rainwater for farming purposes and crop insurance were not practiced by households. This suggests that these practices were less understood and known by smallholder farmers in North-western Ghana. These strategies should be explored by state agencies, NGOs, and other development partners as they have the potential of reducing the vulnerability of smallholder farmers to climatic shocks and stressors that adversely affect agriculture. Smallholder farmers should be educated and trained on rainwater harvesting techniques and government agencies should invest in the provision of rainwater harvesting infrastructure for farmers. Insurance companies should be engaged by the relevant stakeholders to ensure the institutionalisation of crop insurance policies for smallholder farmers.

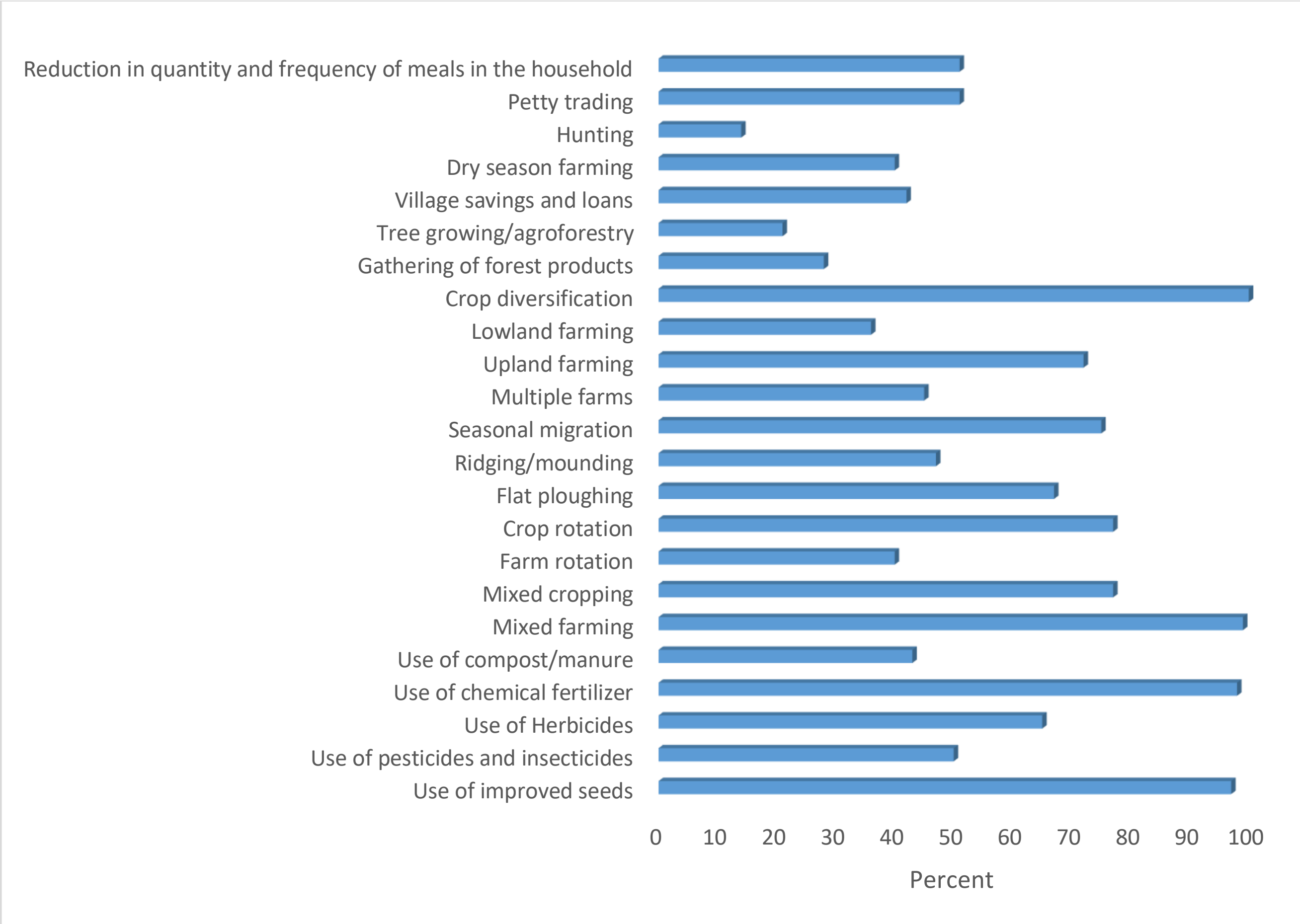


Figure 6. 2: Household adaptation strategies (n = 305)

Source: Field Survey, 2020

To summarise, households in North-western Ghana mostly adopt multiple strategies to adapt to climate change and to sustain agricultural livelihoods. Households were also adopting more farm-based adaptation strategies than non-farm-based strategies. These decisions to adopt multiple strategies were influenced immensely by the internal knowledge and mechanisms of households than external knowledge forces. However, many households were more influenced by their own knowledge systems than external scientific knowledge.

6.4 Conclusion

The chapter discussed how smallholder farming households interfaced local and indigenous knowledge with scientific knowledge in adapting agriculture to climate change at the household level. This was undertaken in three broad areas: sources and access to weather and agricultural information, interfacing knowledge within the context of multiple farm ownership, and hybridisation of crops and livestock at the household and community levels. It was established that smallholder households employed multiple strategies that were both farm-based and non-farm-based measures concurrently. Several of these strategies mirrored both local and scientific knowledge systems in their applications towards sustaining production and making agriculture climate compatible.

CHAPTER 7: DETERMINANTS OF FARMERS' DECISION TO ADOPT LOCAL AND INDIGENOUS KNOWLEDGE SYSTEMS FOR CLIMATE COMPATIBLE PRACTICES

7.1 Introduction

This chapter presents and discusses the factors influencing the decisions of smallholder farmers to adopt local knowledge for climate compatible practices in North-western Ghana. In adopting knowledge and practices to improve agricultural production and build resilience, farmers consider several factors at the household level. These factors are examined by exploring the level to which they influence the adoption decisions at the individual and household levels. They include accessibility, reliability, and awareness of the source of knowledge and information; access to farm capital and implements; land tenure, accessibility, farm size, and labour; the level of formal education, agricultural extension services; farmer-based demographic characteristics; landscape and distance; and socio-cultural beliefs. These factors are discussed in this chapter in relation to how they influence adoption decisions at the individual and household levels.

7.2 Accessibility, reliability, and awareness of sources of knowledge and information

Accessibility to the source of knowledge was an important factor that influenced the household decisions of farmers to adopt local and indigenous knowledge in the study areas. The majority of the respondents (87%) revealed that accessibility to the source of knowledge highly shaped their decisions to adopt LIKS for climate compatible agricultural practices at the household level. For the remaining 11% of the respondents, their decisions to adopt local and indigenous knowledge were not influenced by access to the source of knowledge but other factors. Meanwhile, only two percent of the respondents disclosed a lack of knowledge as a barrier to their inability to adopt LIK for climate compatible agricultural practices at the household level. In terms of scale, 64% of the respondents who revealed to have adopted LIK based on their access to the source of knowledge disclosed that they were highly influenced by this factor. However, about 21% disclosed that they were moderately influenced while 15% revealed that they were lowly influenced by the accessibility of the source of knowledge to adopt LIK. Further analysis of the results shows that the chi-square test of no association with respect to access to source of knowledge and a respondent's decision to adopt LIK was statistically significant (p-value < 0.05) in both municipalities as indicated in Table 7.1. This, therefore, implies that there is high likelihood that smallholder households will continue to rely on LIK for developing agricultural practices irrespective of whether LIK-based practices yield maximum results or otherwise so far as these are easily accessible to farmers. Therefore, although most smallholders tend to be influenced by varied factors to adopt LIK, such influences are often not the same but in turn vary from farmer to farmer. Overall, ease of access to source of knowledge in developing strategies may enhance mass adoption of LIK among smallholder farmers. This resonates with the findings of Nyasimi et al. (2017) who found that the use of CSA practices by smallholder farmers in Lushoto in Northeast Tanzania was influenced by access to the source of information about the practices. Kupika et al. (2021) also found that access to information by smallholder farmers significantly influenced their choices of adopting drought coping strategies in Bunyangu community in Zimbabwe.

Results from FGDs and face-to-face interviews revealed that LIK is a free source of knowledge to smallholder farmers which is usually transmitted from past generations to the current generation. Smallholder farmers held the view that local and indigenous knowledge was more accessible to them and their households at no cost to them. Since local knowledge is mostly transmitted from generation to generation through various social networks, smallholder farmers turn to have significant level of trust and in-depth knowledge on its applications and implications compared to scientific knowledge (Kolawole, Wolski, Ngwenya & Mmopelwa, 2014). A male discussant in Eremon community in Lawra confirmed that *"it (LIK) is our own knowledge, it belongs to us, and it is within our reach at any time. We know much about it unlike the Whiteman's knowledge (scientific knowledge)"* (Excerpt from FGD, Eremon, 2020). Similar views were shared in Nabugubelle community, during in-depth interview:

> *"Our own knowledge systems are available to us for free and one does not need any money to acquire it or any (formal) training on how to apply it. We got it from our grandparents and parents through our traditions and farming activities. I do not need to travel anywhere to learn and acquire it (LIK). That is why we rely on it for information on farming activities"* (Excerpt from In-depth interview, Nabugubelle 2020).

These foregoing revelations further reinforce how farmers' adoption decisions are shaped by their access to knowledge and the source of information. The findings resonate with Nyasimi et al. (2017) who indicated that farmers' decisions to adopt are significantly influenced by whether they have the requisite access to information and knowledge on how to employ climate compatible practices and technologies. Wood et al. (2014) also reported that access to information has a significant positive relation to smallholder farmers' adoption decisions in SSA.

The reliability of knowledge systems was found to significantly influence the adoption decisions of smallholder farming households. Many farmers turn to embrace practices and technologies that were much linked to knowledge sources that they perceived reliable in terms of their ability to understand and apply. The results show that an overwhelming majority of respondents (94.4%) indicated that their decisions to adopt LIK for developing climate compatible agricultural practices were because of its reliability. While about 2.6% of respondents indicated that the reliability of knowledge systems does not influence their adoption decisions, three percent indicated they were oblivious. Though all farmers were influenced in one way or the other, 66% indicated that they were highly influenced by the reliability of knowledge to adopt LIK; 27% were moderately influenced while seven percent were least influenced. Smallholder households in rural North-western Ghana have perceived local and indigenous knowledge to be more reliable than scientific knowledge because of their ability to easily understand and apply it in their daily activities. Hence, LIK has become the basis for smallholder farmers' adoption decision-making. This is consistent with Dube and Munsaka (2018) and Mase et al. (2017) as expressed earlier in this study (see Chapter 3, section 3.4). Furthermore, Davies et al. (2019) reported that the preference of smallholder farmers in employing traditional information for farming activities is as result of the perceived consistencies of LIK over scientific forecast information and knowledge.

A Chi-Square test analysis further revealed that the reliability of the source of knowledge was statistically significant (p-value < 0.05) with farmers' decisions to adopt LIK for developing agricultural practices in Lawra Municipal as indicated in Table 7.1. Meanwhile, in the Sissala

East Municipal, the decisions of all respondents to adopt LIK were influenced by its reliability, thereby making the result of the Chi-square test constant. Thus, smallholder farmers have developed a significant level of trust for the utilisation of LIK over scientific knowledge which has the tendency of affecting willingness to adopt scientific knowledge by smallholder farmers. Therefore, there is need for integration of LIK and scientific knowledge systems to localise climate compatible practices in terms of application and understanding of scientific knowledge and information among smallholder farmers in North-western Ghana.

The level of awareness on improved agricultural practices and technologies was found to be an important factor determining the adoption of practices among smallholder farming households. When farmers have a fair idea about a practice, and can understand its implications, they are able to make a decision on its adoption. It was observed that many farmers were usually reluctant in adopting agricultural practices and technologies that they were less aware of and/or had little knowledge about. About 97% of the respondents revealed that their decisions to adopt were influenced by their levels of awareness on the practices and technologies introduced to them while three percent were uncertain about the effects of awareness on their decision to adopt LIK. Amongst those who agreed of being influenced by their levels of awareness, 70% were highly influenced by their levels of awareness on those practices and technologies; 19% were moderately influenced while 10% of the respondents were less influenced by their awareness as critical for the adoption of LIK.

Generally, the findings suggest that farmers tend to adopt agricultural practices and technologies that are known to them than practices and technologies less known at the local levels. Silvestri et al. (2020) made similar observations where they realised that the adoption of sustainable agricultural intensification practices and technologies among legume crop smallholder farmers in Tanzania was much influenced by their levels of awareness on the practices/technologies available to them. Consequently, they concluded that the decisions to adopt improved agricultural practices and technologies were influenced by a high level of awareness and knowledge among smallholder farmers. Relatively, Baumuller (2018) who explored literature on the ‘Utility of mobile phone-enabled services for smallholder farmers’ found that low level of awareness on mobile phone use among women farmers usually results in minimal utilisation of the weather forecast and other related agricultural information received via mobile phone services.

Table 7. 1: Factors determining smallholder household adoption decisions (n = 305)

Factors	Lawra Municipal (n = 153)				Sissala East Municipal (n = 152)			
	Yes	**No**	**Don't know**	χ^2	**Yes**	**No**	**Don't know**	χ^2
Access to source of knowledge	136 (88.9%)	11 (7.2%)	6 (3.9%)	0.000	130 (85.5%)	22 (14.5%)	0 (0.0%)	0.000
Reliability of knowledge system	136 (88.9%)	8 (5.2%)	9 (5.9%)	0.000	152 (100.0%)	0 (0.0%)	0 (0.0%)	n/a
Land ownership	149 (97.4%)	4 (2.6%)	0 (0.0%)	0.016	140 (92.1%)	7 (4.6%)	5 (3.3%)	n/a
Size of farm	148 (96.7%)	5 (3.3%)	0 (0.0%)	0.006	132 (86.8%)	9 (5.9%)	11 (7.2%)	0.000
Size of labour	140 (91.5%)	13 (8.5%)	0 (0.0%)	0.000	136 (89.5%)	8 (5.3%)	8 (5.3%)	0.000
Level of formal education	141 (92.2%)	12 (7.8%)	0 (0.0%)	0.000	144 (94.7%)	8 (5.3%)	0 (0.0%)	0.026
Awareness of practice/ technology	145 (94.8%)	8 (5.2%)	0 (0.0%)	0.000	152 (100.0%)	0 (0.0%)	0 (0.0%)	n/a
Gender	141 (92.2%)	5 (3.3%)	7 (4.6%)	0.000	136 (89.5%)	4 (2.6%)	12 (7.9%)	0.001
Years of experience	135 (88.2%)	7 (4.6%)	11 (7.2%)	0.000	144 (94.7%)	8 (5.3%)	0 (0.0%)	0.000
Age of farmer	146 (95.4%)	7 (4.6%)	0 (0.0%)	0.001	152 (100.0%)	0 (0.0%)	0 (0.0%)	n/a
Access to credit	135 (88.2%)	12 (7.8%)	6 (3.9%)	0.000	135 (88.8%)	10 (6.6%)	7 (4.6%)	0.000
Access to land	153 (100.0%)	0 (0.0%)	0 (0.0%)	n/a	152 (100.0%)	0 (0.0%)	0 (0.0%)	n/a
Location of farm	134 (87.6%)	14 (9.2%)	5 (3.3%)	0.000	144 (94.7%)	8 (5.3%)	0 (0.0%)	0.000
Distance of farm	137 (89.5%)	8 (5.2%)	8 (5.2%)	0.000	134 (88.2%)	4 (2.6%)	14 (9.2%)	0.000
Cost of inputs	153 (100.0%)	0 (0.0%)	0 (0.0%)	n/a	152 (100.0%)	0 (0.0%)	0 (0.0%)	n/a
Accessibility to inputs	153 (100.0%)	0 (0.0%)	0 (0.0%)	n/a	152 (100.0%)	0 (0.0%)	0 (0.0%)	n/a
Availability of inputs	150 (98.0%)	3 (2.0%)	0 (0.0%)	0.047	152 (100.0%)	0 (0.0%)	0 (0.0%)	n/a
Belief systems	131 (85.6%)	17 (11.1%)	5 (3.3%)	0.000	138 (90.8%)	14 (9.2%)	0 (0.0%)	0.000
Access to extension services	143 (93.5%)	10 (6.5%)	0 (0.0%)	0.000	138 (90.8%)	14 (9.2%)	0 (0.0%)	0.000
Membership to group	133 (86.9%)	7 (4.6%)	13 (8.5%)	0.000	130 (85.5%)	6 (3.9%)	16 (10.5%)	0.000
Training received	148 (96.7%)	5 (3.3%)	0 (0.0%)	0.006	149 (98.0%)	3 (2.0%)	0 (0.0%)	0.048
Simplicity of practice	153 (100.0%)	0 (0.0%)	0 (0.0%)	n/a	152 (100.0%)	0 (0.0%)	0 (0.0%)	n/a

Note: n/a = not applicable, responses were uniform

Source: Filed survey, 2020

7.3 Access to farm capital and implements

Access to credit is important in enabling smallholder farmers obtain relevant farm inputs and improved seeds to enhance agricultural production. It was observed that access to credit determines the utilisation of farm inputs such as fertilizer, pesticides, and improved seeds as well as other farm services such as tractor services for various farm activities. Smallholder farmers with access to credit can acquire farm inputs including improved seeds for higher yields as well as pay for the services of modern farm machineries. The survey results show that the adoption decisions of 89% of the respondents were influenced by their access to credit, while seven percent indicated they were not influenced by access to credit. About four percent of the respondents revealed they did not know whether access to credit influences their adoption decisions. Drawing from Table 7.1, 67% out of the 89% respondents who were influenced, indicated that access to credit highly influenced their adoption decisions; 18% were moderately influenced while 15% were less influenced by access to credit. Hence, the results of the Chi-square analysis show that access to credit was statistically significant (p-value < 0.05) in both Lawra and Sissala East Municipalities.

This suggests that farmers with access to credit were more likely to adopt more scientific knowledge-based practices than farmers with less and/or no access to credit. This agrees with Tadele (2017) who reported that lack of and/or inadequate access to credit among smallholder farmers in Africa significantly hinders adoption of agricultural intensification and other sustainable practices. This adversely affects agricultural productivity and food security. The finding is also consistent with the assertion of Xie et al. (2019) who argue that access to credit is one of the explanatory variables of sustainable agricultural practices with positive effects on smallholder farmers' adoption of sustainable intensification and other climate-smart agricultural practices in Africa. That is, smallholder farmers who have access to credit will likely adopt sustainable agricultural practices because they can pay for the services and inputs than those without access to credit. Also, Kassie et al. (2015) indicated that households with less and/or no access to credit are less likely to adopt sustainable intensification agricultural practices that involve the use of money. Kroeger et al. (2017) also reported that smallholder farmers in SSA who have access to credit and finance were able to acquire and use chemical inputs on their farms. The authors however related that access to credit was the cause for the misuse of agro-chemical inputs among smallholder farmers.

Another factor which influenced the adoption decisions of smallholder farmers in North-western Ghana was the cost of agricultural inputs. High prices of agricultural inputs have been an impediment to utilisation of inputs among smallholder farmers due low household income levels in northern Ghana. Although, the employment of farm inputs among smallholder farmers is relatively common in North-western Ghana, many of the farmers are unable to acquire inputs by themselves and mostly rely on out-growers for supply under unfavourable terms and conditions. According to the survey, the adoption decisions of 74% of the respondents were highly influenced by the costs of farm inputs. Moreover, 15% indicated that the cost of inputs moderately influenced their adoption decisions while 11% indicated a low level of influence. The results revealed that, in both municipalities, the cost of inputs was an important factor smallholder farmers consider before adopting farming practices. This implies that high prices of farm inputs, implements and services are limitations to the utilisation of farm inputs and modern farm implements among smallholder farmers which has adverse impact on food production and household food security in North-western Ghana. This implies that farmers who cannot not afford to purchase improved crop seeds will be limited to the use of indigenous and low-yielding crops. It was revealed that some farmers who could not buy fertilizer due to the sudden increase in the prices of fertilizer for the 2021 farming season had to abandon portions of their farms because the crops could not grow and yield well. In the same year, other farmers diverted from cultivation of maize to the cultivation of groundnuts, soya beans and sesame which do not require the application of chemical fertilizer. Few farmers also mixed chemical fertilizer with poultry droppings to increase coverage on the farm. They also resorted to the use of manure (cow dung and poultry droppings), although its application was limited to very few households.

Therefore, cost of farm inputs significantly influences farmers' adoption decisions as emphasised by Silvestri et al. (2020) who found that the (high) cost of farm inputs negatively affected smallholder farmers' ability to afford sustainable agricultural practices in Tanzania.

Moreover, De Pinto et al. (2020) indicated that many smallholder farmers will adopt CSA practices under reduced cost of production than they will adopt under high cost of production. Elum, Nhamo and Antwi (2018) revealed that high insurance premiums were disincentive to the adoption of crop insurance among smallholder farmers in South Africa.

Apart from the cost of inputs, the availability and accessibility of farm inputs to smallholder farmers also have significant influence on the adoption decisions of smallholder households in North-western Ghana. The decision to adopt local and indigenous knowledge is also dependent on how accessible and available improved inputs are to smallholder households. Where these inputs are not readily available and cannot be accessed by households, these households tend to adopt indigenous inputs which may not be very effective at providing the needed yields of crops under the increasing impacts of climate change. It emerged from the household survey that the adoption decisions of all the respondents were influenced by availability and accessibility to farm inputs. Furthermore, 68% were found to be highly influenced, 19% were moderately influenced while 13% were less influenced. To this end, the adoption decisions of a significant percentage of the respondents were found to be strongly influenced by accessibility and availability of farm inputs to smallholder farmers. This agrees with Kroeger et al. (2017) who reported that the lack of access to improved cocoa seeds affected the adoption of CSA practices by cocoa farmers in southern Ghana. Sahu and Mishra (2013) also reported that farmers with better access to irrigation facilities in India were adopting more sustainable practices than those with very limited access. Similar findings were reported by Menike and Arachchi (2016) in Sri Lanka where the adoption decisions of smallholder farmers were influenced by the level of accessibility to farm inputs. According to Baumuller (2018), the adoption of climate smart services among smallholder farmers in developing countries is motivated by easy access to agricultural inputs and knowledge of the input suppliers, prices, and marketing platforms of the inputs.

7.4 Land tenure, accessibility, farm size and labour

Generally, land ownership is a major factor that affects smallholder farming in northern Ghana, particularly as it relates to land accessibility for farming among women and other vulnerable groups of farmers (Jarawura, 2021). Hence, it emerged as a significant factor that influences farmers' adoption decisions on climate compatible agricultural practices in North-western Ghana. From the survey, about 95% of the respondents indicated that land ownership significantly influences their adoption decisions on local and indigenous knowledge for climate compatible practices (see table 7.1). Only two percent disclosed that land ownership does not influence their adoption decisions while three percent revealed a lack of knowledge. Among farmers whose decisions were influenced by land ownership, 61% believed it was highly influential in enabling adoption, 26% believed it was moderately influential and 13% thought it was less influential in their adoption decisions. Hence, land ownership was statistically significant (p-value < 0.05) in both municipalities as a determinant of farmers' decisions to adopt LIK for promoting climate compatible agricultural practices in North-western Ghana. This agrees with Ali and Erenstein (2017) who indicated that smallholder farmers' adoption decisions are mostly shaped by land ownership. It further agrees with Kupika et al. (2021) who reported that the decisions of smallholder farmers in adopting strategies to cope with climate change in Africa are mostly influenced by their land tenure status.

Land ownership for farming purposes was basically obtained through family inheritance, gifting, and temporary release of land to friends and relations as indicated in chapter four (section 4.13). A further analysis shows that 37.5% of the household respondents who cultivate on family lands were influenced to adopt LIK while 62.5% were influenced to adopt the combination of LIK and scientific knowledge in promoting climate compatible agricultural practices (see Table 7.2). Meanwhile, households who cultivate on gifted lands were basically influenced to adopt the combination of scientific and LIK-based climate compatible practices. Those who were temporarily offered land were also adopting the combination of scientific methods and LIK (83.3%) and LIK solely (16.7%). The chi-square test of independence was also statistically significant (p-value < 0.05). This implies that most farmers in North-western Ghana basically cultivate on family lands and therefore, would want to conserve the land by adopting climate compatible practices to ensure continuous cultivation for the present and future generations. Also, those who cultivate on gifted and temporarily acquired lands also integrated both LIK and scientific knowledge-based practices to conserve and maintain the land for continuous farming as well as preserve it for the landowners. This is because land is generally seen as a source of social and cultural identity in northern Ghana as reported by Derbile, Atanga and Abdulai (2022) and must therefore be preserved and conserved for both present and future generations. According to the authors, land in northern Ghana is mostly seen in three perspectives namely land as an identity, spirit and as life of the local people. Consequently, the actions of the people on matters relating to land are mostly influenced within that context of land as an identity, spirit and as life of the local people. Hence, farmers would usually want to preserve and conserve the land on which they cultivate to maintain these three essentials.

From the above, accessibility to land was yet another factor that smallholder farmers consider in the decision-making process of adopting knowledge systems for agricultural activities at the household level. In northern Ghana, access to land has been a significant matter, particularly as it relates to smallholder agriculture (Kuusaana et al., 2022). From the survey, it was found that the adoption decisions of all the respondents were influenced by their access to land. Among the respondents, the decisions of 74% were highly influenced by access to land, 20% were moderately influenced and six percent were less influenced. Therefore, decisions of smallholder households to adopt local and indigenous knowledge for agriculture were highly influenced by their level of accessibility to agricultural land. It was observed that in the Lawra Municipality most farmers have limited access to agriculture land and consequently tend to adopt practices that mirrored their knowledge systems in a manner that blends with scientific knowledge to engage in farming that is relatively sustainable and intensified in nature. It is relatively difficult for smallholder farmers to access land for farming purposes in the Lawra Municipality in particular, hence, the adoption of climate compatible agricultural practices could be challenging.

Meanwhile, farmers in Sissala East Municipality who have relatively easy access to vast agricultural land were mostly engaged in extensification and unsustainable practices. They have almost diverged from indigenous ways of clearing fields to the use modern machines in land clearing, thereby causing indiscriminate degradation of the vegetation. Similarly, in Namibia, Davies et al. (2019) reported that access to land was a major challenge adversely affecting the adoption of CSA practices among smallholder farmers. According to Kassie et al. (2015), access to land significantly determines the adoption of sustainable intensification practices among smallholder farmers in eastern and southern Africa. Hence, smallholder farmers with limited access to agricultural land are more likely to adopt sustainable and climate compatible practices than those with relatively significant access to land.

Additionally, the size of a farm of a household also influences the decisions of smallholder farmers' adoption of local and indigenous knowledge in developing climate compatible practices and technologies in North-western Ghana. The analysis of the survey results revealed that 91.8% of the respondents adopted local and indigenous knowledge based on the sizes of their farms, while 4.6% were not influenced by the farm sizes and 3.6% of the respondents did not know whether their decisions were influenced by the sizes of their farms. These are presented in Table 7.1. Also, of those who considered the size of farms in their decisions, 53% of them disclosed that it was highly influential in shaping their decision in adopting local knowledge for farming activities. For 26% of the farmers, farm size was moderately influential to their decision to adopt LIK, while 21% of the farmers revealed that it was less influential in shaping their decisions to adopt local knowledge for developing climate compatible farming practices. The relatedness of farm sizes to farmers' decision to adopt LIK resonates with Sahu and Mishra's (2013) observations in India where the sizes of farm significantly shaped the production decisions of farmers.

It was observed that households with larger farm sizes mostly tended to adopt scientific knowledge-based practices and technologies and/or a blend of the two knowledge systems. The utilisation of inputs such as fertilizer, herbicides, pesticides, tractor, and other modern farm implements were common among households with relatively large sizes of farms. On the contrary, households with small-size farms were using manure, mulching, and less chemical inputs on their farms. Moreso, further statistical analyses show that households with farm sizes of 1-2 acres were more influenced to adopt a combination of scientific and local knowledge-based practices (53.5%) while 46.5% were influenced to adopt local and indigenous knowledge-based practices for adapting to climate change. Thus, households with farm sizes of 1-6 acres were generally influenced, in a descending order, to adopt local and indigenous knowledge-based practices than farmers with seven and more acres of farmlands as shown in Table 7.2.

Table 7. 2: Descriptive statistics of some factors and statistical values (n = 305)

	Knowledge system			Total
Age group	**Scientific**	**Local & indigenous**	**Both**	
30-39	0 (0.0%)	3 (30.0%)	7 (70.0%)	10 (100.0%)
40-49	0 (0.0%)	26 (53.1%)	23 (46.9%)	49 (100.0%)
50-59	0 (0.0%)	30 (21.4%)	110 (78.6%)	140 (100.0%)
60-69	0 (0.0%)	15 (19.7%)	61 (80.3%)	76 (100.0%)
70+	3 (10.0%)	13 (43.3%)	14 (46.7%)	30 (100.0%)
Total	3 (1.0%)	87 (28.5%)	215 (70.5%)	305 (100.0%)
N = 305, χ^2 = 53.283, df = 8, P-value = 0.000				
Gender				
Male	0 (0.0%)	81 (36.0%)	144 (64.0%)	225 (100.0%)
Female	3 (3.8%)	6 (7.5%)	71 (88.8%)	80 (100.0%)
Total	3 (1.0%)	87 (28.5%)	215 (70.5%)	305 (100.0%)
N = 305, χ^2 = 30.371, df = 2, P-value = 0.000				
Level of education				
No formal education	0 (0.0%)	70 (49.6%)	71 (50.4%)	141 (100.0%)
Primary	0 (0.0%)	10 (16.4%)	51 (83.6%)	61 (100.0%)
Junior High School	0 (0.0%)	4 (10.3%)	35 (89.7%)	39 (100.0%)
Vocational school	0 (0.0%)	3 (13.6%)	19 (86.4%)	22 (100.0%)
Senior High School	0 (0.0%)	0 (0.0%)	34 (100.0%)	34 (100.0%)
Tertiary	3 (37.5%)	0 (0.0%)	5 (62.5%)	8 (100.0%)
Total	3 (1.0%)	87 (28.5%)	215 (70.5%)	305 (100.0%)
N = 305, χ^2 = 171.534, df = 10, P-value = 0.000				
Farm size (acres)				
1-2	0 (0.0%)	40 (46.5%)	46 (53.5%)	86 (100.0%)
3-4	0 (0.0%)	33 (43.4%)	43 (56.6%)	76 (100.0%)
5-6	0 (0.0%)	14 (26.9%)	38 (73.1%)	52 (100.0%)
7-8	0 (0.0%)	0 (0.0%)	25 (100.0%)	25 (100.0%)
9-10	0 (0.0%)	0 (0.0%)	25 (100.0%)	25 (100.0%)
11+	3 (7.3%)	0 (0.0%)	38 (92.7%)	41 (100.0%)
Total	3 (1.0%)	87 (28.5%)	215 (70.5%)	305 (100.0%)
N = 305, χ^2 = 75.692, df = 10, P-value = 0.000				
Land ownership				
Family land	0 (0.0%)	87 (37.5%)	145 (62.5%)	232 (100.0%)
Gifted land	0 (0.0%)	0 (0.0%)	55 (100.0%)	55 (100.0%)
Temporary land	3 (16.7%)	0 (0.0%)	15 (83.3%)	18 (100.0%)
Total	3 (1.0%)	87 (28.5%)	215 (70.5%)	305 (100.0%)
N = 305, χ^2 = 84.525, df = 4, P-value = 0.000				
Labour size				
1-2	0 (0.0%)	5 (15.2%)	28 (84.8%)	33 (100.0%)
3-4	0 (0.0%)	34 (51.5%)	32 (48.5%)	66 (100.0%)
5-6	0 (0.0%)	20 (23.8%)	64 (76.2%)	84 (100.0%)
7+	3 (2.5%)	28 (23.0%)	91 (74.6%)	122 (100.0%)
Total	3 (1.0%)	87 (28.5%)	215 (70.5%)	305 (100.0%)
N = 305, χ^2 = 26.959, df = 6, P-value = 0.000				
Years of experience				
11-15	0 (0.0%)	0 (0.0%)	2 (100.0%)	2 (100.0%)
16-20	0 (0.0%)	3 (18.8%)	13 (81.2%)	16 (100.0%)
21-25	0 (0.0%)	6 (31.6%)	13 (68.4%)	19 (100.0%)
26-30	0 (0.0%)	19 (63.3%)	11 (36.7%)	30 (100.0%)

	Knowledge system			Total
Age group	**Scientific**	**Local & indigenous**	**Both**	
31-35	0 (0.0%)	21 (48.8%)	22 (51.2%)	43 (100.0%)
36-40	0 (0.0%)	7 (11.3%)	55 (88.7%)	62 (100.0%)
41+	3 (2.3%)	31 (23.3%)	99 (74.4%)	133 (100.0%)
Total	3 (1.0%)	87 (28.5%)	215 (70.5%)	305 (100.0%)
N = 305, χ^2 = 42.618, df = 12, P-value = 0.000				
Distance of farm				
Near home	0 (0.0%)	36 (24.7%)	110 (75.3%)	146 (100.0%)
Far from home	0 (0.0%)	49 (39.2%)	76 (60.8%)	125 (100.0%)
Both	3 (8.8%)	2 (5.9%)	29 (85.3%)	34 (100.0%)
Total	3 (1.0%)	87 (28.5%)	215 (70.5%)	305 (100.0%)
N = 305, χ^2 = 38.992, df = 4, P-value = 0.000				

Source: Field survey, 2020

According to the findings of the study, adopting a local and indigenous knowledge or a combination of LIK and scientific practices among smallholder farmers decreases with increase in the number of acres cultivated. This implies that households with small-size farms are more likely to adopt LIK on one hand, and a blend of scientific and LIK-based practices and technologies on the other hand, while households with large-size farms are most likely to adopt only scientific knowledge-based practices. The Chi-square test of no association on the size of farm against the type of knowledge system adopted was found to be statistically significant (p-value < 0.05) as Table 7.2. Similarly, Maguza-Tembo, Mangison, Edris and Kenamu (2017) found that an increase in the number of acres among smallholder farmers in Southern Malawi reduced their ability to adopt more CSA practices. They argued that smallholder farmers are generally resource constrained and any addition to the number of acres cultivated comes with additional cost for adoption of climate compatible practices which weakens the ability of farmers to adopt. In most cases, smallholder farmers turn to blend the adoption of practices and technologies that are driven by both scientific and local knowledge systems.

The size of labour force available to a household for farming activities also determines the kind of knowledge, practices, and technology to adopt. The size of labour available is related to the size of farm of the household. A household with large size of labour to work on the farm will have no difficulty adopting practices that are labour intensive while a household with limited labour force will adopt practices that are less intensive. In this study, most of the respondents (90%) indicated that the size of labour force available in their households significantly influences their adoption decisions. Seven percent indicated a contrary view, while three percent did not know. Of those who were influenced, 59% were highly influenced, 15% were moderately influenced, while 26% were less influenced by the size of labour force in adopting local knowledge-based practices in promoting climate compatible agriculture. The findings show that adequate labour was required for implementing local and indigenous knowledge-based agricultural practices than scientific knowledge-based practices. The results from Table 7.2 show that 51.5% of the household respondents with labour force size of 3-4 members were influenced to adopt only local and indigenous knowledge-based agricultural practices while 48.5% of the households with same labour force size were influenced to adopt both LIK and scientific knowledge practices in promoting climate compatible agriculture in the study communities.

Following the results presented in the table, the study found that households with more labour force were more likely to adopt a blend of local and indigenous knowledge and scientific knowledge-based practices than households with less labour force. This was further given credence by the Chi-square test of no association which was statistically significant (p-value<0.05). This implies that households with less labour force may more likely adopt practices that are less labour intensive than those with large size labour force. These findings were similar to Akudugu et al. (2021) who reported that the size of household labour supply for agricultural production among smallholder farmers in northern Ghana was a significant factor in determining the adoption of sustainable agricultural practices. According to the authors, it requires a great amount of labour and the available labour force for smallholder households to perform local knowledge-based farm tasks (practices) than scientific driven practices. Akudugu et al. (2021) further found that household labour supply of 526 labour days was used by smallholder irrigation farmers to cultivate eight different crops under rainfed crop production while an average of 574 labour days were used to cultivate 11 different crops under petrol and diesel-powered pump irrigation system. Therefore, they concluded that farming households were mostly guided by the size of labour supply in adopting farm practices and technologies from perspectives of local and scientific knowledge systems.

7.5 Agricultural extension services

Smallholder farmers in North-western Ghana do not have adequate access to extension services over the years, hence households do not have the opportunity of being exposed to sustainable and improved agricultural services to promote climate compatible agriculture. Sustainable agriculture thrives on availability and timely access to extension services as weather information, improved seeds, inputs, and other improved and innovative agricultural practices that ensure sustainable production and household food security. Therefore, smallholder farmers who have access to extension services are more likely to adopt scientific knowledge or a blend of local and scientific knowledge-based practices than farmers who have no or limited access to extension services. Of the respondents, 92% indicated that their decisions to adopt local and indigenous knowledge for climate compatible agriculture were influenced by their limited access to extension services while eight percent were not influenced by access to extension services. Of the 92%, 50% of the respondents were highly influenced, 23% were moderately influenced while 27% indicated low level of influence by access to extension services on their adoption decisions. This implies that many farmers are most likely to rely significantly on their indigenous knowledge, which has been trusted and practiced for many years for agricultural practices that had no and/or limited access to extension services (Davies et al., 2019; Elum et al., 2018). In North-western Ghana, there is inadequate access to extension services among smallholder farmers and this has always made majority of them reliant on local and indigenous knowledge for developing climate compatible agricultural practices. Several studies have shown that access to extension services enhances adoption of climate compatible practices for promoting sustainable agricultural production and food security among households (Agula et al., 2018; Ali & Erenstein, 2017; Kroeger et al., 2017). Dung (2020) and Kassie et al. (2018) related in their respective studies that smallholder farmers' access to extension services is a key determinant of adoption of CSA practices. Dittoh (2020) also reported that limited access to extension services has been a major constraint to the adoption of improved irrigation practices among smallholder farmers in northern Ghana.

The results of the study show that 86% of the respondents indicated that their membership to some groups influenced their adoption decisions, four percent indicated otherwise while 10% of the respondents did not know. Among those who were influenced by group membership in their adoption decisions, 45% were highly influenced, 28% were moderately influenced while 27% were less influenced. Thus, household membership to farmer-based groups significantly influences their decisions in adopting LIK for climate compatible agriculture in North-western Ghana. This finding is consistent with the finding of Dapilah, Nielsen and Friis (2019) who in their study of 'the role of social networks in building adaptive capacity and resilience to climate change' found that smallholder farmers who belonged to organised groups in the Bagri community in the Lawra Municipality had adopted improved climate change adaptation strategies than farmers who were not members of groups. Menike and Arachchi (2016) reported that smallholder farmers' adoption decisions in Sri Lanka were significantly influenced by their membership to farming groups.

It was observed that majority of farmers in North-western Ghana did not belong to any formal farming groups for purposes of accessing agricultural services including training, educating, and sensitising farmers through farmer-field schools on best farming practices. Farmer field schools and other farmer-based learning groupings were highly inadequate in the study communities. It was only in the Lawra Municipal that few similar programmes were found and mostly led by NGOs which did not also focus directly on specific farmer groups but rather focused on communities in general. However, farmers who were under the sponsorship of out-grower companies were usually put in groups primarily for the purposes of distribution of inputs and to ensure effective supervision and monitoring to enhance recoveries of investments from smallholder farmers. The aims of those groups were not for extension services. Therefore, farmers in such groups do not have access to innovative and improved agricultural services and practices. It was further observed that, in both municipalities, social groupings of women were common, and these groups were used for multiple purposes such as improved farming (climate change adaptation programmes), village savings and loans, religious and other activities. Hence Dapilah, et al. (2019) indicated that most female headed households in northern Ghana had membership in social groups than male-headed households.

The simplicity of use and practice associated with sustainable agricultural practices and technologies determines the rate of adoption among smallholder farmers. Farmers' decisions to employ local and indigenous knowledge hinges on the fact that the application of it is relatively simple for smallholder farmers who do not have the advantage of formal education and training on climate compatible practices. From the household survey, it emerged that the adoption decisions of all the respondents were influenced to adopt local and indigenous knowledge-based practices and technologies because their applications were simple. Thus, smallholder farmers do not require formal education and training to enable them to apply local knowledge-based agricultural practices on their farms. Within the context of extent of influence, 69% of the respondents revealed that their decisions were highly influenced. The decisions of 19% of the respondents were moderately influenced, while 12% were less influenced to adopt local knowledge-based practices because their application processes were simple. Therefore, smallholder farmers will mostly adopt practices and knowledge systems which are simple and easy to apply within their context than complex strategies. That is, households would normally avoid the adoption of complex and technical practices because majority of smallholder farmers in North-western Ghana have no and/or low levels of formal education and training as indicated by Derbile et al. (2021). The finding also confirms Mensah and McWilson (2021) who, in their study, found that some households in some Ghanaian cities were not willing to adopt solar home systems that they considered to be complex in their usage. Besides, Guodaar et al. (2021) noted that smallholder farmers in northern Ghana have low educational levels, and are therefore, constrained with access to and use of scientific climate information and adaptive capacities because of the perceived complex nature of these improved practices.

The study also found that the number of years of farming experience has significant influence on the adoption decisions of smallholder farmers in North-western Ghana. About 94% of the respondents disclosed that their adoption decisions were influenced by their years of experience, five percent were not influenced, and four percent did not know. Among those who were influenced by years of experience, 63% of them indicated that their adoption decisions were highly influenced, 23% were moderately influenced while 14% indicated low level of influence. Further analysis of the years of farming experience for households and the type of knowledge system suggests that household respondents who relied solely on LIK for climate compatible farming were farmers with farming experience of 16 years and above as shown in Table 7.2. Also, the table reveals that the number of farmers who adopted both scientific and LIK systems in their farming practices increases with increase in the number of years of farming experience. Hence, the Chi-square test of no association reveals that the results were statistically significant (p-value <0.05). The number of years of farming corresponds to the duration of usage of LIK and related practices among smallholder farmers which in turn offers them the opportunity and ability to evaluate the effectiveness of local knowledge-based practices. The findings agree with Sahu and Mishra (2013) who reported that smallholder farmers' adoption decisions are significantly influenced by their years of experience in farming and in the application of local knowledge systems. The finding also corroborates with Ayanlade et al., (2017) who indicated that smallholder farmers' choices of climate change adaptation strategies at the household level in Southern Nigeria usually correlate with their years of farming experience.

7.6 Household demographic characteristics

The background characteristics of smallholder farmers in North-western Ghana play critical role in the decision-making process of adopting knowledge and climate compatible agricultural practices and technologies to improve and sustain food production and food security among traditional households. Thus, the adoption decisions of farmers are made with consideration to their level of formal education, age and gender which are very important for their understanding and application within the context of socio-cultural beliefs of the people of North-western Ghana.

The level of formal education of farmers was also found to be an important determinant in the adoption of local and indigenous knowledge among farming households in North-western Ghana. From the analysis of the survey results, the study found that the decision to adopt local and indigenous knowledge was shaped by respondents' level of formal education. About 93% of the respondents disclosed that they were influenced to adopt local and indigenous knowledge because of their level of formal education while seven percent indicated the contrary. Of Among the 93% who were influenced by their levels of formal education, 51% of the respondents were highly influenced by their levels of formal education, 18% of the respondents indicated they were moderately influenced while 31% of the farmers' decisions were less influenced by their levels of formal education. Therefore, smallholder households were variedly influenced by their respective levels of formal education in their decisions to adopt local and indigenous knowledge for agricultural production in North-western Ghana. Further analyses show that 49.6% of the household respondents who had no formal education were influenced to adopt only local and indigenous knowledge-based climate compatible practices while 50.4% adopted a blend of indigenous and scientific knowledge-based practices as shown in the Table 7.2. Meanwhile, respondents with tertiary education were also found to have, mostly, adopted a blend of scientific and local knowledge. As a result, the Chi-square test of no association shows that the level of formal education among household members was highly significant ($p\text{-value} < 0.05$).

It is evident that smallholder farmers in North-western Ghana with no and/or low level of education were more likely to rely on local and indigenous knowledge for their agricultural practices than farmers with higher educational levels. This agrees with Tesfahunegn, Ayuk and Adiku (2021) who reported that, in Ghana, high level of education among smallholder farming households increases their ability to practice improved and sustainable soil management options while high illiteracy negatively affect farmers' ability to adopt better practices. The findings further agree with Xie et al. (2019) who suggested that smallholder farmers with low levels and/or no formal education in SSA are less likely to adopt the use of modern scientific agricultural technologies and practices compared to farmers with high levels of formal education. Similarly, Silvestri et al. (2020) found that low literacy among smallholder farmers was a barrier to understanding information received from scientific sources such as radio and mobile phone (short messaging service - SMS) on sustainable agricultural intensification practices in Tanzania. Further, Tabbo and Amadou (2017) in their assessment of newly introduced climate change adaptation strategy packages among rural households in Kaou Local Government area in the Tahoua State of Niger Republic, indicated that formal education was key to building the capacities of rural farmers to equip them with the ability to understand and appreciate climate change processes on their livelihoods for better adaptation.

The results of the study indicate that gender was a key determinant of adoption decisions of 91% of the household respondents. Three percent were not influenced by their gender while six percent were not able to tell if it influences their decisions or otherwise. Among the 91% of the respondents whose decisions were influenced, 58% indicated they were highly influenced by their gender in their decisions to adopt local and indigenous knowledge for climate compatible adaptation. Also, 23% of the respondents indicated that they were moderately influenced to adopt local and indigenous knowledge-based agricultural practices based on their gender while 19% were less influenced. A further analysis of gender and the type of knowledge systems adopted among households shows that 3.8% of female-headed households adopted only scientific knowledge-based practices while no male-headed household did. In contrast, more male-headed households adopted only local and indigenous knowledge-based practices as well as the blend of both local and scientific knowledge-based practices than female-headed households as indicated in the Table 7.2. The results show that the relationship between gender and the knowledge system adopted by smallholder households in North-western Ghana was statistically significant ($p\text{-value} < 0.05$). Furthermore, it was observed on the field that practices and technologies such as making ridges, mounds, tree planting, indiscriminate use of agro-chemicals as well as those practices that relate to traditions and culture were common among male farmers than female farmers. It was also found that women were mostly involved in practices such as village savings and loan schemes, petty trading, cultivation of improved leguminous crops and use of advice from extension workers than male farmers. This is consistent with Xie et al. (2019) who reported that women were more likely to adopt technologies and practices in leguminous plant systems than men.

Generally, female headed households mostly tended to adopt practices that require the actions of female workers while practices and technologies that were much masculine-oriented were mostly adopted by male-headed households. Female farmers were observed to be more reluctant in adopting practices and technologies that were perceived to be expensive, complex, and labour-intensive than their male counterparts. These findings corroborate the findings of Mensah and McWilson (2021) who noted that gender has a positive relationship on the adoption decisions of Ghanaian households. The authors found that male-headed households were willing to adopt solar home systems than female-headed households because women consider solar systems as complex to use. Moreover, in his study of the dynamics of drought-related migration among some farming communities in the Savannah ecological zone in Ghana, Jarawura (2021) found that male farmers were about three times likely to adopt migration as a strategy to droughts than female farmers. This was because men mostly venture into complex and risky livelihoods as principal providers of food and other basic needs of the family. However, Dung (2020) disagrees with the assertion that gender significantly influences the adoption decisions of households in sustainable agricultural practices. This researcher discovered that gender is an insignificant determinant in the adoption of sustainable agricultural practices and technologies among smallholder farmers in Vietnam.

Similarly, the age of a farmer was also found to be a significant determinant in making decisions on adoption of climate compatible practices at the household level. It was revealed that about 98% of the respondents were influenced by their ages to adopt local and indigenous knowledge-based practices while two percent indicated otherwise. Of the 98%, the decisions of 62% of the respondents were highly influenced by their ages, 24% were moderately influenced and 14% were less influenced to adopt local and indigenous knowledge-based practices. It was further observed that older farmers were more inclined with the use of local and indigenous knowledge and therefore adopted indigenous practices more than scientific knowledge-based practices. This is partly because the application of most scientific knowledge-based practices requires formal education and training while the application of local and indigenous knowledge-based practices and technologies does not require any formal education and training. Youthful farmers mostly tend to embrace scientific knowledge-based practices in a manner that many of the practices are indiscriminately applied. For instance, there have been increasing indiscriminate use of farm inputs and equipment such as the use/application of chemical fertilizer, herbicides, pesticides, and use of chainsaw machines for farmland clearing. Thus, the young and energetic farmers were more focused on immediate results (yields) and were more likely, than older farmers, to embrace practices and technologies that promote high yields without recourse to long term implications on the environment.

Moreso, older farmers were less likely to adopt practices and technologies such as spraying with chemical pesticides and related activities because of the health and other negative implications for human and environmental health. Such activities also require energy. Meanwhile, older farmers adopted the use of local materials like ash, cow dung, etc for same purpose of controlling pests and insects. A discussant remarked that

> *"Activities like spraying with knapsack requires strong men; an old man like me cannot carry the heavy knapsack with the chemicals in my back to spray. But I can sprinkle ash on my crops to control pests with ash because it requires just sprinkling it on the crops. It (ash) is not heavy too. Also, I can carry poultry droppings with my bicycle to the farm, but I cannot carry a bag of fertilizer to the farm. I have to look for somebody to carry it there for me. The chemical inputs are also dangerous to our health as old men"* (Excerpt from FGD, Kalsagri 2020).

Further analyses show that most household respondents (78.6%) within the age brackets of 50-59 years were largely adopting a combination of local and scientific knowledge practices with 21.4% adopting solely local and indigenous knowledge-based practices as indicated in Table 7.2. In addition, the results show that respondents within the age group of 40-49 (53.1%) were adopting local and indigenous knowledge-based climate compatible agricultural practices than a blend of the practices. The results were statistically significant (p-value<0.05) and therefore agree with Kassie et al. (2018) who reported that the ages of smallholder farmers in SSA positively correlate to their adoption of sustainable agriculture practices and technologies at the household levels. Similarly, Huang, Wang, Cui and Yang (2020) indicated that aging among farmers significantly hinders their adoption decisions on improved soil and water conservation practices.

7.7 Landscape and farm distance

Landscape was found to be a determinant of farmers' adoption decisions in adopting local and indigenous knowledge for promoting climate compatible agriculture in North-western Ghana. The topography of farmlands as well as the distance of farmlands from the settlement of smallholder farmers are important factors that are taken into consideration when adopting climate compatible practices and technologies. These are elaborated in the ensuing paragraphs.

The adoption decisions of smallholder farmers were mostly aligned with the location of their farmlands and/or the topography of their farms such as upland, lowland, waterlogged, or flood plains. The location of a farm on any of these topographies was contingent on the decisions of the use of local and indigenous knowledge practices. According to the survey results, the adoption decisions of an overwhelming 91% of the respondents were influenced by the locations of their farms, while seven percent were never influenced, and two percent of the farmers were uncertain. Among those who were influenced, 56% of respondents were highly influenced, 25% were moderately influenced while 19% were less influenced by the locations of their farmlands. It was observed that smallholder farmers with farmlands on low-lying, waterlogged and near rivers were likely to adopt practices including the cultivation of crops that were water and extreme moisture friendly while upland farmers were likely to adopt the cultivation of some indigenous crops which they believed were resilient to droughts. Furthermore, farmers whose farms were lowland and waterlogged fields were mostly adopting early planting and the cultivation of early maturing crops to avert the impacts of possible flooding and waterlogging. Smallholder households with farmlands located on hilly and stony areas were engaged in local practices such as stone bunding and other practices that could trap rainfall water to stay for crops usage. Such households also engaged in planting of indigenous sorghum (red sorghum) and millet which were resilient to such topographic characteristics. These findings were similar to the findings of Kassie et al. (2018) who indicated that in Kenya, the slope of farms of smallholder farmers significantly influenced their adoption decisions of sustainable agricultural practices.

The distance of farms from the homes of households also influences the kind of practices that are adopted at the household level to sustain agriculture and food security. The study established that smallholder farmers had their farms either located far from their settlements or located near their settlements and in some cases, both. Hence, the practices adopted mirror the distance of the farmland from homes of the farmers. From the survey, it was revealed that the decisions of 89% of the respondents to adopt local and indigenous knowledge for climate compatible agriculture were influenced by the distance of their farms from their homes. Meanwhile, four percent were not influenced, and seven percent did not know if the distances of their farms influenced their decisions. The results further show that, among those who were influenced by distances of their farms, 53% of them were highly influenced to adopt local and indigenous knowledge practices, 21% were moderately influenced, while 26% were less influenced to adopt local knowledge-based climate compatible practices. Further analyses show that smallholder farmers whose farms were near their homes (backyard farmers) were more influenced to adopt a blend of scientific and indigenous knowledge-based (75.3%) climate compatible practices than adopting solely local and indigenous knowledge-based practices (24.7%) as shown in Table 7.2.

Similarly, farmers whose farms were far from their homes (bush farmers) were also influenced to adopt a blend of practices from the two knowledge systems (60.8%) than they were influenced to adopt only local and indigenous knowledge-based practices (39.2%). However, the results further show that the blend of scientific and local knowledge influenced more backyard farmers than farmers whose farms were far from their homes. The level of association between the type of knowledge systems and the distance of farm from home was shown to be significant (p-value < 0.05). Therefore, the distance of farms from homes greatly influences the adoption decisions on indigenous knowledge practices among smallholder farmers in North-western Ghana. This finding is similar to Kassie et al. (2018) who found that the distances of farms from homes of smallholder farmers in Kenya positively correlated to their adoption decisions on minimum tillage, soil and water conservation, and crop diversification. Relatively, in the review of literature on the utility of mobile phone-enabled services, Baumuller (2018) also reported that the distance to banks and mobile money agents was significantly influencing farmers adoption of mobile phones services among farming households in Africa.

It was further observed that farmers whose farms were near homes were more careful and avoided excessive and indiscriminate use of synthetic inputs like fertilizer, herbicides, pesticides, etc. on their farms than farmers whose farms were far from homes. In the Lawra Municipal where farmers were mostly engaged in backyard farming, inputs were used moderately. This was attributed to the fact that they wanted to reduce the risks of endangering the lives and health of their livestock, and human beings, especially children who could be tempted to eat some edible crops since the farms were near homes. They also engaged in practices such as agroforestry, natural regeneration of the vegetation, less/no bush burning, and use of manure than farmers in Sissala East Municipal. This is to improve the soil fertility due to the continuous cultivation on the same piece of land for many years. On the other hand, farmers in Sissala East whose farms were mostly located several kilometres from their homes (bush farms) were associated with indiscriminate and excessive use of chemical fertilizer, herbicides, pesticides, forest, and land extensification practices, among other unsustainable practices. This finding is contrary to that of Tesfay (2020) who, in his study of whether fertilizer adoption enhances smallholders' commercialisation in northern Ethiopia, found that long distances of farm plots from homesteads significantly reduced fertilizer use among smallholder farmers. However, Kroeger et al. (2017) believed that the misuse of fertilizer and other inputs among smallholder farmers in West Africa was as result of physical and financial access to these inputs as well as a lack of basic technical skills and knowledge on the application of these inputs.

7.8 Socio-cultural beliefs

The socio-cultural values in traditional communities in northern Ghana including North-western Ghana are usually at the forefront of decision-making among the people including smallholder farmers. The taboos, norms and traditional values are, thus, part of the lives of smallholder farmers which are considered in any activity that they engage in, including smallholder agriculture. Therefore, the decisions of smallholder households to adopt agricultural practices have links with their values, beliefs, norms, and taboos that guide their daily living.

From the survey results, 88% of the respondents were influenced by their belief systems to adopt local and indigenous knowledge-based practices while 10% were not influenced and two percent did not know. Among those who indicated as having been influenced, it was revealed that belief systems have high level of influence on 61% of the respondents, 23% were moderately influenced, and 16% were less influenced by the belief systems of their communities. It is therefore evident that, the decisions of most smallholder farming households in North-western Ghana were found to have been influenced by the traditional belief systems of their respective communities. This corroborates the findings of Davies et al. (2019) as indicated in chapter three (section 3.2) of this study. Also, Davies et al. (2020) emphasised that smallholder farmers in Namibia and other SSA countries have strong attachments to their cultural and traditional belief systems. These are usually reflected in their choice of crop cultivation and livestock rearing to the detriment of improved and sustainable agricultural practices. In Zimbabwe, traditional smallholder farmers adopted climate change adaptation practices that reflected their local beliefs, values, and practices because they were more compatible with their local realities than science-based practices (Musarandega et al., 2018). Hence, smallholder farmers' adoption decisions were greatly influenced by their belief systems, cultural and traditional structures. Selato (2017) also found that religious and socio-cultural beliefs of smallholder farmers in Bobirwa sub-District of Botswana were barriers to using scientific forecast information for agricultural purposes because scientific information did not reflect the socio-cultural values and beliefs of the people.

7.9 Conclusion

The chapter has discussed the determinants of smallholder farmers' decisions in adopting local and indigenous knowledge for climate compatible agriculture. The discussions examined the extent to which the various factors influence smallholder farming households' preference for local and indigenous knowledge adaptation strategies in North-western Ghana. Smallholder farmers' decisions to adopt local and indigenous knowledge-based climate compatible practices were influenced by factors such as accessibility, reliability, and awareness of knowledge; access to farm capital; land tenure; access to extension services; the demographic characteristics of households; landscape and farm distance; and socio-cultural beliefs of households and communities. There were varied levels of influence of these factors on the decisions of farmers.

CHAPTER 8: LEVEL OF AWARENESS OF SMALLHOLDER FARMERS ON CLIMATE COMPATIBLE ADAPTATION STRATEGIES IN CROP FARMING

8.1 Introduction

This chapter examines the awareness level of smallholder farmers on some climate compatible agricultural strategies on one hand, and the level of willingness of smallholder farmers to adopt on another hand. The chapter proceeds by exploring the frequency of farmers' engagements with agricultural field extension workers at household and community levels to establish the accessibility or otherwise of smallholder farmers in North-western Ghana to sustainable agricultural practices and their awareness level thereof.

8.2 Awareness of farmers on climate compatible practices

The accessibility and frequency of engagements that smallholder farmers have with extension officers is very important for creating awareness on climate compatible practices among households in North-western Ghana. Therefore, the level of awareness among smallholder households on climate compatible practices usually reflects their level of exposure to extension services from government extension workers, NGOs, and private out-growers. The engagements with farmers are usually undertaken through various media such as agricultural extension services, farmer-based field schools, community radios, and farmer-based and stakeholders training workshops to create awareness and promote the use of climate compatible agricultural practices among smallholder farmers in North-western Ghana. Results of the survey show that 70.5% of smallholder household respondents were engaged (directly or indirectly) in meetings and discussions on agriculture and climate compatible related practices, while 29.5% indicated otherwise. Many of these engagements were mostly facilitated by government extension workers, NGOs, and private out-grower field supervisors.

During engagements, discussions mostly border on the use of improved seeds, inputs, and general climate change adaptation practices. Private out-growers mostly engage farmers prior to the farming season to educate them on the terms and conditions of their operations as well as the registration processes for interested farmers. These meetings and exercises also provided opportunities for discussions on improved and sustainable practices to ensure good yields for farmers to enable full recoveries by the out-grower companies. The grouping of smallholder farmers was identified as one of the strategies employed by most out-growers to enhance full recoveries of their investments from smallholder farmers and to encourage farmers to adopt best practices for improved yields. It, thus, appears that out-growers were more focused on the processes that will enhance recoveries of their investments from farmers with little attention to training and educating farmers on climate compatible practices. In the Sissala East Municipal, several field officers who interacted with farmers were said to be field supervisors employed by out-growers to supervise and monitor distribution of seeds, inputs, etc. to farmers. They also assisted in educating farmers on better farming practices to promote high production and enhance full recovery of investments. The role of state agricultural extension workers was more visible in communities in the Lawra Municipality than in Sissala East Municipal. It was, however, revealed that smallholder farmers were not regularly engaged by state extension services as they do for out-grower companies, and meeting and discussions were mostly informal in nature. The out-growers have strict supervision of smallholder farmers in terms of usage and application of inputs and seeds supplied them to avoid being diverted or sold for other purposes. NGOs, on the other hand, were mostly concerned with provision of alternative livelihoods and income sources for rural women farmers under climate change adaptation programmes. The women were mostly taken through conservation measures such as the use of organic manure, agroforestry, livestock rearing, natural regeneration, and the use of improved crop varieties. These activities were, however, more common in Lawra Municipal than in Sissala East. Women groups were also engaged in small savings and loans associations which were vibrant across the two municipalities. This could be an opportunity for expanding women's access to formal micro-credit services to improve agriculture and household food security in North-western Ghana since women's roles have become pronounced in smallholder agriculture (Minne, Reyes & Doumenjou, 2019; Pettengell, 2015).

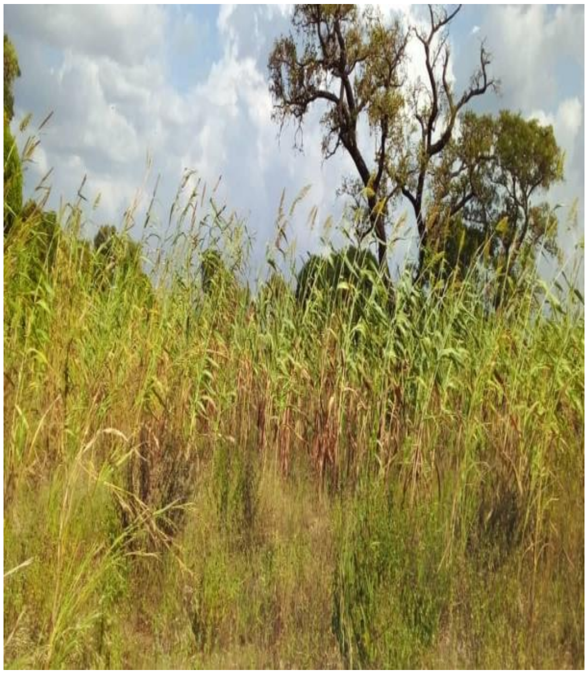
Having examined how smallholder farmers in nortwestern Ghana get to interact with extension workers on matters relating to climate compatible practices, the study proceeds to assess the levels of awareness of smallholder households on some climate compatible agricultural practices.

8.3 Agronomic/crop management strategies

According to the findings of the study, agronomic practices such as crop rotation, the use of the improved crop seeds, mixed farming and mixed cropping were common practices among smallholder households in North-western Ghana. These practices are age-long practices among smallholder farmers and their applications are mostly seen to reflect their own knowledge systems. The level of awareness among smallholder farmers on whether these are climate compatible practices are discussed below.

Crop rotation was one of the common and traditional farming practices among households and communities in northern Ghana as indicated by Omari et al. (2018). Consequently, households in northern Ghana exhibit high levels of awareness and adoption of crop rotation as a climate-smart practice (Agula et al., 2018). To this end, the survey revealed that all the respondents were aware of crop rotation practices in all the study communities. Moreover, a significant proportion of 53% of the respondents indicated high levels of awareness; 19% indicated very high level of awareness level, 20 indicated low level of awareness and eight percent indicated very low awareness level. Thus, most of the respondents (72%) were significantly aware that crop rotation is a climate compatible practice which can promote sustainable agriculture production and food security. This resonates with Taye and Megento (2017) who reported that smallholder farmers in SSA have high levels of awareness on crop rotation and thus, rotate different crops on the same piece of land to conserve soil fertility. It was further found that 97% of the household respondents were willing to continuously adopt crop rotation while three percent indicated otherwise. It emerged that households found crop rotation as a costless practice, which does not also require any physical activity. Hence, its simplicity in application has an added advantage for traditional farmers to adopt in their agricultural practice.

It was observed that the practice of crop rotation was more informed by household level decisions than external influence among smallholder households. Several farmers were rotating the cultivation of cereals, tuber crops (yam), and leguminous crops such as beans, groundnuts, and soya beans on the same piece of land within one year. There were also cases where farmers rotated different cereal crops on the same land year after year as well as rotated leguminous crops, cereals, and tuber crops on the same piece of land within one year. For instance, it was observed that in 2020, a farmer cultivated millet on his farmland and in 2021, he cultivated sorghum on the same piece of land as shown below.



Millet (2020) **Sorghum (2021)**

Figure 8. 1: Crop rotation practices

Source: Field photos

The two photos above show a smallholder farmer in Eremon community in the Lawra Municipality rotating crops on his farmland. The farmer used the same land for the cultivation of leguminous and cereal crops. Thus, during the 2020 farming season, he cultivated cowpea and after harvesting he planted millet on the same piece of land, and in 2021, he cultivated groundnuts and later planted sorghum when the groundnuts were harvested. According to this farmer, it has been his practice of cropping beans and millet in one year and cropping groundnuts and sorghum the following year. He noted that the vines of the legumes were usually left on the field after harvesting to decompose to form manure for enhancing the soil fertility for the growth and yields of the cereal crops. Here, the findings show that the farmer combined mixed cropping and crop rotation as practices to produce food for his family. Therefore, many smallholder farmers would usually integrate different strategies to produce food for household consumption than adopting a single practice.

The use of improved seeds and inputs such as drought resilient varieties, high yielding and early maturing crop varieties was also found to be common among households in the study areas. From the survey, it emerged that 94% of the respondents, indicated that they were aware of the use of improved seeds such as drought-resistant and early maturing crops as a climate compatible practice while six percent were not aware. Among those who were aware, there were varying levels of awareness among them where 28% of the respondents indicated very high level of awareness; 42% indicated high level of awareness; 24% indicated low level of awareness while six percent indicated very low level of awareness. Thus, 70% of the respondents were significantly aware about the use of drought-resistant, high yielding and early maturing crop varieties to promote climate compatible agriculture. Meanwhile 30% of the respondents were less aware about it being climate compatible agricultural practice. Smallholder households were using improved seeds of maize, sorghum, soya beans, and other crops which were early maturing, high yielding and drought-friendly to adapt to rainfall variability. This implies that smallholder farmers in most cases make adjustments to the types of crops cultivated in a manner that resonates with current climatic and environmental conditions to sustain agriculture livelihoods and household food security.

The survey results further show that the majority of the respondents (98%) were willing to adopt the use of improved seeds while an insignificant two percent (n=7) indicated otherwise. This suggests there is potential for revolutionalising smallholder agriculture through introduction of more improved methods and practices to smallholder farmers to promote climate compatible agriculture for sustainable food production in North-western Ghana. The findings agree with Derbile et al. (2019) who reported that majority of smallholder farmers in North-western Ghana were significantly aware and had adopted the use of drought-resistant and early maturing crops in adapting to climate change. An interaction with the Municipal Budget Analysts in both Sissala East and Lawra Municipalities indicated that there has been allocation of funds in the composite budgets of the two municipalities to the respective Departments of Agriculture for education and sensitisation of smallholder farmers on best and sustainable farming practices. It was further noted that the annual allocation of funds for the celebration of the National Farmers' Day on every first Friday of December every year also sought to create awareness, motivate, and encourage farmers to adopt best and improved farming practices for increasing yields and productivity. The exhibition of farm produce during such occasions are usually avenues for raising awareness and intensifying the interest of farmers on new and sustainable methods of farming.

Mixed farming is a common practice among smallholder farmers in northern Ghana. It has been practiced for decades. This is the practice where households concurrently engaged in crop farming and the rearing of poultry and livestock. One hardly finds a typical indigenous household in northern Ghana engaged in sole crop farming or livestock rearing but rather a combination of both rearing and crop farming. The results of the household survey show that all the household respondents (100%) indicated that they were aware that mixed farming was a sustainable agricultural practice which they have been engaged in for several years. Mixed farming is a multipurpose strategy for farmers, where they substitute animals for grains and vice-versa, get manure for their farms from the droppings of the animals, earn income from sale of animals and crops for household keeping and farming activities, and feed livestock from farm residue.

A participant in Babile community in the Lawra Municipality elaborated that

> *"We know the importance of having livestock in addition to crop farming. Crop farming and rearing go together as a traditional activity and cannot be separated. You are not a successful farmer if you do not have poultry and livestock. It is not for nothing that our fathers farmed crops and reared animals at the same time, which we have inherited. You can sell the animals to buy food for the family should your farm crops fail you, and you can equally sell the farm produce to buy livestock if they (animals) die. Many times, it is the animals [and poultry] we sell to cater for other household needs in the family. We do not usually have enough food stuff available throughout the year that we can always sell some to earn household income. Besides, the droppings of the animals are used to fertilise our farms especially for those who cannot afford [chemical] fertilizer"* (Excerpt from FGD, Babile 2020).

Similarly, a male farmer (key informant) noted during an in-depth interview as follows:

> *"No farmer will embrace only crop farming or livestock rearing as a sole activity in any traditional household. You must mix the two [crop and livestock] to be recognised as a farmer in our tradition. In our society, you are a successful farmer if you have abundant food stuff and plenty livestock. How successful are you if you do not have cattle, goats, and sheep? How will you pay the dowries of your wives and perform other traditional activities? Your ability to offer animal from your own flock makes you a distinguished and successful farmer in the society. How will your family survive if the rains fail? With cropping and rearing, your family cannot go hungry! If one fails, the other is available to leverage you. Apart from these, the droppings of livestock are also local fertilizer to us. My home [backyard] farm is solely fertilized with a combination of livestock and poultry droppings. Every off-farm season I make my Fulani to keep the cattle on the farm for their dung. Even on the bush farm, they litter around when they grace on the crop residues. Some farmers carry the droppings from their homes to fertilise their farmlands. Could they have done that if they do not have livestock?"* (Excerpt from In-depth interview, Nabugubelle 2020).

Therefore, mixed farming among smallholder farmers was seen as a deliberate action to compensate the losses in crop and livestock farming in traditional households in North-western Ghana. Thus, mixed farming is a deliberate multipurpose practice among smallholder farmers where crop farming is interfaced with livestock rearing to promote climate compatible agriculture and food security. The practice manages smallholder households through the unforeseen adverse conditions in smallholder farming. The findings resonate with Bogale and Bikiko (2017) who found mixed farming as an indigenous climate-smart crop management strategy to climate change impacts among smallholder farmers in Ethiopia. The authors observed that the sales from livestock usually alleviated food shortages among farming households. Hence, smallholder households demonstrate continuous willingness in practising mixed farming.

Similarly, mixed cropping was also one of the popular farming practices among smallholder farmers in the study communities. Smallholder households demonstrated considerable high level of awareness on the practice, with however varying levels of awareness among all the respondents. Further analyses show that 25% of the respondents indicated very high level of awareness, 54% indicated high level of awareness, while 21% indicated low level of awareness on mixed cropping as a climate compatible farm practice. Thus, 79% of the respondents were significantly aware of mixed cropping as a strategic farming practice that promote sustainable agriculture production and food security among households over the years. Agula et al. (2018)

discovered numerous smallholder irrigators in northeastern Ghana being significantly aware of mixed cropping, resulting in the adoption and practice of mixed cropping as a major ecological-based management practice. Similar findings were reported by Dohmen et al. (2018) who found mixed cropping as a popular CSA practice among cocoa framers in Ghana and Ivory Coast. Dapilah et al. (2019) also indicated that mixed cropping was popularly adopted by both organised group farmers and non-organised group farmers in the Lawra Municipality. Thus, mixed cropping was more commonly practiced among farmers in communities in Lawra Municipal than farmers in Sissala East Municipal. Notwithstanding, 83% of the respondents from both municipalities indicated their willingness to continuously adopt mixed cropping while 17% indicated their unwillingness to adopt the practice.

8.4 Diseases, pests, and weed control practices

Smallholder farmers have been controlling and managing diseases, pests, insects, and weeds on their farmlands over the years in varied ways that resonate with the blend of modern and traditional knowledge systems. Thus, a mixture of traditional and scientific approaches to pests and disease management among farm crops were common practices in North-western Ghana.

The use of pesticides and insecticides among smallholder farmers was in two forms namely traditional and chemical pesticides and insecticides. With the use of chemical pesticides, the survey shows that all the respondents (100%) were aware of the use chemical pesticides and insecticides to control and manage pests and insects on their farms. Most of the respondents (89%) indicated high levels of awareness while 11% indicated low level of awareness on the use of pesticides and insecticides. This might be partly attributed to the emergence of the fall army worm in 2017 across farming communities in Ghana. Farmers are currently encountering this challenge in every farming season. The outbreak resulted in massive and indiscriminate use of pesticides and insecticides among farmers in their attempt to control the spread and damages of the worms. The pesticides were also used on cotton, vegetables, and leguminous crop farms. According to a participant

> *"The emergence of the fall army worm in 2017 has compelled us [farmers] to use pesticides on our farms. If you do not spray your crops, you may lose all to the worm*

> *infestation. Cereals crops such as maize and rice are very vulnerable, and many farmers have lost their entire farm crops to fall army worms. You need to spray several times before the worms can be controlled"* (Excerpt form FGD, Walembelle 2020).

Smallholder farmers who cannot afford pesticides mostly get their farm crops severely destroyed by pests and insects which have adverse implications on household food security. Therefore, farmers have become aware of the use of pesticides and insecticides as reported by Derbile et al. (2019) who found that, in the Wa Municipality of North-western Ghana, many smallholder farmers were using pesticides and insecticides to control pests and insects respectively on their farms. Hutchins et al. (2015) also reported that cocoa farmers were engaged in regular spraying of cocoa farms to control pests and diseases including the cocoa swollen shoot virus which severely affect cocoa trees and cocoa beans. With the increasing incidents of pests, diseases and insects which affect the growth and yields of farm crops, 62.5% of the respondents were willing to continue using chemical pesticides and insecticides to control and manage pests and insects on their farms. Meanwhile, 27.5% of the respondents were not willing to adopt the use of chemical pesticides and insecticides while 9.8% indicated uncertainty about their decisions to adopt.

Leading from the above, many households were also aware of the use of traditional mixture of herbs and other substances for use as pesticides to control pests on crops. The cost of chemical pesticides makes it difficult for some farmers to afford. Farmers have therefore resorted to traditional means of managing crop pests, diseases, and insects on their farms. It was revealed that these traditional means of controlling and managing pests were common among farming households in the past before the use of chemical pesticides became common to farmers. Traditional pesticides were also used due to health reasons since chemical pesticides pose danger to the health and life of humans and livestock. The survey results show that 92.5% of the respondents had varying levels of awareness on the use of organic and/or traditional pesticides while 7.5% indicated lack of awareness on the use of traditional pesticides. Among those who were aware, 56% of them indicated high levels of awareness while 44% indicated low level of awareness. It was evident through FGDs, and key informants' interviews that, traditional pesticides were prepared from the use of ashes, neem seeds and leaves, pepper, cow dung, and other local materials such as wastewater of boiled dawadawa seeds and shea butter residue. These materials were usually mixed with water and sprinkled over the crops. The neem seeds and leaves, roots of *suori* trees, and pepper are pounded and mixed with water to spray over crops. These were mostly used on vegetable fields and backyard farms which were relatively smaller fields. In Kalsagri community, a participant noted that the use of ashes and other local materials as pesticides dates to many years. She noted that past generations were not fortunate to have access to scientific knowledge and its application to agricultural production, and so they relied entirely on their indigenous knowledge systems to control and manage pesticides and insects on their farms.

> *"Our great grandparents were relying on ashes, the leaves and seeds of neem trees to prepare mixtures for preventing and controlling pests and insects from infesting their crops. These local mixtures worked well for them. When we were children, our parents were also using them and up to date many of us still use ashes on our vegetables to prevent pest infestation"* (Excerpt from FGD, Kalsagri 2021).

Similarly, a key informant indicated that shea butter residue and wastewater from boiled dawadawa seeds were effective for not only controlling pests and insects on crop farms but also serve as a repellent to snakes and other reptiles.

> *"The past generations did not have access to the modern pesticides and insecticides that we are using today. So, they were using local mixtures of ashes, suori roots (wild tree with a distinguished scent of ointment), 'chubialing' (the wastewater from boiled dawadawa seeds), 'chumbulung' (residues of processed shea butter), pepper, and other local materials to prevent and control insects and pests on their farm crops. Growing up, my father was using them on our farm which I have also learned to do. I have been using mixtures of these to spray my vegetables. I also put chubialing in containers and place them at various points on my yam farm to prevent pests' infestations and drive away snakes. One thing is that we cannot apply them to large farms due to the difficulty of gathering and processing these mixtures in larger quantities"* (Excerpt from In-depth interview, Dolibizon, 2021).

It was observed that older farmers with many years of farming experience were much aware of these practices than younger farmers. Furthermore, a few farmers were observed to have been using traditional pesticides against the fall army worms on their farms and other pests and insects. This was partly attributed to the difficulty involved in gathering materials and producing the traditional pesticides in larger quantities for large farms.

It also emerged that some farmers were using powdered soap and related detergents to control the fall army worms on their cereal crop farms. According to officers of the Department of

Agriculture, the idea came about when a farmer elsewhere was reported to have washed his knapsack spray container with powdered detergent after use on his farm and then when he poured the soapy water on the fall army worms, they all died within few minutes. The information was then shared with other farmers who experimented and realised it was somehow effective for them, hence many farmers who could not afford the approved pesticides resorted to the use of these mixtures on their farms.

The findings, however, show that farmers could not rely entirely on these locally prepared pesticides in controlling pests and insects on the farms. Consequently, 29% (n=88) of the respondents were willing to adopt the use of traditional pesticides and insecticides while 50% were not willing to adopt. Moreover, 21% of the respondents were uncertain about their adoption decisions. Thus, the willingness to adopt among farming households was low. This may be attributed to the earlier reasons elaborated above.

The use of herbicides has emerged as one of the most common ways of weed control among farmers in North-western Ghana in recent years. All the household respondents indicated significant level of awareness on the use of herbicides for weed control and management. It emerged that the level of awareness on herbicide use was high among the majority of the respondents (77%) with only 27% indicating low levels of awareness. This suggested that there was high usage of herbicides among farming households across the study communities. This corroborates the finding of Derbile et al. (2019) who indicated that majority of smallholder crop farmers in North-western Ghana were using herbicides in controlling weeds on their farms.

It was observed that there was indiscriminate and excessive use of herbicides among smallholder farmers in the study communities. This poses adverse threats to soil and water health as well as human and other living organisms. This practice, if not regulated through farmer education and training, has the tendency of accelerating the depletion of soil nutrients, water pollution, and depletion of vegetative and other natural resources. There is the need for training, sensitisation, and education of farmers on the proper use of herbicides to limit the effects and impacts of excessive and indiscriminate application on soil, water, and other natural resources. This is particularly necessary since many smallholder farmers are unable to read and understand best application practices on the use of herbicides due to high illiteracy.

8.5 Access to agricultural extension services

Access to and use of agricultural extension services are important for improving smallholder agriculture production. With increasing impacts of climate change and variability on smallholder agriculture, it is important for smallholder farmers to be educated and trained on innovative and improved methods of agricultural production to sustain food production and food security as well as sustain the viability of the natural environment. There is the need to create awareness and make accessible to farmers the requisite extension services such as provision of timely and accurate weather information, education and training on rainwater harvesting for farming, use of improved seeds and inputs, use of mobile phones for receiving weather and general agricultural updates, and management and reduction of agricultural risks through crop insurance. These services should be extended to smallholder farming households through state agricultural extension workers and other stakeholders in the agricultural value-chain. It emerged from the survey that a significant proportion of the respondents (67.5%) had varied levels of awareness on the use of extension services while 32.5% indicated a lack of awareness. Among those who were aware, 60% of the respondents were found to have low levels of awareness while 33% of them indicated high level of awareness on the use of extension services. Thus, many households had low awareness levels on the availability, accessibility, and use of extension services for improving smallholder production and food security in the study communities.

It was observed that there was limited access to agricultural extension services among smallholder households which greatly hindered the use of climate compatible practices and services. This was elaborated by the Municipal Director of Agriculture in Sissala East where he noted that his department did not have adequate field staff to effectively provide farmers with extension services.

> *"We have inadequate field staff to provide services to farmers. Considering the number of farming communities in the municipality, the number of field officers we currently*

> *have are woefully inadequate. One field officer oversees more than 10 communities which is too much work for him/her. And even with the few staff, we are faced with inadequate means of transport which affects movement. With this challenge how do they visit farmers in the communities on regular basis?"* (Excerpt from In-depth interview, Municipal Director of Agriculture, Sissala East 2021).

The staff and offices of the Department of Agriculture in the municipalities need adequate staffing and retooling to enhance effective and efficient delivery of extension services to smallholder farmers in all communities to achieve sustainable agriculture and food security in North-western Ghana. Field staff should be provided with motor bikes and other necessary logistics to enable them visit communities and engage farmers on climate compatible agricultural practices on regular bases. There is the potential of the use of community radio stations in the two municipalities to provide smallholder farmers with agriculture and weather information. However, the cost of airtime was identified as a barrier since the Department of Agriculture could not afford to pay on regular basis to have engagements with farmers via the community radio stations. Thus, adequate funding of programmes by the central government through the Ministry of Food and Agriculture was a serious challenge to the provision of extension services to farmers.

Besides, the efforts of government extension officers could be complemented by the activities of private out-grower companies, through their field supervisors and radio programmes. It was observed that in Lawra Municipal, the out-grower companies were not common, but the activities of state agriculture extension agents and NGOs were relatively significant in terms of field visits compared to Sissala East. This corroborates with Dapilah et al. (2019) who acknowledged the significant role of NGOs in promoting climate compatible initiatives among women farmers in the Lawra Municipality. As indicated by Mango et al. (2017), the provision of agricultural services contributes significantly to raising awareness among smallholder farmers on sustainable agricultural practices. There have significant emphases on the need to create awareness and access to extension services for smallholder farmers to promote the adoption of climate compatible and smart agricultural practices and technologies in SSA (Kupika et al., 2021, Agula et al., 2018, Kassie et al., 2018).

The practice of harvesting rainwater for agricultural purposes may be popular in other SSA countries but very rare in Ghana and North-western Ghana in particular. The study finds that smallholder farmers were not harvesting rainwater for agricultural purposes in North-western Ghana. Households demonstrated very little level of awareness on the practice, although they harvest rainwater for domestic chores during the rainy season. Majority of the respondents (83%) indicated that they were not aware that rainwater could be harvested for farming purposes while 17% indicated awareness on the practice. Among the 17% who were aware, they learned of the practice in some communities in neighbouring Burkina Faso and through NGO training workshops. It was revealed that they had never practised it nor seen it practised in Ghana. Therefore, their levels of awareness were very low. Thus, the awareness on rainwater harvesting among households was principally limited to using it for domestic purposes than crop farming in North-western Ghana. It was common to see women in traditional homes in North-western Ghana harvesting rainwater whenever it is raining for several domestic purposes such as washing, cooking, bathing, and building. but not for watering of crops and other farming activities. The Municipal Budget Officer for Sissala East Municipal Assembly lamented that even though the people in the municipality do business with the border communities in neighbouring Burkina Faso, they have not been able to adopt some of the good agricultural practices such as harvesting rainwater for farming during the dry season, small irrigation schemes, agroforestry, and general protection of the natural environment. He noted that the Municipal Assembly tended to implement the policies of central government at the local levels. As such, it was difficult for the assembly to finance any project on harvesting rainwater for farming in the municipality when it does not form part of government's policies on agriculture.

Consequently, only 20.6% of the respondents indicated their willingness to adopt rainwater harvesting as a farming practice. Meanwhile, the majority of the respondents (60.7%) were unwilling to adopt while 18.7% were uncertain. This could be as result of the fact that the facilities required for rainwater harvesting and storage until commencement of the dry season are lacking in the communities. The foregoing findings were contrary to Khatri-Chhetri et al. (2017) who reported that smallholder farmers in Rajasthan State of India had significant level of awareness on rainwater harvesting as a popular alternative approach to inadequate water for agricultural activities. Bogale and Bikiko (2017) also indicated there were high levels of awareness and high rates of adoption of rainwater harvesting among smallholder farmers in Ethiopia as a strategy to water shortage. To promote this smart practice of farming in North-western Ghana and northern Ghana by extension, it would require significant investment in education, training, and sensitisation to raise awareness of smallholder farmers on rainwater harvesting as well as provide rainwater harvesting and storage facilities to farmers in their respective communities. That is, adequate investment is needed by the government, NGOs and other development partners to provide for rainwater harvesting and storage facilities and also build the capacities of farmers on the practice to complement rain-fed agriculture in North-western Ghana.

In the mid of growing variability in the rainfall pattern and consequent farming season, access to and use of forecast weather information has become important for sustaining smallholder farming in northern Ghana. However, the survey results show that 51% of the respondents were not aware of the use of scientific forecast weather information and services for farming. Only 49% of the respondents indicated that they were aware of the use of scientific weather forecast information services. Among those who were aware, the majority of them (72%) have significantly low levels of awareness. Farmers mostly do not have access to adequate and reliable forecast weather information and generally must rely on indigenous methods of forecasting to plan for the farming season. It was also revealed that on the few occasions that farmers were given forecast information on rainfall for the upcoming farming seasons, it turned to be inaccurate and highly unreliable. This made farmers doubtful of forecast information. Hence, 52% of the respondents in the household survey were not willing to rely on scientific weather forecast information for their farming activities. However, 41% of the respondents were willing to adopt the use of scientific weather forecast information and services to enhance the planning of farming activities while seven percent were uncertain.

The lack of adequate accessibility, understanding and application of weather forecast information and services could partly be responsible for low interest in the use of scientific forecast information. Therefore, the use of community radio stations in North-western Ghana in creating awareness among farmers and enhancing accessibility, understanding and application of forecast information from the Ghana Meteorological Agency must be intensified. Additionally, weather forecast information should be made available to local radio stations by the Ghana Meteorological Agency for onward transmission to smallholder farmers in the rural communities. It was observed that community radio stations were major means from which farmers could access and/or receive weather information; however, these community radios did not have access to forecast information on regular basis from the relevant stakeholders. Bogale and Bikiko (2017) blamed the use of local knowledge for weather information and farmers' low awareness on the use of weather information among smallholder farmers in Ethiopia on lack of access to weather information. Similarly, Fagariba et al. (2018a) advocated adequate access to weather information among smallholder farmers because of its potential of increasing smallholder farmers' awareness levels and adoption rates among households to increase and sustain production.

In a similar way, smallholder farmers in North-western Ghana did not know how to use mobile phones for accessing weather and other related information even though many households have access to mobile phones. Indeed, majority of the respondents (89%) were not aware that they could access weather information from their mobile phones through various platforms such as short messaging service, WhatsApp, Facebook, etc. as indicated by Baumuller (2018). Only 11% of the respondents were aware but were not also using the services. This finding departs from Silvestri et al. (2020) who reported that smallholder farmers in Tanzania were much aware of the use of radio and mobile phones for accessing information on sustainable agricultural practices including weather information.

In North-western Ghana, the use of mobile phones among households is becoming common albeit low and/or lack of knowledge in its use for accessing weather and related information for farming purposes. This may be attributed to the high illiteracy rate among smallholder farmers in North-western Ghana coupled with inadequate training as indicated by some scholars (Abdulai et al., 2021; Derbile et al., 2021; Dakurah, 2018; Fagariba et al., 2018a). Consequently, this also affected the willingness of farmers to adopt the use of mobile phones for accessing weather information, resulting in the unwillingness of 56% of the respondents to adopt such knowledge. This is principally because several users of mobile phones cannot read and understand weather information due to their illiteracy levels. Silvestri et al. (2020) indicated that illiteracy among smallholder farmers in SSA has been a major challenge to the adoption of sustainable climate compatible practices. Therefore, formal education and training are important for farmers to acquire, understand and conveniently apply new and improved technologies in farming as related by Fagariga, Song and Baoro (2018a). According to Baumuller (2018), high levels of education among smallholder farmers significantly influence their adoption of the use of mobile phone services for farming.

It was, however, observed that some farmers were using mobile money services to pay for the services of farm implements and inputs. This could serve as an entry point to leapfrog farmers on to the use of mobile phone platforms for smart farming through training, education and sensitisation by agricultural extension workers and other stakeholders in the agricultural value chain.

Agricultural insurance as a climate compatible practice was a rare practice to smallholder farmers in North-western Ghana. Smallholder farmers were, consequently, not aware of the practice of crop insurance as shown in the survey that 98% of the respondents were not aware of crop insurance while only two percent indicated awareness. The agriculture sector in Ghana including North-western Ghana remains an industry where insurance companies are still exploring possibilities to venture into. There are perceived high risks associated with agricultural insurance since the rainfall pattern in northern Ghana has become more fragile in recent years. Besides, agriculture in North-western Ghana is mainly subsistent and rainfed, which further increases the risk for both farmers and insurance companies. According to the Lawra Municipal Director of Agriculture,

> *"Agriculture in northern Ghana remains a risky sector to the insurance industry because of the uncertainty and variability of the rainfall pattern. Insurance companies think they may be paying more insurance claims than any other sector. They have always argued during training workshops that insurance premiums for agriculture may be high for smallholder farmers to pay. Nonetheless, we have been trying to engage and sensitise farmers on it [insurance] so that one day it can come to fruition"* (Excerpt from In-depth interview, Lawra Municipal Director of Agriculture, 2021).

Thus, insurance premiums are forecasted to be high and expensive for smallholder farmers to pay on one hand, and on the other hand, payment of claims are forecasted to be inevitable every year for insurance companies comes at huge cost to the companies. This corroborates McKinley (2014) who averred that crop insurance is not suitable for smallholder farmers in Ghana because it is very expensive to operate due to challenges of rainfall variability.

McKinley et al. (2016) noted further that crop insurance in Ghana could remain difficult with conventional farming until farmers practice climate-smart farming with specific recommended farm and land management practices. It emerged a significant proportion of the respondents (64.6%) in the household survey were not willing to adopt crop insurance, while 25.6% were willing to adopt crop insurance and 9.8% did not know if they will adopt or not. Therefore, much education and sensitisation on the crop insurance is needed to create the needed awareness and understanding to enhance the level of willingness of both insurance companies and farmers to practice it.

8.6 Soil management practices

It is reported that carbon can be sequestered to reduce emissions through soil management practices such as agroforestry, no and/or minimum tillage, natural rehabilitation, afforestation, mulching, and general organic farming (Brevik et al., 2017). These strategies help to conserve soil moisture and fertility to promote crop growth (see Pereira et al., 2017). However, mulching is an age-old practice particularly among yam and vegetable farmers in northern Ghana for soil water/moisture retention and for improving soil fertility for crop growth. The survey results show that 81% of the respondents have high levels of awareness on mulching as a climate compatible practice while 19% indicated they were less aware that mulching was a compatible agricultural practice. the high awareness level could be attributed to the fact that mulching is a common practice that smallholder farmers in the Guinea Savannah agroecological zone of northern Ghana mostly engage in to improve water retention ability and fertility of soil for crop productivity (Omari et al., 2018).

It was revealed that in both municipalities of Sissala East and Lawra, mulching was a basic and common practice among yam farmers, where farmers mulch the mounds after planting. The nurseries of vegetables such as tomatoes, onions, cabbage, pepper, garden eggs, etc. were also mulched to conserve moisture for germination of the seedlings. This conforms the findings of Agula et al. (2018) who found mulching as a common practice among irrigation farmers in the Upper East Region of northern Ghana. Generally, mulching was observed to be limited to yam and vegetable nursing activities which may partly be the reason why much has not been achieved on conservation agricultural practices in Ghana. Many farmers still burn the residues on their farms after clearing, instead of leaving them to serve as mulch which will later decompose to form manure for crop growth and productivity. Smallholder farmers mostly believed that mulching cannot be extended to other crops such as cereals following the large acres that are cultivated and the possibility of getting materials to cover such fields. This resonates with Kassam et al. (2014) who also believed that the unavailability of material for mulching affects the practice of mulching on large farms. Kassam et al. (2018) also concluded that the limited application of mulching and other conservational practices has affected the spread of conservation agriculture globally. Mulching is a multi-purpose practice which also comes with a manure component with the decomposition of the debris (such as leaves and grasses) to improve soil fertility for crop growth. According to the FAO (2017:19), mulching is common among smallholder farmers in SSA because of its "multipurpose nature of reducing runoff, increasing water infiltration, conserving moisture and controlling weeds". This presents a stepping board to upscaling mulching from yam and vegetable cultivation to cover cereal crop farming in North-western Ghana. Demonstration and experimental farms can be established to train and educate farmers on how to promote mulching on other food crops fields.

Generally, the responses from the household survey indicated low level of awareness on agroforestry practices among smallholder farming households in North-western Ghana. It emerged that 54% of the respondents were not aware that agroforestry is a climate compatible agricultural practice. The practice of growing trees and crops together was not prominent, particularly in the Sisaala East communities. However, 46% of the respondents indicated varied levels of awareness on agroforestry as a sustainable farming practice. Among those who were aware, 63% of them had low levels of awareness on agroforestry practices while 37% were significantly aware. Thus, many of the respondents lacked adequate awareness levels on agroforestry practices as sustainable agricultural practices in North-western Ghana. This finding differs from Fagariba et al. (2018a) who indicated that smallholder farmers in the Sissala West District of Upper West Region were engaged and preferred agroforestry practices in adapting to climate change. Bogale and Bikiko (2017) also found that tree planting was the most adopted practice among smallholder farmers in Ethiopia in adapting to climate variability, which however is not the case in this study. About 53% of the respondents indicated lack of willingness in adopting agroforestry farming practices while 47% were willing to adopt agroforestry practices. There is the need for sensitisation and education of smallholder farmers by the Department of Agriculture and NGOs on the importance of interfacing tree growing with cropping in the drive for achieving sustainable agriculture and food security.

It was observed that many participants in the study communities in Lawra Municipality had relatively fair understanding about agroforestry practices than participants in Sissala East Municipal. Some smallholder farmers in Lawra communities were observed to have grown trees on their farms while others allowed the growth of natural trees on their farms. In Sissala East communities, on the other hand, farmers cleared almost all trees on their farmlands including shea trees and other trees of economic value, confirming Kroeger et al., (2017) who observed that many smallholder farmers in Ghana engaged in poor tree and soil management practices. This might be attributed to the fact that communities in the Lawra Municipality have been sensitised and trained on natural regeneration of the vegetation and agroforestry practices in their efforts to conserve and improve land for farming.

The practice of minimum tillage was observed as an emerging practice among some smallholder farmers, particularly farmers who use herbicides. Smallholder farmers in North-western Ghana use farm implements such as tractors, bullocks, and hoes in tilling the land for planting of planting crops. The tractors and bullocks are used to plough flatly while the hoes mostly are used in making ridges and mounds for planting. It is important to mention that hoes can also be used to till land in any other way during field preparation for planting. Minimum tillage was not common practice among smallholder farmers. Therefore, the awareness level of it being a climate compatible practice was significantly low among households. The survey results show that 55% of the respondents indicated they were not aware while 45% had varied levels of awareness. Among those who indicated awareness of the practice, 10% of them had high level of awareness, 68% indicated low level of awareness and 22% indicated very low level of awareness. Thus, majority of the respondents (90%) of the 45% who were aware had low levels of awareness. This implies that minimum tillage has not yet been introduced to farmers and farmers may not have known the benefits of the practice. The relevant stakeholders such as the staff of the Department of Agriculture, NGOs, out-growers, and the authorities of Municipal Assemblies should undertake farmer capacity building including education and sensitisation to enhance adoption at the household levels. This is particularly important because 70% of the respondents were not willing to adopt minimum tillage as a sole practice. Only 30% of the respondents indicated their willingness to adopt the practice. Thus, many smallholder farmers in North-western Ghana were not aware of minimum tillage practices and consequently were not willing to adopt.

It was revealed during focus group discussions that participants who had fair knowledge on minimum tillage practices were people who had ever lived and engaged in farming in southern Ghana where the 'slash and burn' practice was common. However, in North-western Ghana the very few households who partly practice minimum tillage do not practice 'slash and burn' but rather engaged in excessive spraying of fields with herbicides. The minimum tillage practice was highly limited to very few farmers who also practice it on small fields. It was practised mostly to avoid late planting. The findings corroborate with Buah et al. (2017) who reported that minimum tillage in North-western Ghana was still practised by very few smallholder farmers. However, Agula et al. (2018) revealed that smallholder farmers in the Upper East Region of Ghana were practising minimum and conservation tillage as farm management practices and had significant high levels of awareness on them. Consequently, Fagariba, Song and Soule (2018b) attributed the low adoption of minimum tillage practices to the fact that many smallholder farmers do not understand the actual benefits of minimum tillage on one hand and may not be significantly aware of the consequences of human activities such as extensive tillage farming on the other hand.

There were varied understanding of the practice of rehabilitation of degraded lands among farming households in the two study municipalities. Much of the understanding related to the fact that farmers have, over the years, been practising the system of allowing cultivated lands to fallow for years and retain fertility. Others have also planted trees such as cashew, mango trees, teak, and other species which allow the land to regard fertility for crop farming. From these perspectives of understanding, 92% of the respondents in the survey indicated varying levels of awareness while eight percent were not aware. Further analyses of those who were aware revealed that 20% of the respondents had very high levels of awareness, 31% indicated high levels of awareness, 20% indicated low level of awareness, and 29% indicated very low level of awareness. Thus, 51% of the respondents had high levels of awareness while 49% had low levels of awareness on the practice. This indicates that rehabilitation of degraded lands was not a novelty but a practice that farmers engaged in in different forms such as natural regeneration, shifting cultivation and other practices. The findings corroborate with Agula et al. (2018) who reported that smallholder farmers in northeastern Ghana were engaged in rehabilitating vegetation for farming and hence exhibited significant levels of awareness on the practice. Similarly, Bogale and Bikiko (2017) reported that smallholder farmers in Ethiopia rehabilitated degraded lands for farming after their awareness were created on sustainable land management practices.

It is therefore, suggested that awareness on rehabilitation of degraded lands through deliberate tree planting and natural regeneration should be created among smallholder households to promote the practice to achieve climate compatible agriculture. This is particularly necessary for smallholder farmers who are willing to adopt the practice of rehabilitation of degraded lands for farming purposes. It emerged from the survey that all the respondents (100%) in Lawra Municipal were exposed to different means of land rehabilitation processes and were willing to continue with the practice. In the Sissala East Municipal, 84% of the respondents indicated their willingness to adopt rehabilitation of degraded lands, particularly through the shifting cultivation method and tree growing. The natural vegetative regeneration initiative by the Centre for Indigenous Knowledge and Organisational Development (CIKOD) an NGO in the Lawra Municipality was instrumental for the knowledge and awareness level of households in the municipality on the need for rehabilitation of degraded lands through natural regeneration.

As part of the project, communities were protecting the natural environment from bush fires and other activities that degraded the environment. These initiatives were mostly inadequate, if not lacking in the Sissala East Municipality. NGOs including CIKOD should extend their services to the Sissala East and other municipalities and districts to promote the practice of rehabilitation of degraded lands for climate compatible crop farming.

8.7 Soil fertility improvement practices

One of the ways by which smallholder farmers in North-western Ghana improve soil fertility for crop growth and enhanced yields is through the use of organic manure from animal and poultry droppings. Therefore, all the household respondents (100%) were found to have been aware of the use of organic manure as soil nutrient and moisture conservation practice. Despite smallholder farmers being aware of the use of organic manure, the adoption and practice of it was relatively low among smallholder households compared to the use of chemical fertilizer. This suggests that high level of awareness on a practice among smallholder farmers may not (entirely) lead to mass adoption of the practice. hence this departs from Silvestri et al. (2020) and Baumuller (2018) who indicated that high level of awareness on climate smart and compatible practices corresponds to mass adoption among smallholder farmers in SSA.

It was revealed that smallholder farmers were highly concerned about the fact that the use of organic manure particularly animal droppings promotes the growth and spread of alien weeds on their farmlands. It emerged from participants that the use of ruminant droppings (particularly cow dung) either directly or indirectly has resulted in the invasion of farmlands by alien weed species. It was explained that the alien cattle of the Fulani people which grazed on their farm residues during the off-farm season have contributed to the introduction of some invasive weeds that are thorny in nature and severely affect the health, growth and yields of all types of crops. It was revealed that those weed species were not available and known to them until in the mid-1990s when the Fulani intruded into the region with their cattle from the Sahel regions of Africa. Therefore, the fear of promoting weed growth on farms was a major challenge affecting the use of organic manure by many farmers in North-western Ghana. This corroborates with Babasola et al. (2017) who also indicated farmers' belief that the use of organic manure promotes invasion of weeds, pests and diseases on crops contributed to low adoption of organic fertilizer among vegetable farmers in Kwara State of Nigeria to farmers.

Another reason for low adoption of organic manure was that it could only be applicable to smaller farm sizes and not large farms. It was seen as a difficult task in mobilising large amounts of manure/compost to fertilize a farm size of more than five acres of land. A participant in Dolibizon community in Sissala East Municipal noted that

> *"It is very difficult for a farmer with more than five acres of farmland to rely on manure to fertilize them. Manure application is applicable to backyard farms which are usually smaller. What we rather do these days is that we gather and/or buy poultry droppings from the poultry farmers and mix them with chemical fertilizer. We do not use cow dung because it spread weeds"* (Excerpt from FGD, Dolibizon 2021).

It is important to train farmers on how to make manure using livestock droppings and other materials in a manner that it will not promote the growth and spread of alien and invasive weeds on farmlands. This is an effective way to increase awareness and promote adoption of organic manure among farmers in North-western.

The use of chemical fertilizers was one of the most popular farming practices among households in North-western Ghana, despite being costly to farming households. All the respondents (100%) indicated a high level of awareness on the use of chemical fertilizers in all the study communities. Fertilizer use was common among all households as it has become a predominant means of improving soil fertility and increasing crop yields and productivity in North-western Ghana. This corroborates with Derbile et al. (2019) who also indicated that smallholder farmers in the Wa Municipality of North-western Ghana use chemical fertilizer to improve soil fertility and increase crop yields. It also relates to the findings of Tesfay (2020) who found that an increase in the amount of fertilizer used led to an increase in plot productivity among smallholder farmers in northern Ethiopia. It was observed that many smallholder farmers engaged in indiscriminate use of fertilizers in both municipalities. However, indiscriminate use of fertilizers by farmers in Sissala East was more pervasive in Sissala East Municipal than in Lawra Municipal. This was attributed to farmers' quest to maximise yields under changing climatic conditions. Aryal et al. (2021) observed that a lack of knowledge among smallholder farmers on the balanced use of chemical fertilizer contributes to its over-use.

Generally, farmers demonstrated high interest in the use of chemical fertilizers, except that many households could not afford to buy fertilizer on their own due to high prices as indicated by Fagariba et al. (2018a). Hence, smallholder farmers, particularly in Sissala East mostly rely on out-growers who supply them on certain terms and conditions for repayment after harvesting of their farm crops. That is, farmers were usually supplied with fertilizers and other farm inputs by out-grower companies during the farming on credit basis, and the repayment made in kind after farmers have harvested. It was observed that the adoption and use of chemical fertilizers were mostly influenced by the corresponding increase in yields for smallholder farmers, which agrees with Tesfay (2020). The Government of Ghana has also subsidised fertilizer for farmers which also contribute to its use among many households. However, smuggling of subsidised fertilizer to neighbouring Burkina Faso has been a major cause of subsidised fertilizer shortage and high prices in North-western Ghana. The 2021 farming season was worse for smallholder farmers where increases in fertilizer prices were doubled, and many households could not afford. It was particularly pervasive in Sissala East Municipality and its neighbouring Sissala West District where there were many direct unapproved entry points into major cities and market centres in Burkina Faso.

8.8 Livelihood diversification

Smallholder farmers mostly diversify their livelihoods in many forms to sustain life and provide for family needs. Households, in addition to farming, engage in other non-farm activities including petty trading, local savings and credit schemes, gathering of forest products, production and sale of charcoal, logging, and unregulated small-scale mining (popularly called *galamsey* in Ghana). It is important to mention that households also diversify cropping farming by cultivating different types and varieties of crops which have different resistance and yielding potentials under different climatic conditions to sustain production and household food security in North-western Ghana. Crop farming is also complemented with livestock and poultry rearing in traditional households in North-western Ghana. These have made households become more aware about diversification as a sustainable practice for promoting climate compatible agriculture. From the survey results, all the household respondents (100%) indicated that they were highly aware of diversifying their livelihoods as a better practice to cope with climate change impacts at the household and community levels. Several studies have reported about livelihood diversification being very common practice among farming households in Ghana and SSA at large (Akudugu et al., 2021; Kupika et al., 2021; Dapilah et al., 2019; Derbile et al., 2019; Fagariba, 2018a, 2018b; Bogale & Bikiko, 2017).

8.3 Conclusion

Smallholder farmers' awareness levels on climate compatible farming practices were examined to understand how climate compatible agriculture can be promoted among smallholder farmers in North-western Ghana. These practices were categorised as agronomic/crop management strategies; disease, pests and weed control and management strategies; extension services strategies; soil management strategies; soil fertility improvement strategies; and livelihood diversifying strategies. The study found that the awareness levels of households on the various practices were appreciable especially practices that have attachment with indigenous knowledge systems of farmers. It was also revealed that accessibility and availability of strategies to farmers also enhanced awareness but in a manner that smallholder farmers could not properly apply them due to absence of training. For instance, households were aware of the use of chemical fertilizer, pesticides, and herbicides but they did not understand the dangers involved in the misapplication of these inputs. Hence, the applications of these inputs were done indiscriminately because they have access to them through government subsidy or out-grower initiatives. It is therefore prudent to sensitise, educate and train smallholder households on climate compatible agricultural practices which will enhance their understanding, knowledge, skills, and attitudes towards adoption for sustainable agricultural production and food security. Moerover, the awareness among households on climate compatible practices mostly corresponded to continuous willingness of farmers to adopt the practices except in some few cases. These exceptions usually related to practices where their applicability turns to be constrained by availability, and accessibility to farmers.

CHAPTER 9: SUMMARY OF FINDINGS, CONCLUSIONS AND SUGGESTIONS

9.1 Introduction

This chapter presents the summary of the findings of the study, and draws conclusions and suggestions based on the key findings. It is important to recall the aim and objectives of the study to appreciate the summary of the findings as well as the conclusions drawn, and the suggestions offered. The aim of the study was to explore the potential use of local and indigenous knowledge of smallholder farmers in promoting climate compatible agriculture in northern Ghana and how this interfaces with scientific knowledge. The aim was operationalised through the following four objectives:

1. To establish trends in climate change and explore how climatic risk and agricultural vulnerability are assessed through local and indigenous knowledge systems by smallholder farmers in the Upper West Region.
2. To explore the dynamics of interfacing the application of scientific, local and indigenous knowledge systems in promoting climate compatible agriculture in the Upper West Region of Ghana.
3. To determine the factors that may influence smallholder farmers' decisions in adopting local and indigenous knowledge systems for climate-compatible agricultural practices in the Upper West Region.
4. To determine the level of awareness of smallholder farmers on climate compatible agriculture and document adaptation measures developed in the Upper West Region.

The objectives of the study were addressed through the following four research questions:

1. What climate change trends exist and how do smallholder farmers assess climatic risk and agricultural vulnerability through local and indigenous knowledge systems in the Upper West Region of Ghana?

2. What dynamics exist in interfacing scientific, local, and indigenous knowledge systems in food crop and livestock production in the Upper West Region of Ghana?

3. Which factors determine smallholder farmers' decisions in adopting local and indigenous knowledge systems for climate-compatible agricultural practices in the Upper West Region?

4. What is the level of awareness of smallholder farmers on climate compatible agriculture and which adaptation measures have been developed in the Upper West Region?

The study adopted the mixed method approach where a combination of quantitative and qualitative research approaches was used. The mixed method approach allowed for triangulation of data which compensated weaknesses associated with both qualitative and quantitative methods in the research process. The concurrent mixed method procedure was employed by the study. The methods employed in data collection included face-to-face interviews, focus group discussion, and observation for the qualitative aspect of the study while a household survey using a questionnaire was conducted among 305 household heads in the six selected study communities in the two municipalities (Sissala East and Lawra). Meteorological data on rainfall and temperature were collected as secondary data from the Ghana Meteorological Agency for the period 1960-2018 for both municipalities.

Analyses and presentation of the qualitative research were undertaken through detailed descriptions, transcriptions, direct quoting and paraphrasing of information given by the respondents under themes and sub-themes built from the research objectives. Statistical tools such as Statistical Package for the Social Sciences (SPSS version 20) and Microsoft Excel (Microsoft Office 365) were used in the analyses and presentation of the quantitative data generated from the household survey.

9.2 Summary of findings

Concerning climate change trends and smallholder farmers' assessment of climatic risks and agricultural vulnerability, the study found that there was increasing uncertainty and unpredictability in rainfall and temperature patterns over the year in North-western Ghana. The rainfall pattern was characterised by decreasing pattern of yearly rainfall, late onset, early cessation, and limited distribution over North-western Ghana. Hence, there have been shifts and contractions in the rainy and farming seasons which negatively impacts on food crop production and food security. The meteorological data on rainfall from the period 1960-2018 confirmed that rainfall for the two municipalities was variable with mean total annual rainfall decreasing at decreasing rates. These changes manifest in recurrent floods and droughts during farming seasons with devastating effects on crop yields and general food crop production in North-western Ghana. There was decreasing frequency in the occurrence of floods with corresponding increases in the frequency and intensity of droughts (dry spells) in North-western Ghana over the decades. The impacts of these were severer for smallholder farmers who have low adaptive capacities. There was a drastic decrease in the frequency of occurrence of the fall of hailstones during the rainy season which was a local indication of poor rainfall pattern. Temperatures were observed to be increasing over the years with longer heat seasons being experienced than in the past decades. The intensity of temperatures during the heat seasons in North-western Ghana was observed to have increased with an extended duration over the years. This was confirmed by the meteorological data on temperature where both mean minimum and mean maximum temperatures showed an increasing trend at decreasing rates. These prolonged high temperatures aggravate the extreme heat conditions which manifest in health risks for human and livestock as well as affect crop yields and growth.

Regarding the interfacing of scientific, local and indigenous knowledge systems for agriculture production, it emerged that the majority (66.6%) of the smallholder farming households were using both scientific and local knowledge in developing adaptation strategies to climate change in North-western Ghana. Thus, smallholder farmers interfaced local and indigenous knowledge with scientific knowledge to develop climate compatible strategies at the household levels to sustain smallholder agriculture within the context of increasing impacts of climate change in North-western Ghana. The major sources for accessing weather and general agricultural information and services among smallholder farmers were through observing natural phenomena (activities of trees, birds, insects, clouds, stars, wind, etc.), family members, friends, radio stations and extension workers. These sources of information were interfaced with one another to develop strategies that were applicable within their local context of agricultural production. These strategies have been categorised in this study into farm-based and non-farm-based adaptation measures to climate change as examined in chapter six. The interface of scientific and local and indigenous knowledge systems among smallholder farmers has enabled them to develop farming practices that promote crop yields and sustain the land and environment for continuous agriculture over the years. This can serve as an opportunity for introducing and transitioning farmers onto climate compatible practices to achieve sustainable smallholder agriculture and household food security in North-western Ghana.

Determinants of farmers' decisions in adopting local and indigenous knowledge systems was also investigated and it emerged that smallholder farmers' decisions in adopting local and indigenous knowledge in developing climate compatible practices were influenced by several factors. These factors included gender, years of experience, access to and reliability of knowledge systems, age of farmers, access to credit, access to land, cost of inputs, availability of inputs, size of farm, land ownership, size of labour force, distance and location of farms, level of formal education, belief systems, access to extension services, and other factors. These factors were found to mostly influence the majority of households' adoption decisions in the study communities and North-western Ghana.

Smallholder farmers' awareness on climate compatible adaptation strategies remain a critical area. The study found that household were more aware of practices that mirrored local and indigenous knowledge systems as well as practices that were directly linked to immediate high yields and productivity as contained in Chapter Eight. The awareness of farmers on the use of chemical fertilizer, pesticides and herbicides were linked to the fact that these enhance high yields and productivity. It was discovered that majority of the respondents were not aware of climate compatible practices such as rainwater harvesting for farming, minimum tillage farming, agroforestry, use of meteorological weather information, use of mobile phones for accessing weather and agriculture information, and agriculture insurance. As indicated earlier, these practices do not mirror farmers' local and indigenous knowledge systems on one hand and were also highly not accessible to smallholder farmers. The awareness among households on climate compatible practices mostly corresponded to continuous willingness of farmers to adopt the practices except some few cases. These exceptions usually related to practices where their applicability turns to be constrained by availability, accessibility to farmers.

9.3 Conclusions

The phenomenon of climate change underpins agriculture and food security in northern Ghana. The increasing trend of climate change in the form of increasing variability in rainfall and temperature over the years poses uncertainty about the prospects of smallholder agriculture in contributing to the ending poverty and hunger as stipulated in the SDGs (SDGs 1 and 2). Smallholder farmers continue to suffer declining crop yields and low production over the years through erratic rainfall patterns and increasing temperatures which manifest in increasing droughts, high temperatures and floods. The pursuit of climate compatible agriculture for sustainable food production must be a priority for smallholder households, local authorities, and development actors. This is particularly important due to the actions of smallholder farmers which are becoming increasingly a source of concern in their role in contributing to climate variability in northern Ghana. The increasing use of synthetic agro-chemical inputs and indiscriminate extensification among smallholder farmers confirms the concerns raised by CSOs and other critiques of climate-smart agriculture and sustainable intensification agriculture. Nevertheless, there is potential for the integration of local and indigenous and scientific knowledge in developing agricultural practices and technologies that can produce maximum yields with reduced damages to the ecosystem. This potential presents a pragmatic approach for promoting climate compatible agriculture as exhibited through the interface of scientific and local knowledge by smallholder farming households.

There are significant appreciable levels of awareness of smallholder farming households on climate compatible agricultural practices in North-western Ghana even though the understanding and implementation of the concept of climate-smart agriculture was still very low among farming households. Households were more aware of local and traditional knowledge practices than scientific practices. This was particularly serious due to inadequate provision of extension services to smallholder farmers. These services were woefully inadequate to transition smallholder agriculture to climate compatible agriculture within a reasonable time. Creating access to extension services, credit, modern technology and services, and reliable meteorological weather information. were necessary to transition smallholder farmers onto climate compatible agriculture which will promote sustainable food production and ecosystem resilience in North-western Ghana and northern Ghana in general.

9.4 Suggestions

Drawing from the summary of the key findings and the conclusions, the following suggestions are made:

- Considering the increasing variability of rainfall and temperatures and the impact posed on smallholder agriculture, it is suggested for stakeholders in agriculture including MoFA, NGOs, farmer-based organisations, and development partners to intensify sensitisation, education, and training of smallholder farmers to create awareness and promote climate compatible agriculture in North-western Ghana.
- The provision of extension services which include meteorological information on weather patterns to farmers is relevant for promoting climate compatible agriculture. Hence, the Department of Agriculture and the Ghana Meteorological Agency should effectively collaborate to provide timely and reliable information to smallholder farmers through localised platforms such as community radios, community/farmers' forums, farmer-field schools, and others. The information should be integrated into the indigenous systems to make it more acceptable to smallholder households. This will enable smallholder farmers to plan agricultural activities in accordance with the forecast and variations in seasons within their local context.
- Many strategies are directed at adaptation to the neglect of mitigation, thereby neglecting the co-benefits that come with the pursuit of a combination of adaptation and mitigation strategies. Therefore, emphasis should be placed on integrating mitigation and adaptation measures to achieve the co-benefits for building resilient and low emission agricultural systems by promoting agroforestry and afforestation practices among smallholder farmers in North-western Ghana. This will further ensure that the opportunities and threats associated with both adaptation and mitigation are respectively harmonised and addressed to achieve sustainable agriculture and development.
- The potential of abundant sunshine and dry season irrigation in northern Ghana has not been utilised by successive governments and development partners in Ghana. Therefore, there is the need for investment in irrigation using renewable energy systems to engage farmers in agriculture in all seasons. Thus, the abundant sunshine provides opportunity for the use of renewable energy for irrigation purposes in northern Ghana including North-western Ghana. This will lessen the burden and risk of over-dependence on

rainfed agriculture and its susceptibility to rainfall variability which threaten food security. This will also build long term resilience as well as reduce emissions using renewable energy, thereby achieving both adaptation and mitigation simultaneously in the agricultural sector.

- There is also the need to regulate the use of agro-chemical inputs among smallholder farmers to reduce the potential of surface water pollution and the associated emissions of GHGs. MoFA through the Department of Agriculture should partner with related NGOs, out-growers, and other partners to undertake intensive education, sensitisation, and training of smallholder farmers on the proper use of agro-chemicals to minimise the indiscriminate application and disposal of agro-chemical waste material in farming communities in North-western Ghana.

9.5 Contribution to knowledge

The study contributed to knowledge by revealing the over-rated perceptions in the rates of changes and variability in rainfall and temperature in North-western Ghana among smallholder farmers and scholars. The extent to which changes and variability in mean total rainfall and mean maximum and minimum temperatures were perceived proved to slower and/or lower by the meteorological data for the two districts than usually reported by scholars. That is, although the meteorological data confirmed respondents' perceptions on changes in rainfall and temperatures, it showed that rates of changes were at decreasing rates.

The study also revealed the fact that sustainable agricultural practices such as climate-smart and compatible agricultural practices and technologies were still not adequately and deliberately introduced to farmers in North-western Ghana as done some parts of Ghana and other SSA countries.

The study also serves to supplement the general literature on climate change in relation to how smallholder farmers have interfaced scientific, local and indigenous knowledge over the years to sustain agricultural production and food security in North-western Ghana.

9.6 Suggestions for further research

The study focused on the adaptation aspect of climate compatible agriculture with little attention for climate change mitigation. It is therefore suggested that further research by other scholars be conducted on climate change mitigation in relation to how smallholder farmers are interfacing scientific, local and indigenous knowledge to achieve reduced emissions.

There is also the need for further research on the changes and impacts of sunshine and wind on smallholder agriculture on one hand, and on the other hand, examining the prospects of wind and sunshine as sources of renewable energy to facilitate irrigation for smallholder farmers.

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APPENDICES

APPENDIX 1: ETHICAL CLEARANCE CERTIFICATE

UNISA university of south africa

UNISA-CAES HEALTH RESEARCH ETHICS COMMITTEE

Date: 27/01/2020

Dear Mr File

NHREC Registration # : REC-170616-051
REC Reference # : 2019/CAES_HREC/197
Name : Mr DJM File
Student #: 63993465

Decision: Ethics Approval from 23/01/2020 to completion

Researcher(s): Mr DJM File
63993465@mylife.unisa.ac.za

Supervisor (s): Prof G Nhamo
nhamog@unisa.ac.za; 012-433-4725

Working title of research:

Climate compatible agriculture: Interfacing scientific, indigenous and local knowledge in the Upper West Region, Northern Ghana

Qualification: PhD Environmental Management

Thank you for the application for research ethics clearance by the Unisa-CAES Health Research Ethics Committee for the above mentioned research. Ethics approval is granted until the completion of the project, **subject to submission of yearly progress reports. Failure to submit the progress report will lead to withdrawal of the ethics clearance until the report has been submitted.**

Due date for progress report: 31 January 2021

*The **minimal risk application** was **reviewed** by the UNISA-CAES Health Research Ethics Committee on 23 January 2020 in compliance with the Unisa Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.*

The proposed research may now commence with the provisions that:

1. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.

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2. Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study should be communicated in writing to the Committee.
3. The researcher(s) will conduct the study according to the methods and procedures set out in the approved application.
4. Any changes that can affect the study-related risks for the research participants, particularly in terms of assurances made with regards to the protection of participants' privacy and the confidentiality of the data, should be reported to the Committee in writing, accompanied by a progress report.
5. The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study. Adherence to the following South African legislation is important, if applicable: Protection of Personal Information Act, no 4 of 2013; Children's act no 38 of 2005 and the National Health Act, no 61 of 2003.
6. Only de-identified research data may be used for secondary research purposes in future on condition that the research objectives are similar to those of the original research. Secondary use of identifiable human research data require additional ethics clearance.
7. No field work activities may continue after the expiry date. Submission of a completed research ethics progress report will constitute an application for renewal of Ethics Research Committee approval.

Note:

*The reference number **2019/CAES_HREC/197** should be clearly indicated on all forms of communication with the intended research participants, as well as with the Committee.*

Yours sincerely,

Prof MA Antwi
Chair of UNISA-CAES Health REC
E-mail: antwima@unisa.ac.za
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Prof MJ Linington
Executive Dean : CAES
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APPENDIX 2: HOUSEHOLD SURVEY QUESTIONNAIRE

COMMUNITY NAME:

Number: **Date:**

CLIMATE COMPATIBLE AGRICULTURE: INTERFACING SCIENTIFIC, INDIGENOUS AND LOCAL KNOWLEDGE IN THE UPPER WEST REGION, NORTHERN GHANA

Introduction and Background

For field research assistants (begin like this):

My name is …………………… I have been engaged by Mr. **DRAMANI JUAH M-BUU FILE**, a PhD student at the University of South Africa with student identification number **63993465**. He is gathering data for his thesis on the topic: ***"Climate compatible agriculture: Interfacing scientific, indigenous and local knowledge in the Upper West Region, northern Ghana".*** The Sissala East and Lawra Municipalities have been chosen as study municipalities and this community chosen as one of three study communities for this municipality.

The aim of the research is to explore the potential use of local and indigenous knowledge of smallholder farmers in promoting climate compatible agriculture in the Upper West Region, northern Ghana. It thus explores the potential of the knowledge of smallholder farmers and how it can be interfaced to promote climate compatible agriculture for sustainable livelihoods in the Upper West Region and northern Ghana by extension.

The results of the research are strictly for academic purposes; thus, for the attainment of my PhD and for academic publications in journals and other academic platforms. The information provided will also be treated as strictly confidential and anonymous. Your identity will not be disclosed in any data published in the thesis and journals. There are no risks associated with this research and your participation is highly voluntary. You are free to withdraw from this survey at any point or time. I will appreciate it if you spend approximately 35 minutes of your time to answer this questionnaire. I will also seek your kind permission to take photos, but no name will be put against any photo taken.

Should you require further clarity, please do not hesitate to contact me on 0207784736 or dramani_file@yahoo.com or contact my supervisor, Prof Godwell Nhamo on +27-73-163-1114 or nhamog@unisa.ac.za

SECTION A: DEMOGRAPHIC CHARACTERISTICS OF RESPONDENTS

A1. Age group

S/N	AGE	TICK
1	20-29	
2	30-39	
3	40-49	
4	50-59	
5	60-69	
6	70+	

A2 Gender

s/n	Gender	Tick
1	Male	
2	Female	
3	Wish not to disclose	

A3. Level of education

s/n	Level of education	Tick
1	No education	
2	Primary	
3	Junior high school	
4	Vocational	
5	Senior high school	
6	Tertiary	

A4. Marital status

s/n	Marital status	Tick
1	Married	
2	Single	
3	Divorced	
4	Widowed	

A5. Ethnicity

s/n	Ethnicity	Tick
1	Sissala	
2	Dagaaba	
3	Waala	
4	Others (specify)	

A6. What is the size of your household?

s/n	Size of household	Tick
1	1-2	
2	3-4	
3	5-6	
4	7+	

A7. How many years have you lived in this community?

s/n	Years	Tick
1	6-10	
2	11-15	
3	16-20	
4	21-25	
5	26-30	
6	31-35	
7	36-40	
8	41+	

A8. Is food crop farming the major occupation of your household?

s/n	Response	Tick
1	Yes	
2	No	

A9. How many years have you been farming?

S/N	Years	Tick
1	5 & below	
2	6-10	
3	11-15	
4	16-20	

5	21-25	
6	26-30	
7	31-35	
8	36-40	
9	41+	

A10. What is the average size of your farm in acres?

s/n	**Acres**	**Tick**
1	1-2	
2	3-4	
3	5-6	
4	7-8	
5	9-10	
6	11+ (specify)	

A11. How did you acquire your farmland?

s/n	**Land acquisition**	**Tick**
1	Family	
2	Rented	
3	Bought	
4	Gifted	
5	Sharecropping	
6	Temporal farmland	
7	Others (specify)	

A12. What are the types of crops you cultivate on your farm?

s/n	**Crop**	**Tick all those applicable**
1	Maize	
2	Sorghum	
3	Guinea corn	
4	Rice	
5	Millet	
6	Yam	
7	Beans	
8	Soya	
9	Groundnuts	
10	Potatoes	
11	Cassava	

12	Cotton	
13	Bambara beans	
14	Others (specify)	

A13. List the livestock you rear

s/n	Livestock	Tick all those applicable
1	Cattle	
2	Goats	
3	Sheep	
4	Donkeys	
5	Pigs	
6	Fowls	
7	Ducks	
8	Turkeys	
9	Guinea fowls	
10	Others (specify)	

A14. What type of farming are you engaged in?

s/n	Type of farming	Tick
1	Crop farming only	
2	Livestock rearing only	
3	Both crop and livestock	
4	Others (specify)	

SECTION B

THEME 1: CLIMATE CHANGE TRENDS AND SMALLHOLDER FARMERS' ASSESSMENT OF CLIMATIC RISKS AND AGRICULTURAL VULNERABILITY THROUGH LOCAL AND INDIGENOUS KNOWLEDGE SYSTEMS

B1. Have you observed any changes in weather and climatic elements over the past 5 or more years as a farmer?

S/N	Response	Tick
1	Yes	
2	No	
3	Don't know	

B2. If yes, indicate the observed general changes in relation to the following variables over the years

s/n	Variable	Increased	Decreased	Moderate	No change	Don't know
		1	**2**	**3**	**4**	**5**
1	Rainfall					
2	Temperature					
3	Wind					
4	Sunshine					

B3. Indicate your position on the following statements in relation to observed changes in climate patterns in your community over the past five or more years.

S/N	Climate variability and change	strongly agree	Agree	Uncertain	Disagree	Strongly disagree
		1	**2**	**3**	**4**	**5**
1	Increased total rainfall					
2	Decreased total rainfall					
3	Limited distribution/coverage of rainfall in recent years					
4	Late start (onset) of the rains in recent years					
5	Early start of rains in recent years					
6	Early stop of rains in recent years					
7	Late stop of the rains in recent years					
8	Change in planting dates in recent years					
9	Longer rainy season in recent years					
10	Shorter rainy season in recent years					
11	Increasing temperatures over the past 30 or more years					
12	Increasing incidents of dry spells in recent years					

13	Decreasing incidents of dry spells in recent years					
14	Increasing frequency of floods in recent years					
15	Decreasing frequency of floods in recent years					
16	Increasing incident of strong and destructive winds/rainstorms in recent years					
17	Decreasing frequency and less strong and destructive winds/rainstorms in recent years					
18	Rainfall pattern is highly uncertain and unpredictable in recent years					
19	Increasing number of sunny days during the peak of the rainy season in recent years					
20	Decreasing number of sunny days during the peak of the rainy season in recent years					

B4. Indicate the observed changes in frequency of the following climatic related hazards

s/n	**Hazard**	**Increasing 1**	**Decreasing 2**	**Moderate 3**	**No change 4**	**Don't know 5**
1	Floods					
2	Drought					
3	Dry spell					
4	Rainstorm					
5	Extreme heat					
6	Extreme cold					
7	Hailstones					
8	Extreme sunshine					
9	Bush fires					
10	Pests & diseases					

B5. As a smallholder farmer, indicate (by ticking all applicable ones) your source of weather information for agricultural activities over the years

s/n	Source	Tick
1	Radio	
2	Television (TV)	
3	Agriculture Extension Officers	
4	Local knowledge systems	
5	Mobile phones	
6	Farmers group meetings	
7	Friends	
8	Newspapers	
9	Family members	
10	Social media (Facebook, WhatsApp etc.)	
11	Others (specify)	

B6. Indicate (tick all applicable) the month in which the following most likely occur from your years of experience

s/n	Variable	J	F	M	A	M	J	J	A	S	O	N	D
1	Floods												
2	Drought												
3	Dry spells												
4	Pests												
5	Extreme winds												
6	Extreme heat												
7	Peak of rainy season												
8	Extreme cold (Harmattan)												
9	Sunshine												
10	Onset of rainy season												
11	Stop of rainy season												
12	Bush burning												

B7. Indicate the impact (effects) of the following on food crops production

s/n	Variable	Good yields	Moderate yields	Poor yields	No impact	Don't know
1	Floods					
2	Droughts					
3	Pests & diseases					
4	Extreme heat					
5	Extreme winds					
6	Bushfires					
7	Low soil fertility					
8	Extreme Sunshine					

B8. Indicate (by ticking all applicable) the rainfall conditions favourable for the production of the following livestock

s/n	**Livestock**	**Rainfall**		
		Extreme	**Moderate**	**Low**
1	Cattle			
2	Sheep			
3	Goats			
4	Pigs			
5	Guinea Fowls			
6	Fowls			
7	Ducks			
8	Turkey			

B9. Indicate (by ticking all applicable) the temperature conditions favourable for the production of the following livestock

s/n	**Livestock**	**Temperature**		
		Extreme	**Moderate**	**Low**
1	Cattle			
2	Sheep			
3	Goats			
4	Pigs			
5	Guinea Fowls			
6	Fowls			
7	Ducks			
8	Turkey			

B10. Indicate (tick all applicable) in relation to the location of your farmland(s)

s/n	**Location**	**Yes**	**No**
1	Upland		
2	Lowland		
3	Flat land		
4	Waterlogged area		
5	Flood plains		
6	Near river		

B11. Indicate the distance of your farmland(s) from home

s/n			
1	Near home (backyard)		
2	Far from home (bush farms)		
3	Both		

B12. Indicate the number of years you have been farming on your current piece(s) of land

s/n	Years	Tick
1	1-3	
2	4-6	
3	7-9	
4	10+	

SECTION C

THEME 2: DYNAMICS IN INTERFACING SCIENTIFIC, LOCAL AND INDIGENOUS KNOWLEDGE SYSTEMS IN FOOD CROP AND LIVESTOCK PRODUCTION

C1. Indicate which of the following knowledge systems you rely on for weather and agricultural information in your community/household?

s/n	Knowledge system	Tick
1	Scientific knowledge systems (e.g. radio, TV, internet, agric officers, etc.)	
2	Local and Indigenous knowledge systems (e.g. behaviour and activities of birds, trees, insects, etc.)	
3	Both knowledge systems	

C2. Have you changed the types of crops cultivated over the years due to climate change?

s/n	Response	Tick
1	Yes	
2	No	

C3. If yes in C2, indicate (tick all applicable) the crops you have stopped cultivating

s/n	Crop	Tick
1	Maize	
2	Millet	
3	Sorghum	
4	Guinea corn	
5	Rice	
6	Groundnuts	
7	Bambara beans	
8	Cowpea	
9	Yam	
10	Potatoes	
11	Others (specify)	

C4. Indicate if you have now adopted crops that are:

s/n	Crop/livestock	Tick
1	Early maturing	
2	Drought resistant	
3	Water loving (e.g. rice, etc)	
4	Pests & disease resistant	
5	Long maturing	
6	High yielding	
7	Others (specify)	

C5. Have you changed the types of livestock reared over the years due to climate change?

s/n	Response	Tick
1	Yes	
2	No	

C6. If yes in C5, indicate livestock you have brought on board. Give the respondents a list here. Use same list you used earlier.

s/n	Livestock	Tick all those applicable
1	Cattle	
2	Goats	
3	Sheep	
4	Donkeys	
5	Pigs	
6	Fowls	
7	Ducks	
8	Turkeys	
9	Guinea fowls	
10	Others (specify)	

C7. Indicate (tick all applicable to you) how you are adapting to climate change

s/n	Strategy	Tick
1	Use of early maturing crops	
2	Use of drought resistant crops	
3	Use of pesticides & insecticides	
4	Use of herbicides	
5	Use of chemical fertilizer	
6	Use of compost/manure	
7	Mixed farming	
8	Mixed cropping	
9	Mono cropping	
10	Farm rotation	
11	Crop rotation	
12	Flat ploughing	
13	Ridging/mounding	
14	Seasonal migration	
15	Multiple farm ownership	
16	Upland farming	
17	Lowland farming	
18	Crop diversification	
19	Gathering of forest products	
20	Agricultural insurance	
21	Tree growing/agroforestry	
22	Village savings & loans	
23	Dry season farming	
24	Hunting	
25	Rainwater harvesting	
26	Petty trading	
27	Reduction in quantity and frequency of meals in the household	

SECTION D

THEME 3: FACTORS DETERMINING FARMERS' DECISION IN ADOPTING LOCAL AND INDIGENOUS KNOWLEDGE SYSTEMS FOR CLIMATE COMPATIBLE PRACTICES

D1. Indicate (tick all applicable) the extent to which the following factors influence your decision in adopting local and indigenous knowledge for developing climate compatible agricultural strategies

s/n	Factors	High	Medium	Low	Don't Know
		1	**2**	**3**	**4**
1	Accessibility to source of knowledge				
2	Reliability of knowledge system				
3	Land ownership				
4	Size of farm				
5	Size of labour force				
6	Level of formal education				
7	Awareness of practice/technology				
8	Gender				
9	Years of experience				
10	Age of farmer				
11	Access to credit				
12	Access to land				
13	Location of farm (upland, lowland)				
14	Distance of farm from home				
15	Cost of inputs (Affordability)				
16	Accessibility to inputs				
17	Availability of inputs				
18	Belief systems (values, norms)				
19	Access to extension services				
20	Membership to farmer groups				
21	Training received				
22	Simplicity of practice				
23	Others (specify)				

SECTION E

THEME 4: LEVEL OF AWARENESS AND RATE OF ADOPTION OF SMALLHOLDER FARMERS ON CLIMATE COMPATIBLE AGRICULTURE FOR DEVELOPING ADAPTATION STRATEGIES

E1. Have you ever been engaged in any discussions or meetings (by agricultural officers) regarding climate compatible agricultural practices (good farming practices)?

s/n	**Response**	**Tick**
1	Yes	
2	No	

E2. If yes in E1, how often do you receive education and awareness on climate compatible practices and technologies?

s/n	**Frequency**	**Tick**
1	Daily	
2	Weekly	
3	Monthly	
4	Quarterly	
5	Yearly	

E3. Indicate (tick all applicable) your level of awareness of the following climate compatible practices.

S/N	Strategy	Very high 1	High 2	Low 3	Very low 4	Not at all 5	
1	Rainwater harvesting for farming						
2	Mulching						
3	Crop rotation						
4	Use of drought resistant crops/breeds						
5	Mixed farming						
6	Mixed cropping						
7	Agroforestry						
8	Minimum tillage						
9	Use of weather information and services						

10	Use of mobile phones for weather information						
11	Agriculture extension services						
12	Use of organic manure						
13	Use of chemical fertiliser						
14	Rehabilitation of degraded lands						
15	Use of (chemical) pesticides						
16	Use of organic pesticides						
17	Excessive use of herbicides						
18	Agricultural insurance						
19	Crop/livelihood diversification						

E4. Indicate (tick all applicable) your willingness to adopt or rate of adoption of the following climate compatible agricultural practices.

S/N	Strategy	Very high 1	High 2	Low 3	Very low 4	Not at all 5	Don't know 6
1	Rainwater harvesting for farming						
2	Mulching						
3	Crop rotation						
4	Use of drought resistant crops/breeds						
5	Mixed farming						
6	Mixed cropping						
7	Agroforestry						
8	Minimum tillage						
9	Use of weather information and services						
10	Use of mobile phones for weather information						
11	Agriculture extension services						
12	Use of organic manure						
13	Use of chemical fertiliser						
14	Rehabilitation of degraded lands						
15	Use of (chemical) pesticides						
16	Use of organic pesticides						
17	Excessive use of herbicides						
18	Agricultural insurance						
19	Crop/livelihood diversification						

END OF INTERVIEW. THANK YOU VERY MUCH FOR YOUR TIME.

APPENDIX 3: FACE-TO-FACE INTERVIEWS GUIDE AND OBSERVATION CHECKLIST

CLIMATE COMPATIBLE AGRICULTURE: INTERFACING SCIENTIFIC, INDIGENOUS AND LOCAL KNOWLEDGE IN THE UPPER WEST REGION, NORTHERN GHANA

Part A

Guide for face-to-face interviews with community opinion leaders and seasoned smallholder farmers (45 minutes)

1. How has rainfall changed over the past years?
2. How has temperature changed over the past years?
3. What do you think accounts/causes for these changes?
4. How often do the following occur and how do they affect food crop farming?
    - Floods
    - Dry spells
    - High temperatures/sunshine
5. What strategies do you adopt in response to climatic change?
6. What factors will you consider in adopting local and indigenous knowledge for developing adaptation strategies?
7. What are your sources of weather information?
8. Have you ever been engaged in any discussion or meeting on good agricultural practices (practices that promote environmental sustainability and agriculture production)?

Part B

<u>INTERVIEW GUIDE FOR MUNICIPAL PLANNING AND BUDGET OFFICERS</u>

1. How does the assembly deal with issues of climatic risks and smallholder agricultural vulnerability in its medium-term development plans and composite budgets? (Researcher will probe how this is done over the past years and the successes and others of it – how it addresses climate compatible agriculture)

2. How does the assembly promote climate compatible agricultural practices through medium-term development planning and composite budgeting? (Researcher will probe for insights on how scientific and local knowledge systems are incorporated into the plan in the direction of climate compatible agriculture)

3. What steps have you (the assembly) taken to create awareness and adoption climate compatible practices among smallholder farmers in the municipality?

4. What factors do you consider when planning and budgeting for climate compatible agriculture, in relation to adoption by smallholder farmers, in the medium-term development plan and composite budget of the municipal assembly respectively?

Part C

INTERVIEW GUIDE FOR MUNICIPAL DIRECTORS OF AGRICULTURE AND EXTENSION OFFICERS

1. What climatic risks have you identified among smallholder farmers in the municipality?
2. What has been the trend in rainfall and temperature relation to the farming calendar over the years?
3. What are the prospects and constraints of smallholder farmers in interfacing scientific and indigenous knowledge in adapting to climate change?
4. What farming practices have you observed among farmers in the municipality?
5. Do you consider these farming practices among smallholder farmers as climate compatible practices? Why do you say so?
6. What/which agricultural practices do you encourage among smallholder farmers in the municipality? (Researcher will probe to know if smallholder farmers are aware of these climate compatible agricultural practices in the municipalities and how whether they practice them)
7. Are these climate compatible practices? Why do you say so?

8. From your experience as an agriculture officer, what factors do you think influence smallholder farmers' decisions to rely on local and indigenous knowledge systems in developing adaptation strategies in the municipality? Probe: factors influencing farmers' decisions in the adoption or otherwise of climate compatible practices
9. What has been your experience in the field, working with smallholder farmers to adopt climate compatible agricultural practices in the municipality? Any challenges?

THANK YOU VERY MUCH FOR YOUR TIME.

FIELD OBSERVATION CHECKLIST

1. Farm practices
2. Types of crops cultivated
3. Livestock reared at household level
4. Location of farms- upland, lowland, close to river/stream etc.
5. Size of farms
6. Etc.

APPENDIX 4: FOCUS GROUP DISCUSSIONS GUIDE

CLIMATE COMPATIBLE AGRICULTURE: INTERFACING SCIENTIFIC, INDIGENOUS AND LOCAL KNOWLEDGE IN THE UPPER WEST REGION, NORTHERN GHANA

Climate change trends and vulnerability assessment

Q1. How have the following climatic variables changed over the years

1. Rainfall
2. Temperatures

Q2. How have you been predicting rainfall over the years as smallholder farmers?

Q3. How have you been adapting to rainfall and temperature variabilities over the years as smallholder farmers?

Q4. How do you (farmers) interpret the following in relation to rainfall?

s/n	Variable	Local name/term	Meaning
1	Tick-dark clouds		
2	Nests of river beds hang low to water level		
3	Nests of river beds hang high to water level		
4	South-north movement of hornbills		
5	North-south movement of hornbills		
6	Shedding of leaves of some plants (eg rosewood tree)		
7	Flowering of some wild plants		
8	Bumper fruiting of wild plants		

9	Singing by ‘rain’ birds		
10	Morning rains at onset of rainy season		
11	Migration of ants in groups		
12	Intensive croaking of toads and frogs after rains		
13	Availability and movement of millipedes		
14	Others (specify)		

Q5. Indicate and state the reason for the location of your farm

s/n	Location	Tick	Reason for the location
1	Upland		
2	Lowland		
3	Flat land		
4	Waterlogged area		
5	Flood plains		
6	Near river		
7	Near home (backyard)		
8	Far from home (bush farm)		

<u>Dynamics of interfacing scientific, and local and indigenous knowledge</u>

Q1. How have you sustained food crop farming over the years in this era of increasing climate and environmental variability?

Q2. What crops do you cultivate? And where and how do you acquire the seeds for planting?

Q3. How are the following activities undertaken during the agricultural (farming) season?

s/n	Activity	How it is done (implements, inputs, etc.)
1	Land preparation	
2	Planting or sowing	
3	Fertilisation	
4	Weeding	
5	Protection (from pests, animals, birds, etc.)	
6	Harvesting	
7	Processing (on farm)	
8	Packaging (on farm)	
9	Transportation (from farm to home)	
10	Storage	
11	Marketing	

NB: Researcher will probe into the type of equipment (traditional and modern) used by farmers for each activity. The probe will also include the transitions in those activities over time.

<u>Factors influencing farmers' decisions in adopting local and indigenous knowledge for developing adaptation strategies</u>

What factors influence you to adopt local and indigenous knowledge in developing agricultural practices and strategies?

<u>Awareness of climate compatible practices among smallholder farmers</u>

Q1. How often have you been engaged in discussions on good agricultural practices, as smallholder farmers?

Q2. Indicate how you respond to the following:

s/n	Variables	
1	Low crop yields	
2	Low soil fertility	
3	Low soil moisture/water	
4	Degraded lands	
5	Preserving water bodies	
6	Preserving forest/vegetation	
7	Pests & disease control	
8	Soil erosion	

THANK YOU VERY MUCH FOR YOUR TIME.

APPENDIX 5: GHANA METEOROLOGICAL AGENCY PERMISSION LETTER

GHANA METEOROLOGICAL AGENCY

P. O. Box LG 87, Legon-Accra, Ghana
Tel: +233-30-701 2520
Fax: +233-30-2511981
Digital Address: GA-485-3581

E-mail: gmet@meteo.gov.gh
Website: www.meteo.gov.gh

Our ref:
Your ref:

Dramani Juah M-Buu File
National Disaster Management Organisation
P.O.Box 151
Wa
Upper West Region

12 June 2019

Dear Sir,

RE: REQUEST FOR RESEARCH PERMISSION

Your letter dated 22 May 2019 on the above subject matter refers.

I wish to assure you of the support of the Ghana Meteorological Agency through the provision of weather and climate information in writing your thesis on the "Climate compatible agriculture: interfacing scientific, indigenous and local knowledge in the Upper West Region, northern Ghana".

It is our understanding that the information and data that we will provide will be used strictly for academic purposes.

Yours faithfully

Andrew Nkansah
Deputy Director-General
For: Director-General

APPENDIX 6: LAWRA MUNICIPAL ASSEMBLY PERMISSION LETTER

OFFICE OF THE LAWRA MUNICIPAL ASSEMBLY
(CENTRAL ADMINISTRATION DEPARTMENT)

In case of reply the date and number of this letter should be quoted

Our Ref: LMA/G.77/121
Your Ref:
Tel:
Email:

REPUBLIC OF GHANA

LAWRA MUNICIPAL ASSEMBLY
IN UNITY WE BUILD

Post Office Box 23,
Lawra,
Upper West Region.

04/07/ 2019.

LETTER OF ASSURANCE TO CONDUCT RESEARCH WORK IN THE LAWRA MUNICIPALITY

We refer to your letter dated 22nd May, 2019, on the above subject matter and wish to grant you permission to conduct the stated research in the Lawra Municipality.

You are also allowed by the strength of this letter to contact the proposed informants as stated in your letter for the needed information.

Thank you.

MOHAMMED ABDUL-MAJEED
(MUNICIPAL COORDINATING DIRECTOR)
FOR: MUNICIPAL CHIEF EXECUTIVE

DRAMANI JUAH M-BUU FILE
NATIONAL DISASTER MANAGEMENT ORGANIZARION
POST OFFICE BOX 151
UPPER WEST REGION

APPENDIX 7: SISSALA EAST MUNICIPAL ASSEMBLY PERMISSION LETTER

SISSALA EAST MUNICIPAL ASSEMBLY

In case of reply the date and number of this letter should be quoted

Our Ref: SEMA/UWR/

Your Ref:

Republic of Ghana

Post Office Box 12
Tumu, Upper West Region
Telephone: 0392097264/5
E-mail:
sema.tumu2017@gmail.com

Date: 17th October, 2019

RE-APPLICATION FOR RESEARCH PERMISSION LETTER

The Sissala East Municipal Assembly acknowledges receipt of your letter requesting for permission and an assurance of our support to conduct a study towards attaining a PHD.

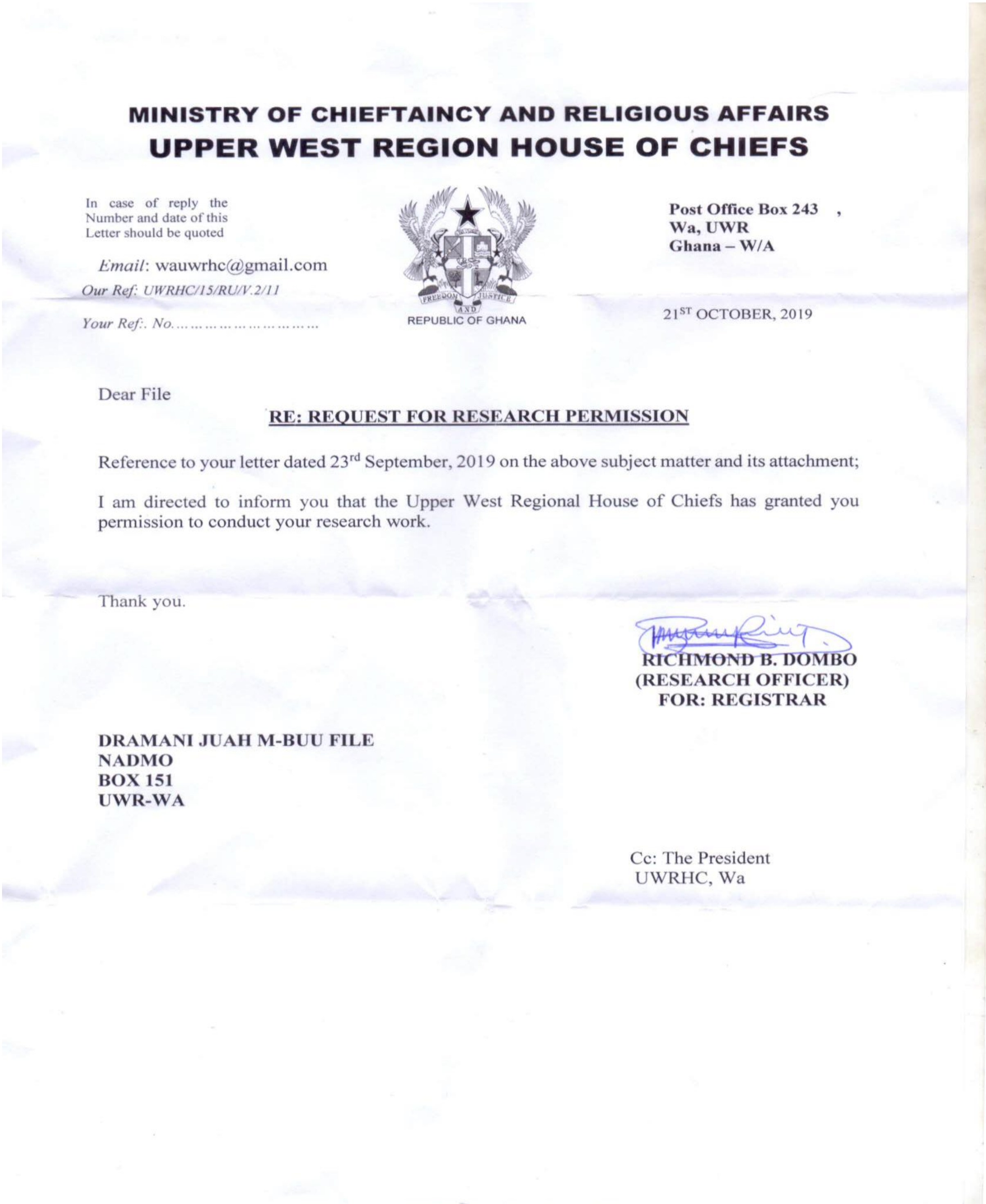
I wish to indicate that, the Municipal Assembly is ready to assist you by allowing you to engage relevant staff and also help provide you with any information necessary to your course of study.

Thank you.

NABIEBAKYE FIRMIN-ROGER
MUNICIPAL COORDINATING DIRECTOR
FOR: MUNICIPAL CHIEF EXECUTIVE

DRAMANI JUAH M-BUU FILE
NADMO
BOX 151. UPPER WEST REGION.
WA

APPENDIX 8: UPPER WEST REGIONAL HOUSE OF CHIEFS PERMISSION LETTER



MINISTRY OF CHIEFTAINCY AND RELIGIOUS AFFAIRS

UPPER WEST REGION HOUSE OF CHIEFS

In case of reply the Number and date of this Letter should be quoted

Email: wauwrhc@gmail.com

Our Ref: UWRHC/15/RU/V.2/11

Your Ref:. No.……………………………

FREEDOM AND JUSTICE

REPUBLIC OF GHANA

Post Office Box 243 ,
Wa, UWR
Ghana – W/A

21ST OCTOBER, 2019

Dear File

RE: REQUEST FOR RESEARCH PERMISSION

Reference to your letter dated 23rd September, 2019 on the above subject matter and its attachment;

I am directed to inform you that the Upper West Regional House of Chiefs has granted you permission to conduct your research work.

Thank you.

RICHMOND B. DOMBO
(RESEARCH OFFICER)
FOR: REGISTRAR

DRAMANI JUAH M-BUU FILE
NADMO
BOX 151
UWR-WA

Cc: The President
UWRHC, Wa