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Aspects of food security and climate change resilience in Semi-arid Northern Ghana

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Abstract

With increasing climate change and variability, agricultural productivity continues to decline causing global food insecurity to rise particularly in the Global South. In the predominantly rain-fed agricultural context of semi-arid Northern Ghana, farmers continue to contend with worsening and increasingly unpredictable climatic conditions. Within the context of rising climatic stressors, concerns of post-harvest food loss in smallholder farming communities in Northern Ghana is on the rise. Though existing literature shows that post-harvest loss (PHL) in the Global South is a major challenge to achieving food security, little is known about the determinants of PHL outcomes in smallholder farming communities. Moreover, the complexities of climate change impacts on smallholders have prompted attention to examine other existing resilience building strategies in smallholder contexts. Backyard gardening has emerged as one such resilience building strategies given its potential of meeting the food and nutritional requirement of smallholder households.

Using data from a cross sectional survey of 1100 smallholder farmers in the Upper West Region (UWR) of Ghana, this study first examined the determinants of PHL within the context of climate change and food security. Results from a multiple linear regression model showed a significant association between PHL and a number of variables including demographic and household socio-economic factors. Female primary farmers (α=-1.063; $p \leq 0.05$), household size, specifically households with 8-11 members (α=-1.880; $p \leq 0.05$), joint decision-making (α=-1.257; $p \leq 0.05$), as well as financial remittance (α=-2.622; $p \leq 0.05$) were all significantly associated with lower likelihood of PHL. On the contrary, being single in marital status (α= 2.081; $p \leq 0.05$), farmers belonging to the poorer (α=1.67; $p \leq 0.05$) and poorest (α=2.859; $p<0.001$) households, livestock rearing (α=1.851; $p \leq 0.05$), and mold infestation (α=6.340; $p \leq 0.05$), were significantly associated with higher likelihood of PHL. These findings demonstrate the need for agricultural policies to begin prioritizing household socio-economic challenges such as access to agricultural credit, as well as the promotion of joint household decision-making arrangements in the study context. The creation of participatory learning spaces for male and female farmers may also be a viable way of promoting gendered knowledge transfer for PHL prevention in this context.

The study also examined the association between the practice of backyard gardening and smallholder farmers' resilience to the impacts of climatic stressors. The findings revealed that smallholders who practiced backyard gardening were significantly (OR=9.105; $p<0.001$) more likely to be resilient than those who did not. This finding reinforces the need for backyard gardening to be encouraged as a way of spreading risk and building resilience to the impacts of climate change. Given the comparative advantages (e.g., proximity, manageability, the use of green manure, animal droppings etc.) that are associated with backyard gardening, it has the potential of offsetting the losses that farmers may record on their long-distance farms and can therefore strengthen their resilience capacity in times of climatic stressors like drought and erratic rainfalls.

Keywords: Post-harvest loss; climate change resilience; backyard gardening; smallholder farmers; Northern Ghana.

Summary for Lay Audience

About 250.3 million, representing nearly one-fifth of the population in Africa, are currently experiencing hunger. Sub-Saharan Africa (SSA) alone constitute about 234.7 million of the hungry population in the continent (FAO et. al, 2021). Also, nearly 3.4 billion of the global population resides in rural areas, mostly smallholders who are highly vulnerable to climate change (IPCC, 2022). The prevalence of food insecurity among smallholder farmers in SSA is attributed to climate change, and other socio-economic factors. In Ghana, climate change and food insecurity are major challenges to most smallholders. Farmers in northern Ghana lack the appropriate coping and adaptation strategies for climate change and post-harvest loss (PHL) prevention (Baral & Hoffmann, 2018). Also, some scholars have highlighted the potentials of dry season gardening in building smallholder farmers' resilience to climate change. There is however little research on the factors that shape PHL in smallholder farming contexts, as well as the association between dry season gardening and smallholders' resilience to climate change impacts. In contributing to the literature on PHL and backyard gardening as a climate change resilience strategy, this thesis examined the determinants of PHL, and also examined the association between backyard gardening and smallholder farmers' resilience to climatic stressors.

Overall, poverty, lack of access to affordable credit facilities and socio-cultural factors like joint agricultural-related decision-making, were all significant determinants of PHL in the study context. The practice of backyard gardening was also significantly associated with good resilience to climate change. The study thus suggests that in smallholder farming contexts like northern Ghana, agricultural policies that target PHL prevention should focus on addressing the underlying socio-economic constraints of smallholder farming households. The study also suggests that policy initiatives that aims at improving smallholder farmers' resilience to climatic stressors, should recognize and prioritize supplementary farming practices like backyard gardening given that backyard gardening has the potential of spreading

the risk of crop failure from drought, and can concurrently reduce smallholder farmers' vulnerability to food insecurity.

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Chapter 1

1.1 Introduction

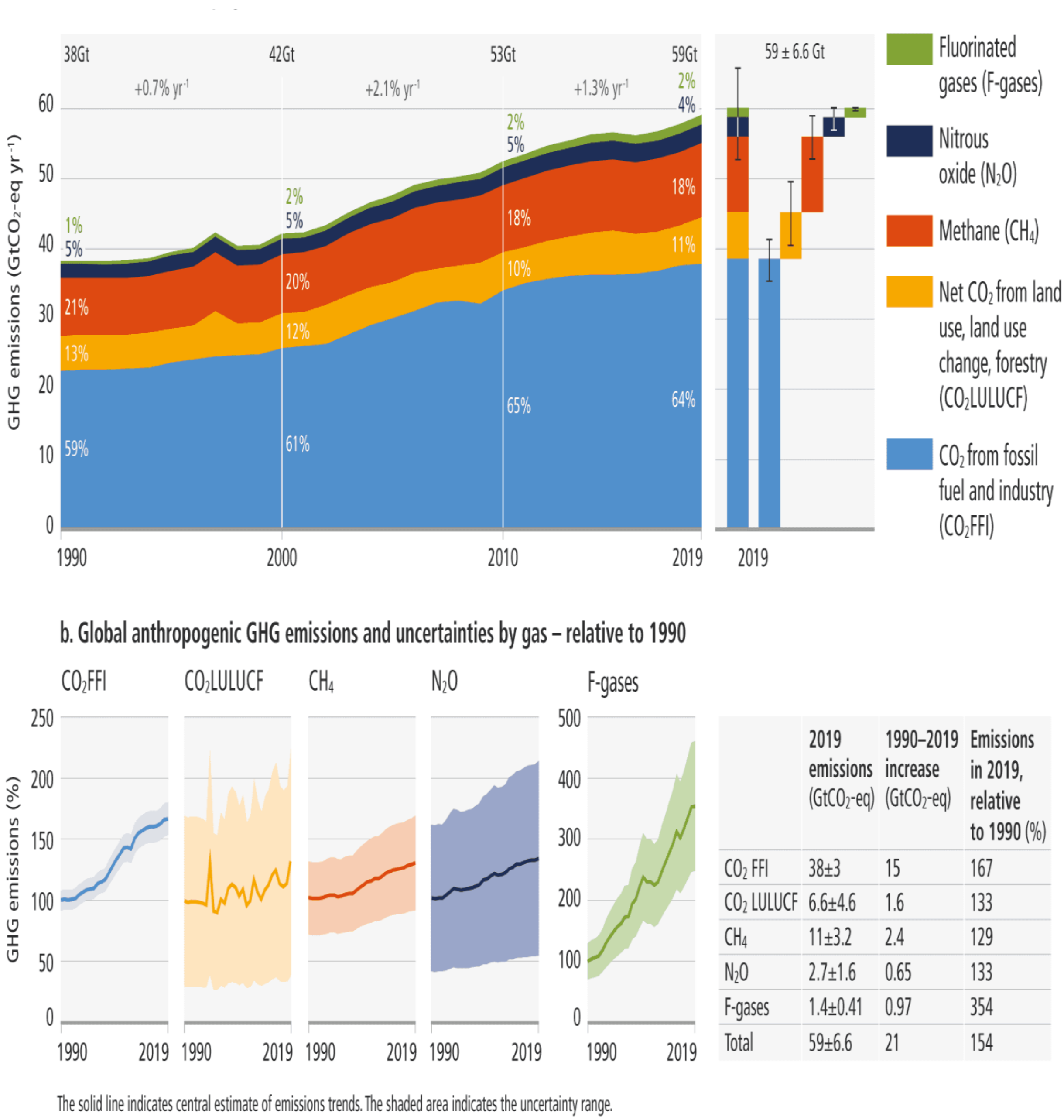
Within the context of climate change and food insecurity in semi-arid Northern Ghana, this thesis examined the determinants of post-harvest food loss, and backyard gardening as a climate change resilience strategy in the Upper West Region (UWR) of Ghana. This introductory chapter thus provides an overview of climate change and variability, post-harvest loss, and backyard gardening in Sub-Saharan Africa (SSA) and semi-arid northern Ghana. The chapter also outlines the research objectives, the significance of the research, and the structure of the entire thesis.

1.2 Study background

1.2.1 Climate change impacts on agriculture

There is now a consensus on global climate change. Climate change and variability are widely recognized as having the potential of exacerbating poverty (IPCC, 2021). Human induced changes are not only considered the principal agents of climate change on the planet, but also the force behind the shifting of the earth away from its relatively stable Holocene period into a new geological epoch, termed as the Anthropocene (IPCC, 2018). Since the 1750s, observed increments in the concentration of atmospheric greenhouse gases (GHG) have been unequivocally caused by anthropogenic activities (IPCC, 2021). The concentration of atmospheric CO_2 in 2019 alone was observed to be higher than at any time in at least the past two million years (IPCC, 2021). Similarly, global atmospheric concentrations of CH_4 and N_2O were higher in 2019 than at any time in at least 800,000 years (IPCC, 2021). Figure 1 below shows the net impact of anthropogenic greenhouse emissions at a global level. Though the risks of climate change are unevenly distributed, the disadvantaged or less privileged communities and people in countries at all levels of development are generally at greater risk (IPCC, 2014). Changes in the patterns of rainfall and temperature, accompanied by extreme weather events like floods, droughts, severe thunderstorms, and heat waves, can significantly erode the assets of marginalized people, push them into poverty, and further undermine their livelihoods. Across the globe, most vulnerable and poor people are dependent on climate sensitive activities like agriculture, highly susceptible to increasing temperatures and variability in rainfall patterns. Yet projections for future climate scenarios suggest that climate change would further heighten the risk of food insecurity, water scarcity, and economic recession if global warming increase beyond 1.5°C (IPCC, 2018). Africa has one of the highest vulnerabilities to desertification from changing climatic conditions (IPCC, 2019). Climate change and variability thus present Africa and the SSA region with the risk of low agricultural productivity. Figure 2 below provides evidence of changes in global mean temperature for the past decades. According to IPCC (2021), many regions in Africa stand the risk of experiencing increment in the frequency and severity of agricultural and ecological droughts. Several factors including the existence of widespread poverty, over dependence on rain fed agriculture, limited access to capital and technology, and inadequate public infrastructure, makes the situation even worse in Africa. Hence projections are that food production and access will be severely affected by climate change in the region (Ngcamu and Chari, 2020; Nkegbe and Kuunibe, 2014).

Sub-Saharan Africa (SSA), aside having one of the highest proportions of malnourished populations in the world, it is also one of the most vulnerable regions to climate change impacts (IPCC, 2022; FAO et al., 2021; Ahmadalipour et al., 2019). The Subcontinent has been experiencing increased drought due to rising temperatures and reduced rainfall patterns with devastating impacts on the region's agricultural productivity. Undoubtedly, climate variability is a major setback to achieving food security in SSA (IPCC, 2022; Nkegbe and Kuunibe, 2014).



	2019 emissions ($GtCO_2$-eq)	1990–2019 increase ($GtCO_2$-eq)	Emissions in 2019, relative to 1990 (%)
CO_2 FFI	38±3	15	167
CO_2 LULUCF	6.6±4.6	1.6	133
CH_4	11±3.2	2.4	129
N_2O	2.7±1.6	0.65	133
F-gases	1.4±0.41	0.97	354
Total	59±6.6	21	154

Figure 1: Global net anthropogenic GHG emissions 1990-2019

Source: IPCC, 2022.

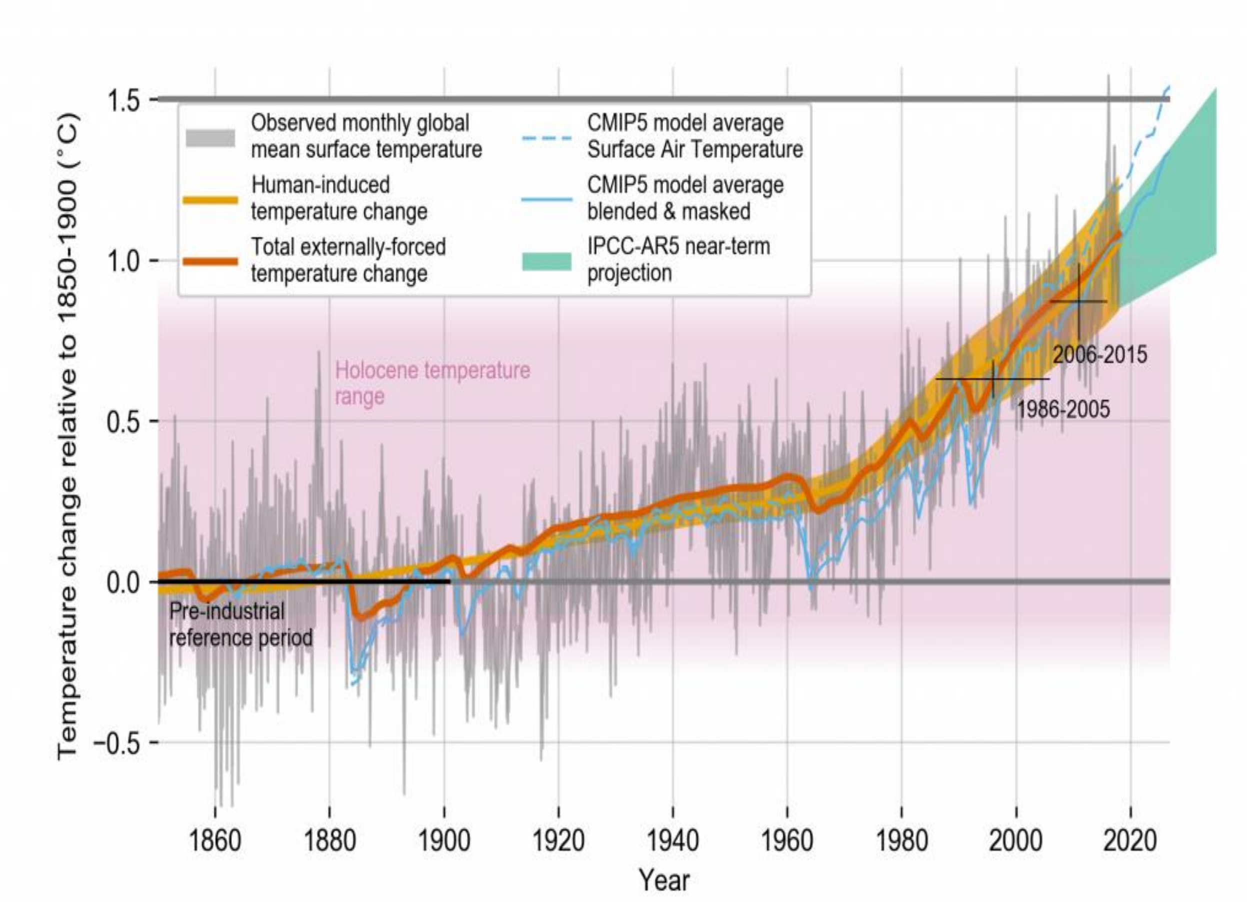


Figure 2: Changes in global mean surface temperature (GMST) over a period of instrumental observations.

Source: IPCC (2018).

Ghana is one of the countries that stand a high risk of low agricultural productivity from climate change impacts in SSA. The agricultural sector of Ghana is dominated by smallholder farmers that extensively depend on rainfed agriculture with irrigation accounting for only 0.2% of total cultivable land (Bawayelaazaa et al., 2016). Given that the agricultural sector of Ghana is largely rainfed, the sector is highly vulnerable to the catastrophic impacts of climate change and variability. The northern half of Ghana which coincides with the Savannah ecological zone of the country, stand the highest risk of crop failure and low productivity due to the already existing arid conditions of the area.

Northern Ghana has about 40% of all arable land in Ghana (Bawayelaazaa et al., 2016). Also, nearly half of the households (46%) in Northern Ghana obtain their income from crop cultivation while close to a third (29%) rely on agro-pastoralism. Together, these two groups represent 75% of the population, which underscores the relevance of agriculture as a major livelihood source to households in the region (Ghana CFSVA, 2012). Unlike the southern sector which has a bimodal rainfall, Northern Ghana only has one rainy season, usually from July to September. Together with high poverty rates, most farming households in Semi-arid Northern Ghana are struggling to produce sufficient food for consumption. The adverse impacts of climate change are therefore more pronounced in the region because of its physical and economic vulnerability. Meanwhile, a significant proportion of what farmers struggle to produce under climate stressors is lost post-harvest. Given the climatic conditions in Northern Ghana, most farmers engage in livestock rearing and dry season gardening as complementary livelihood activities. Climate change and variability however threaten these livelihood activities.

1.2.2 Post-harvest loss in smallholder agriculture

Post-harvest loss (PHL) refers to measurable reductions in both the quantity and quality of harvested produce (Affognon et al., 2015; Kiaya, 2014). PHL can occur either through food loss or food waste. The mechanical or pathological deterioration in the physical mass of food represent quantitative losses, while qualitative losses are the deterioration in nutrient content, color, flavor, shape etc. (Porat, 2018). Globally, between 25-30% of food produced is either loss or wasted (IPCC, 2019). While the share of quantitative food waste and loss (FWL) in developing countries is much higher at the production and post-harvest stages, in developed countries of North America, industrialized Asia, and Europe, FWL is higher at the consumer level, ranging from 45% to 60% of total losses (Gromko & Abdurasulova, 2019). This thesis focuses on losses at the production level, specifically, losses recorded by smallholder farmers through post-harvest handlings (e.g., during drying, threshing, winnowing, shelling, storage etc.). Though there is no consensus on the magnitude of losses, in Sub-Saharan Africa (SSA), post-harvest losses (PHLs) are commonly recorded during on-farm storage, and through poor handling of produce including the processing and distribution stages (FAO et al., 2021; FAO, 2013; Porat, 2018). The economic value of PHL is estimated at USD 4 billion in SSA (FAO et al., 2021). In Ghana, the UWR is one of the three most vulnerable regions with high degree of crop failure and food insecurity due to climate variability and associated PHL (Atuoye et al., 2019).

PHL reduction is considered a major pathway to attaining food and nutritional security in the SSA region (Affognon et al., 2015), and yet it remains a major challenge to smallholder farmers in Ghana (Baral & Hoffmann, 2018). In Ghana, PHLs are recorded on the field (e.g., during heaping and on-farm storage), during shelling or threshing, drying, and through poor storage facilities (Alhassan and Kumah, 2018; Opit et al., 2014). The UWR being the poorest region in Ghana with about 80% of its population actively engaged in agriculture, it is imperative to examine the determinants of PHL in order to identify potential areas for policy action.

1.2.3 Backyard gardening as resilience strategy to the impacts of climatic stressors

The UWR has one of the lowest intensities of rainfall in Ghana as shown in table 1 below. It also has the highest poverty rate (70.7%) coupled with socioeconomic characteristics worse than other regions (GSS, 2015). The deteriorating soil fertility and erratic rainfall over the past 20 years has further led to a massive decline in crop yields in the region (Atuoye et al., 2019). Not surprisingly therefore, the region has one of the highest incidences of food insecurity in Ghana. With growing concerns on issues of food security and the adverse impacts of climate change on smallholders' livelihoods, the adoption of climate resilient agricultural strategies has become very crucial. Backyard gardens has emerged as one of the effective means by which smallholder farmers can withstand the adversities of climatic stressors.

Backyard gardening is a supplementary farming practice in which crops (e.g., vegetables, fruits and cereals) are cultivated on a physically enclosed piece of land, usually for household consumption (Ayambire et al., 2019). In Ghana, apart from open space farming, backyard gardens constitute the second largest form of urban agriculture. For instance, approximately 50% of all households in Accra are engaged in backyard gardening (Ayambire et al., 2019). In rural communities, backyard gardening enhances the food security of impoverished farmers and reduce their expenditure on food (Thomas and Terblanche, 2021). Research has variedly noted the potential role of backyard gardening in enhancing food security and promoting resilience among smallholders, particularly in times of crisis (see Hou, 2020; Camps-Calvet, 2015; Okvat and Zautra, 2011). Given the increasing impacts of climate change in the UWR, this study investigates the potential of backyard gardening as a climate resilience building strategy in the region.

Table 1: 10-year and 30-year regional averages of rainfall data (mm) in Ghana

Region	**10-Year Average (2006-2015)**	**30-Year Average***
Western	1,456	1,558
Central	1,250	1,252
Grater Accra	749	788

Volta	1,319	1,340
Easter	1,142	1,180
Ashanti	1,346	1,345
Brong Ahafo	1,257	1,244
Northern	1,122	1,155
Upper East	927	912
Upper West	817	1,022
Total	11,385	11,796
Average	**1,138**	1,180

Source: MoFA. Facts and figures, (2015). *(1961 – 1990)

1.3 Research Questions

Amid the ongoing climatic stressors and food insecurity challenges, various studies have been conducted on PHL estimations (e.g., technology adoption and improved storage systems) and methods of PHL prevention (see FAO et al., 2021; IPCC, 2019; Opit et al., 2014;Gromko & Abdurasulova, 2019). However, what remains understudied, is the socio-economic determinants of PHL in the smallholder contexts (Kulwijila, 2021). Since smallholders dominate the agricultural sector of Ghana, knowledge of the determinants of their PHL outcomes will be useful to policy makers in designing policies that aim at achieving food security. Such knowledge is important in SSA at large where smallholders account for nearly 75% of all agricultural production (Salami et al., 2010).

Also, while there has been extensive research and literature elsewhere on the role of community gardening in urban resilience to climate change (Burchard-Dziubińska, 2021; Camps-Calvet et al., 2015; Colding and Barthel, 2013; Okvat and Zautra, 2011;), backyard gardening as an agro-ecological practice that is common among impoverished smallholders in the SSA region, is sparsely researched. Therefore, taken together, the primary research question that this thesis seeks to answer is: what factors influence post-harvest loss in the Upper West Region (UWR) of Ghana and how does backyard gardening improve climate change resilience among smallholder farmers in the region? The specific research questions are: 1) what are the determinants of post-harvest loss among smallholders in UWR; and 2) does the practice of backyard gardening affect smallholder farmers' resilience to climate change? Therefore, this study has two main research objectives:

1. To investigate the predictors of post-harvest loss among smallholder farmers in the UWR of Ghana.
2. To examine the association between backyard gardening and smallholder farmers' climate resilience.

1.4 Relevance of the study

This study will contribute to the broader literature on food security and climate change resilience. Given that agricultural production in the Sub-Saharan African (SSA) contexts is dominated by smallholder farmers, knowledge on the determinants of their post-harvest loss (PHL) outcomes will provide policy insights for reducing food insecurity in region. Also, the study will provide insight on the role of backyard gardening in smallholder farmers' resilience to climatic stressors within the study context and similar contexts across SSA. Context specific knowledge in the study area will be relevant in drafting policies for PHL prevention and climate resilience among smallholders. Collectively, this body of knowledge will provide broader insights for similar resource poor contexts across the world, particularly in the identification of policy entry points for meeting specific SDGs including SDG 2 and 12 which target addressing global hunger and promoting sustainable consumption, respectively.

1.6 Thesis Structure

This thesis has six (6) chapters. Chapter (1) is the introductory chapter that provides an overview of climate change and variability, and the challenge of food insecurity from the global perspective down to the study context within Ghana. Also, chapter one states the research objectives and highlights the significance of the study. Chapter (2) consist of literature review on global and local climate change and variability. It also discusses food insecurity and post-harvest loss, as well as backyard gardening as a potential resilience building strategy among smallholders in Ghana and SSA. The chapter further expounds the conceptual and theoretical underpinnings of the thesis. Chapter three (3) presents the study methodology. The chapter further discusses the study design, data collection and sampling, and data analytical techniques. Chapter four (4) and five (5) present the two manuscripts in this thesis. Chapter four (4) presents a manuscript that examines the determinants of post-harvest loss (PHL) among smallholder farmers in the UWR of Ghana. Chapter five (5) examines the association between backyard gardening and smallholder farmers' resilience to the impacts of climatic stressors in the region. The two manuscripts are integrated into the thesis as they explore twin challenges (climate change and food insecurity) that afflict smallholder farmers in semi-arid regions of Ghana. Lastly, chapter six (6) contains a summary of the study. The chapter highlights the study's key theoretical and empirical contributions to literature on smallholders' resilience to climate change, and the determinants of PHL in smallholder communities. Also, the chapter presents suggested policy recommendations and directions for future research.

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Chapter 2

2.0 Literature review

2.1 Introduction

This chapter contains a review of literature on climate change and food security with emphasis on semi-arid northern Ghana. It also provides a brief background on the synergies between food insecurity and post-harvest loss, and gardening as a resilience building strategy in the context of climate change. The chapter also provides an explanation to the theorical framework being adopted in this study.

2.2 Climate change and smallholder agriculture

Climate change, particularly the increasing frequency and intensity of extreme weather events has brought about surface water scarcity, exposed millions of people to acute food insecurity, and consequently hindering global efforts to meet the Sustainable Development Goals (SDGs), specifically SDG 2 (IPCC, 2022). Over the past 50 years, climate change has slowed down global agricultural growth although overall agricultural productivity has increased considerably (IPCC, 2022). The agricultural sector is highly sensitive and vulnerable to global climate change as it is by far the biggest utilizer of water resources (Calzadilla et al., 2013). The sector thus faces the largest known economic impact of climate change due to its sensitivity to climate variability (Mendelsohn, 2009; Orking and Clima, 2008). However, there are regional differences with which the impacts of climate change are felt in the agricultural sector. While temperate and polar regions are projected to gain in terms of agricultural productivity, tropical regions of developing countries are particularly expected to suffer significant losses of agricultural production from the warming conditions of climate change (Kurukulasuriya and Rosenthal, 2013;

Mendelsohn, 2009; Mendelsohn and Dinar, 1999). Along the margins of semi-arid and arid regions, the amount of arable land, length of growing seasons, and yield potentials, are all expected to decrease dramatically due to climate change and variability (Kotir, 2011).

Already, many countries in SSA are faced with semi-arid conditions that pose a challenge to agricultural productivity. Although agriculture provides about 70-80% of employment in SSA and constitutes about 30% of the region's gross domestic product (Calzadilla et al., 2013), climate change however accounts for almost 60% of yields variability in the region (Aryal et al., 2020). The agricultural sector of SSA has therefore been characterized by low productivity from climate change impacts. In the late 1970s and early 1980s for instance, while Asia experienced a massive increment in food production through the Green Revolution, per capital food production in SSA rather stagnated (Calzadilla et al., 2013). Countries in the SSA are expected to experience severe declines in food production from future climate scenarios (IPCC, 2022; Serdeczny et al., 2017; Abdul-Razak and Kruse, 2017; Mendelsohn, 2009). For instance, though maize is the most widely cultivated staple crop in SSA, primarily grown by smallholders, projections are that the overall production of maize will decrease with future climate scenarios (Adhikari et al., 2015). Climate change is therefore exacerbating the challenge of food insecurity in SSA.

2.3 The impacts of climate change on smallholder agriculture in Ghana

The agricultural sector is vital in poverty reduction in most developing countries where rural dwellers depend largely on the sector for their livelihood. In Ghana, although agriculture is a major driving force of economic development, employing about 50% of the active labor force in the country (GSS, 2019), climate change is adversely affecting progress of the sector. Evidence of the negative impacts of climate change on Ghana's agricultural sector include the reduction in crop productivity (Asante and Amuakwa-Mensah, 2015). While high temperatures and low rainfall are expected in the decades ahead (2020, 2050, 2080), desertification is also estimated to be increasing at a rate of 20,000 hectares per annum (Asante and Mensah, 2015). Though with some level of uncertainty, the outbreak of pests and diseases, water and heat stresses, loss of arable lands, and increased PHLs, are some of the impacts of climate change in Ghana (De Pinto et al., 2012).

Even though smallholders dominate the agricultural sector of Ghana, they however stand higher risks of suffering from the impacts of climate change due to their massive dependence on rain-fed agriculture (Fosu-Mensah et al., 2012). In northern Ghana for instance, smallholders have minimal livelihood alternatives, and therefore depend on the rainfed agricultural system of the region despite its vulnerability to climate change and variability (Abdul-Razak and Kruse, 2017). In this region, the trend of climatic variables such as rainfall and temperature are irregular with dire economic impacts on agriculture (Bawayelaazaa et al., 2016). The Upper West Region (UWR) is one of the most vulnerable to climate change impacts in semi-arid northern Ghana. Drought, floods, severe thunderstorms, and increasing temperatures are some of the ongoing climatic stressors in the UWR (Yidana, 2016). Despite the region having the second highest (80.4%) regional proportion of households engaged in agriculture, it has one of the lowest agricultural output per annum (GSS, 2019). Overall, lack of adaptive capacity has been highlighted as a major reason for the adverse impacts of climate change on Ghana's agricultural sector (Asante and Amuakwa-Mensah, 2015). The adoption of rigorous adaptation strategies is therefore a necessary mechanism for lessening impacts and for building resilience (IPCC, 2022; Hannah et al., 2017).

2.4 Climate change adaptation and resilience among smallholder farmers

Adaptation means an adjustment to the actual or anticipated impacts of climate change to lessen harm, or to exploit available opportunities (IPCC,2014). Global climate change presents a diversity of risks and adverse consequences to humans and socio-ecological systems. The vulnerability of societies to these climate related risks may exacerbate ongoing social and economic challenges, particularly for societies depending on resources that are sensitive to climate change. In regions like Africa, it is imperative to adopt measures that will lessen the impacts of climate change. Adaptation is a crucial mechanism for the sustenance of livelihood and quality of life (IPCC, 2022; Zolnikov, 2019). While climate mitigation is a necessary strategy, it is unlikely to be sufficient as a climate policy, hence every country is expected to adopt measures for enhancing resilience of its agricultural systems to the immediate shocks of climate variability (Aryal et al., 2020; Codjoe et al., 2011).

Smallholder farmers in Ghana are engaged in diverse adaptation options. They rely on different adaptation strategies including the use of soil moisture conservation, drought tolerant crops, and early maturing seeds in their adaptation efforts (Abdoulaye et al., 2017). Also, while some farmers resort to adjustment in planting dates to meet the rainy season, others focus on the planting of tree crops that are more tolerant to changes in climatic variables and can simultaneously supply shade and shelter for crops that do not thrive well in hot temperatures (Barimah et al., 2014). Specifically in the Upper West region of Ghana, most smallholder farmers resort to the use of drought tolerant seeds, water harvesting, and the application of chemical fertilizers as adaptation measures (Yidana, 2016). An assessment of climate change adaptation options in Africa by Guan et al., (2017) has revealed that among all the adaptation measures, intensification of fertilizer application has the most dramatic benefit on crop output levels. Despite the availability of several climate change adaptation options, the efforts of smallholder farmers in Ghana are impeded by several barriers. Key among these barriers is the lack of financial resources for adoption and effective implementation of relevant adaptation strategies (Antwi-Agyei et al., 2015). Given that climate change adaptation efforts are consistent with the prioritization of sustainable development, and Sustainable Development Goals (SDGS), specifically goal 13 (climate action), it is important to explore more simpler and affordable adaptation options in the smallholder context.

2.5 Gardening and resilience to climate change impacts

Different forms of gardens exist across the globe. Common among them are community gardens, garden allotments, and backyard or home-grown gardens. Backyard or home gardens as interchangeably used in literature, differ from community gardens. Community gardens are public spaces managed by volunteers or members of the community for the production of food, shrubs, flowers and plants on individually assigned plots (Uwajeh and Ezennia, 2018). Backyard gardens on the other hand consist of private spaces, characterized by proximity to home, relatively smaller in size than a normal farm, and as a production system easily practiced by the improvised minority (Uwajeh and Ezennia, 2018). Backyard gardening in most instances is for food production as a supplementary rather than the main source of family consumption. The meaning and motivation for gardening may also vary from one region to another, and over time. Sanyé-Mengual, et al., (2018) for instance highlighted the motivations for gardening into five categories of: cook's gardens, teaching gardens, environmental gardens, hobby gardens and aesthetics gardens. In the Global North, backyard gardens have been crucial during historical events like wars and economic depressions (Sanyé-Mengual, et al., 2018). During the 1900s, gardens played a crucial role in saving millions of people from starvation. British urban residents for instance had access to their nutritional needs during World War I through backyard gardens (Barthel and Isendahl, 2013). Also, following the global economic crisis of 2008, agriculture was brought into cities in a wide and diverse manner including community gardening and backyard gardening. More recently, following the outbreak of the Covid-19 pandemic, lockdowns and food shortages, there has been a renewed interest in backyard gardening and home-grown foods (Lin et al., 2021; Mullins et.al., 2021). Interest in backyard gardening thus emanates from growing concerns on food security, urban sustainability, and resilience to climate change impacts. Studies show that gardening has the potential to strengthen the resilience of communities to climate change and food crisis (Gulyas and Edmondson, 2021; Langemeyer et. al, 2021; Taguchi and Santini, 2019). Even in climate change mitigation efforts, gardens can facilitate the process of carbon sequestration, and decrease new greenhouse gas emissions. Moreover, gardens offer communities an opportunity to obtain essential nutrients, culturally appropriate foods, traditional fruits and vegetables that are unavailable in retail shops (Lin and Egerer, 2020). The financial limitations of marginalized groups in society have further promoted the creation of gardens to tackle food insecurity (Sanyé-Mengual, et al., 2018; Barthel and Isendahl, 2013).

In most Low and Middle-income Countries (LMIC), especially those of Africa, backyard gardens form an integral component of the agricultural landscape and local food production systems (Shakya et al., 2014). Backyard gardens have been a traditional source of nutrient-dense food in Africa whereby edible and medicinal plants are grown by the rural poor for all-year round household consumption (Mokone et al., 2018). In Ghana for instance, backyard gardening is practiced in all the six agroecological zones as a long-established tradition. In the study context, backyard gardens are not always located right behind the gardeners' abodes. Rather, they could be located in close proximity to the household compounds for easy access (Galhena et al., 2013; Ibrahim, 2014; Ayambire et al., 2019). The nature and practice of backyard gardening in the urban and rural areas of Ghana are slightly different. For instance, the availability of arable lands in the rural areas, free from competing developmental needs, conflicts and litigations, allows rural gardeners the flexibility of constructing their gardens at desired locations. However, in most urban settings (e.g., Accra and Kumasi), backyard gardens are typically constructed right beside the gardeners' home for several reasons including the shortage of arable lands, high cost of land, as well as conflicts and litigations surrounding ownership and boundary issues (Shakya et al., 2014). Also, urban and rural dwellers resort to the use of different materials for the construction of their backyard gardens. While backyard gardens in urban settings are mostly constructed using metal fences which can be expensive, in typical rural contexts, gardeners tend to use tree branches and shrubs, a practice that negatively affects the environment (Jonas and Romanus, 2017). Consequently, local land governance in parts of the UWR including communities in the Nadwoli-Kaleo district are prohibiting the cutting of trees for the construction of backyard gardens (Darimani, 2014).

Backyard gardeners in the study context and similar contexts across Ghana, rely on simple hand tools and implements (e.g., hoes, rakes, cutlasses etc.) for field preparation. Aside that, they utilize animal droppings and compost from home to stir up the fertility of soil in their gardens. Vegetables, grains, and fruit trees (e.g., pawpaw and mango) are mostly raised in these gardens to complement household food supply in Ghana (Ayambire et al., 2019). Backyard gardening thus play a crucial role in meeting the food needs of farming households. Insufficient rainfall is however highlighted as a major obstacle to backyard gardening in Ghana (Shakya et al., 2014; Ibrahim 2014). As a result, in parts of the UWR where dams exist, dry-season gardens are often clustered along these dams (Jonas and Romanus, 2017). Overall, although extant studies point to backyard gardening as having the potential of building smallholder farmers' resilience to climate change impacts (Uwajeh and Ezennia, 2018; Langemeyer et. al, 2021), in the UWR of Ghana, backyard gardening remains an under-researched component of the agricultural stock of smallholder farmers.

2.6 Food security and Post-harvest loss

Food security is a condition that exists when people at all times, have access to sufficient, safe and nutritious food for normal growth and healthy life (FAO, 2006; IPCC, 2014). Throughout human history, hunger and famine have occurred due to a variety of interrelated causes including environmental crisis (Baro and Deubel, 2006). Reducing the risks of food insecurity from climate change remains one of the major challenges of the 21st century (Campbell et al., 2016; IPCC, 2014; Brown et al., 2015; Orking and Clima, 2008). Africa is particularly off track to meeting the SDG 2 target of ending hunger and ensuring access to safe, sufficient and nutritious food by all, at all times (FAO et al., 2021; FAO, 2020). Projections indicates that by 2030, Africa will account for more than half of all undernourished population in the world (FAO et al., 2020). In the year 2020 alone, about 281.6 million people in Africa (representing one-fifth of the continent's total population) were faced with hunger (FAO et al., 2021). Likewise in Sub-Saharan Africa (SSA), hunger and undernourishment are pressing concerns. Global food insecurity is not only caused by climate change and low agricultural productivity, but also post-harvest losses.

Post-harvest loss (PHL) has been highlighted in literature as a crucial but understudied driver of global food insecurity (see Sheahan & Barrett, 2017; Muroyiwa et al., 2020; Delgado et al., 2021). PHL occurs due to a range of factors including biodeterioration by microorganisms, improper handling, poor transportation, processing, packaging and distribution, as well as poor logistics and storage conditions (Kiaya, 2014; Mezgebe et al., 2016). Consequently, such losses contribute to high market food prices through a reduction in food supply. Notwithstanding global efforts to increase the availability of food through food loss prevention, post-harvest food loss remains a major challenge in Africa (Muroyiwa et al., 2020). For instance, the maize grain in Africa records between 14%-36% of losses on annual basis due to poor post-harvest management.

PHL is therefore a major constrain to the attainment of food and nutritional security in Africa and the SSA region (Sugri et al., 2021; Tefera, 2012). Worsening climatic conditions (e.g., high heat and humidity) further causes PHL in Africa, especially in places where the presence of post-harvest rains prevents the proper drying of crops (Delgado et al., 2021). Amid climate variability, PHL, particularly on-field and storage losses are bound to increase. Existing studies on PHL in Ghana have called for further studies to investigate and understand the determinants of PHL in the smallholder context (see Sugri et al., 2021; Ansah and Tetteh, 2016). To contribute to literature, this component of the thesis focuses on the factors that influence post-harvest food loss among smallholder farmers in the UWR of Ghana, specifically, losses that are recorded through post-harvest handlings and processing (during threshing/shelling, winnowing, drying, storage etc.).

2.7 Theoretical framework

This thesis draws theoretical insights from political ecology. Political ecology focuses on the study of power relations, social struggles, and political conflicts in the appropriation of ecological and natural resources (Watts & Peet, 2004). Political ecology dates back to the 1980s (see Watts,1983; Blaikie & Brookfield, 1987) and was largely influenced by environmentalism (Perreault et al., 2015). Though earlier studies in political ecology were largely focused on the Global North, political ecology is however not limited in scope, space, themes, or scales. A key feature of political ecology is that it is an evolving concept, constantly embracing a range of scientific techniques and concepts, and exploring complex interdisciplinary research themes (Perreault et al., 2015; Walker, 2005). Political ecology is therefore neither limited to any specific research topic (e.g., resource governance, resource conflicts, agrarian livelihoods etc.) nor scale (e.g., household, community, landscape, rural, urban). Given the broad nature and appeal of the concept, a multiplicity of research methodologies (both quantitative and qualitative methods) has been utilized in academic research in the field (Perreault et al., 2015). Also, political ecology is dedicated to topics of social justice and political change among marginalized groups such as indigenous people, religious minorities, women, impoverished smallholder farmers (see Nyantakyi-Frimpong, 2019a; Kansanga et al., 2019; Collins, 2008).

According to Perreault et al., (2015: p.307), political ecology is key to understanding how climate change affects people and places. The specific aspects of political ecology adopted in this thesis will be discussed in subsequent paragraphs. These would include the political ecology of vulnerability, resilience, environmental change and marginalization. This thesis is therefore grounded on the theoretical constructs of vulnerability and resilience.

Vulnerability is the state of being susceptible to harm due to stresses from environmental or social change (Adger, 2006). Within the context of climate change, vulnerability is conceptualized as the function of exposure, sensitivity, adaptive capacity, and the characteristics of a system (Adger, 2006). Given that vulnerability to climate change is a differentiated experience among smallholder farmers, policy attention ought to be shifted towards harnessing local autonomous adaptations (Nyantakyi-Frimpong, 2019c; Adger et al., 2003). Moreover, different social and political identities, as well as unique experiences of marginalization in smallholder communities, lead to differences in climate change vulnerability (Thornton et al., 2014; Perreault et al., 2015; Nyantakyi-Frimpong, 2019c). For instance, though the impacts of climate change are irregularly distributed, improvised smallholders tend to be more vulnerable due to lack of adaptive capacity (IPCC, 2014). Therefore, other factors (e.g., knowledge of climate change, household labor size, decision-making arrangement, ability to practice backyard gardening etc.) may further shape smallholder farmers' vulnerability and resilience to climatic stressors.

Vulnerability to climate change thus varies across space, income levels, and livelihood types among others (Thornton et al., 2014).

On the other hand, resilience is "the ability of groups or communities to cope with external stresses and disturbances that emanates from social, political and environmental change" Adger, (2000; p. 347). The concept of resilience originated from the study of ecology. Early studies in resilience focused on predator-prey relationships and the implications for the stability of ecosystems (May, 1972; Holling, 1973). Although the concept of resilience is widely used in the literature of ecology, its meaning and measurement is highly contested, hence, there is hardly any consensus on its definition (Adger, 2000). Also, though earlier studies on resilience were largely focused on single equilibrium systems with fixed capacities (Folke, 2006), the concept has however evolved to include multi-stable systems (Folke, 2006; Holling, 1973). Resilience studies that focus on the interaction of multiple factors (e.g., socio-economic, political, cultural and ecological) and the influence thereof on a systems' ability to adapt, learn, self-organize, and act or respond to perturbations is termed socio-ecological resilience (Carpenter et al., 2012; Folke, 2006; Adger, 2000). Socio-ecological resilience is dependent on a system's ability to anticipate, prepare, and adapt to, or recover from environmental stressors (Jones et al., 2018). Adaptation is therefore a critical component in the concept of resilience. Within the context of climate change, adaptation broadly refers to the process of adjusting to climatic shocks to lessen vulnerability, and to enhance resilience (IPCC, 2014). In smallholder farming communities, climate change adaptation, although predominantly autonomous, adaptation initiatives and policies tend to be structured with emphasis on "technological fixes" which has largely proven ineffective in building the resilience agrarian communities to climatic shocks (Antwi-Agyei et al., 2018; Adger et al., 2003). In relation to food security, contemporary discussions on climate resilience include issues pertaining to the resilience of cities through rooftop gardens, vegetation gardens, community gardens, home grown or backyard gardens etc. (see Mullins et al., 2021; Gulyas and Edmondson, 2021; Hou, 2020; Lal, 2020; Okvat and Zautra, 2011). Likewise, within the smallholder context in agrarian communities, backyard gardening is considered an effective climate resilience strategy, capable of meeting the food requirements of smallholder households amid climate variability (Fehr and Moseley,2019; Galhena et al., 2013; Musotsi et al., 2008).

A strong connection also exists between political ecology, environmental change, and livelihood studies given that livelihood frameworks build on a political ecological understanding of the interaction between nature and society (Perreault et al., 2015. page 332). For instance, environmental change has the potential to undermine the livelihoods of agriculturalists and pastoralists and could therefore increase their marginalization in society. In developing economies that are heavily dependent on agricultural production, the livelihoods of the rural poor are under constant threat of climate change and variability (Owusu et al., 2021). In the smallholder farming contexts of Africa for instance, farmers rely extensively on direct sunlight for the drying of produce before storage. However, extreme weather events (e.g., erratic rainfalls and severe thunderstorms) tend to prevent sufficient drying, and in most cases, lead to mold infestation in produce with high moisture content (Sheahan and Barrett, 2017; Tefera, 2012). Therefore, in agrarian communities, significant proportions of produce are lost post-harvest due to climate variability (Abera et al., 2020; Gromko and Abdurasulova, 2019; Addo et al., 2015; Aidoo et al., 2014). In Ghanaian context, Owusu et al., (2021) in their assessment of post-harvest grain loss uncovered that climatic events like erratic rains and severe thunderstorms drive post-harvest losses during and after harvesting. Understanding the complex relationships and interactions between environmental change, socio-economic deprivation and livelihood manifestation is needed to improve the food security issues in smallholder context. Consequently, this thesis uses political ecology framework to examine aspects of food security and climate change resilience among smallholder farmers in the Upper West Region (UWR) of Ghana.

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Chapter 3

3.0 Methods

3.1 Introduction

This chapter provides background to the study context and describes the study methodology. It also describes the study design, and sampling techniques. This chapter thus provides a general overview of the study methodology even though the two manuscripts integrated into this thesis contain their individual method sections.

3.2 Study Context

Upper west region (Figure 3) is located in the northwestern corner of Ghana, bounded by Burkina Faso at the north and west, and lying between latitude 9.8°-11.0° North and longitude 1.6°-3.0° West. It has a total land area of 18,476km2, and constitutes 7.8% of the total national land area (Ghana Statistical Service, 2013). The total population of Upper West region (UWR) is 702,110 (GSS, 2013) and has the second largest regional proportion (80.4%) of households engaged in agricultural activities in the country (GSS, 2019). Although agriculture is the main livelihood activity in the region—employing slightly over 80% of the region's population (Ghana Statistical Service, 2013)—the UWR is however the most food insecure region in Ghana, with about 34% of the population being severely food insecure (Atuoye et al., 2017). Notwithstanding the considerable progress Ghana has made towards improving national food security, there is regional unevenness. The UWR is part of the dry Savannah regions that fare the worst in Ghana, and also the poorest region in Ghana (GSS, 2013; Luginaah et al., 2009). In this region, 9 in every 10 people lives on less than a dollar per day (GSS, 2013). All the three districts in study are ranked among the poorest in the country. The Wa West district has the highest poverty count and therefore ranks as the poorest district in Ghana, while the Nadowli-Kaleo and Lawra districts also ranked 17th and 13th positions, respectively in terms of poverty (GSS, 2015).

The region experiences a single maxima rainy season usually between May and October. There is a long dry season during which the rainfed agriculture in the region becomes impossible. The vulnerability of UWR to climate change is reflected in the declining trend in rainfall (Rademacher et. al, 2014). The region has average temperatures of 28°C and peaking at about 38°C. In the past decades, temperatures in the region have increased by 1.7°C and projected to increase by 3°C by 2050 (Adiku et al., 2017). Increasing temperatures, erratic rainfall, and other climatic stressors (e.g., severe thunderstorms, droughts, and floods) in the region, thus present more challenges to smallholder farmers in the process of food production. As a results, agricultural productivity in the region is drastically declining (Mohammed et al., 2021). Farmers in the region are resorting to different measures including backyard gardening to boost their resilience against climatic stressors like drought. Backyard gardening has been an age-old livelihood activity that households in the UWR engage in to meet their food and nutritional requirement. However, the increasing rates of food insecurity in the region (Mohammed et al., 2021; Atuoye et al., 2017) has led to renewed calls for national policy regarding backyard gardening as a climate resilient strategy. Given that the UWR has a single maxima rainy season, coupled with semi-arid weather conditions, poverty, and high incidence of food insecurity, the promotion of dry season backyard gardening in the region may therefore enhance all-year round food provisioning in smallholder farming households.

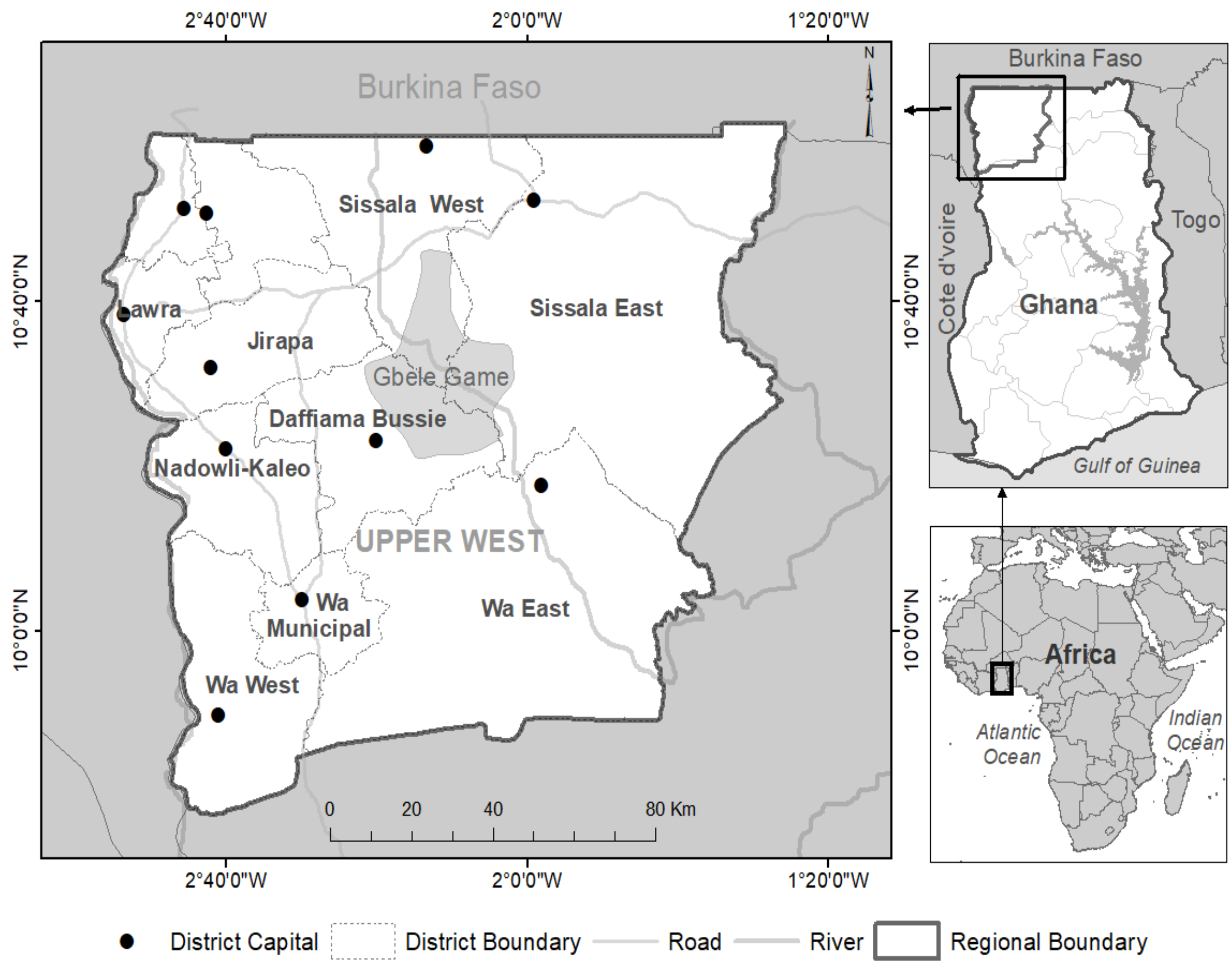

Figure 3: ***Map of Upper West Region***

3.3 Study design

A quantitative design was utilized to examine; (i) the determinants of post-harvest loss among smallholder farmers, and (ii) the association between backyard gardening and smallholder farmers' resilience to climatic stressors in UWR. Quantitative design is more appropriate in measuring the predictive relationships between study variables (Creswell and Creswell, 2017), relevant for establishing new relationships, confirming or validating existing ones, and for developing generalizations from findings (Williams, 2007). Also, quantitative design was considered the most appropriate with due consideration to the nature of the research questions.

It is important to note that this study is underpinned by post-positivist ontology and epistemologies. Post-positivism is based on the premise that the acquisition of scientific knowledge is not devoid of the individual researcher's emotions, interests, and biases (Sukamolson, 2007). Contrary to traditional positivism, the stance of post-positivism is that absolute certainty in research is unattainable (Clark, 1998). According to Sukamolson (2007), social scientific studies should focus more on confidence — the reliability of findings and how well outcomes are estimated, rather than emphasis on absolute certainty. Hence, in this research, while I attempt to approximate reality as best as possible, I also recognize that my subjectivity may shape my interpretation of findings. Therefore, the aim of this research is not to establish absolute reality on post-harvest losses and climate change resilience in semi-arid Ghana, but to approximate these challenges as best as possible.

3.4 Data collection and sampling techniques

This thesis is based on a broader survey on farmer livelihood and agricultural production in the UWR of Ghana administered in 2019 (between July to August). A survey team was constituted, consisting of three researchers and six local research assistants. Certain criteria were taken into consideration in the selection of the research assistants. Proficiency in local languages, familiarity with the study context (i.e., the Upper West Region), research experience, and most importantly, being a resident of the study community, were some prerequisites for the selection of the six research assistants. Each of the three researchers supervised two research assistants in each of the selected districts. Apart from past research experience, the research assistants were given five days intensive training on the survey instrument and ethics and safeguarding protocols per ethical guidelines of the University of Western Ontario's Non-Medical Research Ethics Board. The research assistants signed an agreement of confidentiality to protect the privacy and anonymity of the study participants. Prior to the data collection and as part of the training, the survey questions were role played and extensively discussed to ensure the meaning of the questions was consistent across local languages and districts. The research assistants sought oral consent from participants in their local languages. Only participants who consented to participate in the survey were asked further questions. Community leaders (i.e., opinion leaders) were also engaged by the research team to explain the purpose of the study. It was a household survey that targeted the primary farmer(s) of each household. Questionnaires were thus administered to the primary farmer of each household to respond on behalf of the household. The survey included questions on household demographics, agricultural production, household food security, household expenditure, livelihood activities, gender relations, adaptive capacity and resilience. A multi-stage sampling method was used to select 1100 smallholder farming households. First, three districts (Wa West, Lawra, and Nadowli-Kaleo) were selected using purposive sampling. Selection was based on the prevalence of impoverished smallholder farmers in the study districts. This sampling technique was found more convenient because it allows researchers to deal solely with the targeted population (in this case, smallholder farmers). At the District level, a simple random sampling was used to select the study communities/villages in each of the three Districts. Finally, a systematic sampling (every fifth household selected to participate in the survey) was then used to select household units in the study communities. This gave all farming households an equal chance of being included in the research survey. This study thus utilized data from a cross-sectional survey with smallholder farmers (n=1100) as part of a Social Science and Humanities Research Council funded project. The sample was proportionately distributed among the three selected districts (i.e., Lawra = 295, Nadowli = 367, Wa West = 438) based on their populations. The dependent variables (post-harvest loss and climate resilience) were self-reported measures. Though a major challenge in estimating the magnitude of food loss is a question of methodological appropriateness, it is however reasonable to believe households self-reports based on well-organized questionnaire that follow standard survey protocols (Sheahan & Barrett, (2017). With regards to climate resilience for instance, participants were asked questions including 'how would you rate your ability to handle flood/drought/ erratic rain related stress?' According to Jones & Tanner, (2015), households have a good understanding of the mediators of their ability to anticipate, recover, and adapt to climate change stressors.

Ethical approval for this research was granted by the University of Western Ontario Non-Medical Ethics Research Board. Following the protocols of the University of Western Ontario Non-Medical Ethics Research Board, the purpose of the study was duly made known to participants of the study. The study participants were made to understand that their participation in study would neither offer any direct benefits to them nor make them incur any direct cost apart from the time spent discussing their livelihoods with the researchers. Participants were however made to understand that the study may benefit them indirectly as findings from the study may be shared with local, national, and international institutions to inform or guide policy initiatives that can address their concerns as smallholder farmers. Issues of privacy, confidentiality, and anonymity were guaranteed and unequivocally communicated to participants. Participants were also made to understand that they have the right to withdraw from taking part in the survey when they see the need to. The sample size of the study was arrived at using the formula below:

Equation 1: $n = \frac{N}{1+N(e)^2} = \frac{702110}{1+702110(0.03)^2} = \frac{702110}{1+702110(0.0009)} = 1{,}110$

Where 'n' represents the sample size, 'N' represents the population size, and 'e' represents the margin of error or level of precision (Gomez and Jones, 2010). The formula assumes 95% confidence interval. The study considered 3% (0.03) margin of error or level of precision in choosing the sample size. Also, the sample sizes for the selected Districts were determined based on their population sizes using the formula below:

$P = \left(\frac{population\ of\ District}{total\ population\ of\ all\ Districts}\right) \times n$, where p = sample proportion, n= total sample size

3.5 Data analysis

This section provides a broad description of the analytical methods employed in this dissertation. Detailed description of the specific analytical approaches for each research objective is provided in the respective manuscripts. Processing of data was done in Stata version 15 where the data was first subjected to screening for errors in data entry and coding. This was necessary to prevent bias and to ensure the credibility of statistical estimates. The dependent variable (i.e., post-harvest loss) for the first manuscript was a continuous variable hence a multiple linear regression model was employed. For the second manuscript, the dependent variable (i.e., resilience to climate change) was a binary outcome for which a logistic regression model was employed in the analysis. The formulas for linear regression and logistic regression models are shown below.

Formula for linear regression model

$\bar{Y} = b_0 + b_1x_1 + b_2x_2 \ldots + b_px_p$

Where $\bar{Y}$=the predicted value of post-harvest loss.

x_1 through x_p=the independent variables.

b_0=the value of $\bar{Y}$ when all the independent variables are equal to zero

b_1 through b_p=the estimated regression coefficients.

Formula for logistic regression model

$$\pi(X) = \frac{\exp(\beta0 + \beta1X1 + \cdots + \beta kXk)}{1 + + \exp(\beta0 + \beta1X1 + \cdots + \beta kXk)}$$

π = probability that an observation is in the category of the dichotomous Y value known as the success,

exp = the exponential function,

β0 = intercept

β1 = the coefficient of first predictor variable

βk = the coefficient of the last predictor variable.

3.6 Rigor

Several measures were taken throughout the research process (study design, data collection and analysis) to ensure the robustness of results from statistical estimates. For instance, during the study design, survey questions were made as simple as possible, easier to interpret and translated to the study participants in their respective local languages. This was done to ensure that respondents understood the questions they were asked. Research Assistants were also recruited based on their past experiences (e.g., data collection), level of education (i.e., tertiary education), and proficiency in local languages of the study communities. Aside that, they received comprehensive training on ethical and safeguarding protocols, and on the survey instrument through a pretest of the survey instrument. The researchers supervised and monitored research assistants throughout the data collection process to ensure that the collected data is of high quality. The total sample (n = 1100) was also large enough for generalization across smallholder farmers in northern Ghana and similar context in SSA. Also, prior to data analysis stage, in order to ensure the credibility of statistical estimates, the collected data was screened for missing values, and errors in data entry and coding, using Stata Version 15. This robustness is essential for the reliability, validity, and generalizability of the study findings.

3.7 Conclusions

This chapter described the methodological design utilized in this research. It thus described the study design, data collection instrument, sampling techniques, and the data analysis. Finally, the chapter highlighted the steps that were taken throughout the research to ensure validity, reliability, generalization, and overall robustness of the study findings.

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Chapter 4

Title: Determinants of post-harvest loss among smallholder farmers in the Upper West Region (UWR) of Ghana.

4.0 Abstract

Food insecurity is a global problem with higher proportions of affected populations located in the Global South. In smallholder farming communities across Africa, evidence suggests that post-harvest loss (PHL) is one of the crucial but understudied drivers of food insecurity. In Ghana for instance, PHLs are recorded during harvesting, grading, and packing. PHL prevention has the potential of significantly mediating the problem of food insecurity in Africa given that the proportion of food lost during post-harvest activities could feed a significant proportion of the region's food insecure population. However, a paucity of knowledge exists on the factors that influence PHL in the Global South, especially among smallholders. Using data from a cross sectional survey of 1100 smallholder farmers in the Upper West Region (UWR) of Ghana, results from a multiple linear regression analysis showed that female farmers significantly reported lower PHL (α=-1.063; $p \leq 0.05$) compared to their male counterparts. Also, larger households (8-11 members) reported lower PHL (α=-1.880; $p \leq 0.05$) compared to relatively smaller households (less than 5 membership). Invariably, households that engage in joint decision-making processes, reported lower PHL (α=-1.257; $p \leq 0.001$) when compared to household in which unilateral decisions tend to be made. Moreover, farmers who received financial remittances (α=-2.622; $p \leq 0.05$) recorded lower PHL compared to those who did not. However, households that received climate information from the local community (α=2.018; $p \leq 0.05$), reported higher PHL compared to those who relied on expert knowledge. Also, farmers who reared livestock (α=1.851; $p \leq 0.05$),

were significantly associated with higher PHL in the study context. These findings demonstrate the need to for agricultural policies to take into consideration both household and farm related factors in the quest to reduce post-harvest food loss.

Keywords: Post-harvest loss; food insecurity; Semi-arid Northern Ghana

4.1 Introduction

Post-harvest loss (PHL) is a major driver of food insecurity in Africa and globally. Globally about 25 –30% of the total food produced is either lost or wasted (IPCC, 2019), hence one out of every four calories produced for human consumption is eventually not consumed (FAO; 2013; Lipinski et al., 2013). Yet, global food demand is expected to increase by 40% in the next 4 decades (FAO, 2011). As observed by Kumar & Kalita, (2017), the proportion of food lost due to PHL alone could address the food needs of a significant proportion of the food insecure population in the Global South. Poor post-harvest management alone accounts for 20-30% of annual food loss in Africa, with an estimated economic value of 1.6 billion USD (FAO, 2010). On annual basis, the volumes of food that are lost in Sub-Saharan Africa (SSA) through PHL, are estimated at USD 4 billion for grains alone (Affognon et al., 2015). In SSA countries like Ghana, PHL is a major challenge to smallholder farmers (Baral & Hoffmann, 2018). For instance, empirical evidence shows that about 30% of maize harvest in Ghana does not get to consumers due to PHL (Opit et al., 2014). In terms of loss per component, field losses (e.g., during harvesting, heaping etc.), shelling or threshing, drying, storage losses through molds infections and poor storage, and losses caused by insects were found to accounting for 5%, 1.5%, 0.5%, 15% and 8% respectively for the overall PHLs among smallholder farmers in Ghana (Opit et al., 2014). Also in the Ghanaian context, Addo et al. (2015) in their assessment of post-harvest losses of tomatoes in the three ecological zones of Ghana, noticed a 4.6%-8.85% quantitative losses during harvest, 3.6%-13.75%

losses during grading and parking, between 2.3% to 7.4% and 2.6% to 3.3% during transportation and marketing respectively. Specifically in the Upper West region of Ghana, post-harvest losses of maize grains for instance, are high during post-harvest handlings like winnowing, on-farm transportation, loading and unloading of produce (Alhassan and Kumah, 2018).

Amid poor agricultural infrastructure and increasing climate variability, PHL is bound to increase, particularly on-field and storage losses (FAO, 2020). Yet, knowledge on proper post-harvest handling, proper storage, packaging, and safe transport of food stuff to distribution points is limited (Addo et al, 2015; Delgado et. al, 2021). Climatic conditions like high heat and humidity causes PHL especially in places where the presence of post-harvest rains prevent the proper drying of crops (Delgado et al., 2021). The effects of climate change on food loss are postulated to be even more devastating in sub-Saharan Africa (SSA) due to low adaptive capacity (IPCC, 2019; Muller, 2009). This is especially the case of countries like Ghana where smallholder farmers largely depend on direct sunlight for the drying of their produce. In the absence of proper storage and transportation facilities to control temperature and humidity, the suitable environment for pest and insect infestations is created by adverse climatic conditions that causes both pre-harvest and post-harvest losses (Addo et al., 2015). Post-harvest food loss is therefore a general problem in SSA, and farmers' capacity to adapt depends largely on access to financial resources and appropriate technologies for post-harvest handling and proper storage of harvest. In SSA, PHL reduction is therefore a major pathway to achieving food and nutritional security (Affognon et. al, 2015). Despite its importance in the sustainability of food security in context of climate change, there is relatively little literature that explains the intricate determinants of PHL in the study context. In response, the objective of this research is to examine the factors that influences PHL among smallholder farmers in the Upper West Region of Ghana.

4.2 Food loss in context

Food loss is the amount of food lost in the hands of producers or through the chain of distribution while food waste is food lost at the consumer level (Sheahan & Barrett, 2017). According to Sheahan and Barret (2017), food loss can be conceptualized not only in terms of quantity loss (physical amount of food lost in kilograms or calories) but also in quality loss (decrease in nutritional value/loss of important nutrients, or through contamination). In fact, qualitative loss is of equal importance and concern because of the health consequences that may result from consuming poor-quality food. Low quality food products may be dangerous to consumer's health, wellbeing, and productivity (According to FAO, 2011). Quality loss though difficult to detect, is a crucial concern because of the prevalence of micronutrient deficiencies and food-borne health hazards such as aflatoxin contamination (Sheahan & Barrett, 2017). For instance, the gradual development of esophageal and liver cancer is caused by mycotoxins, toxic compounds that are naturally produced by fungi that grow on food stuff. The presence of these contaminants in food, retards growth and are immunosuppressive when consumed (Sheahan & Barrett, 2017). Fungal and pest infestations that threatens the safety of food is therefore a serious concern that can be prevented through investments in PHL reduction programs. Moreover, a loss in quality could lead to massive loss in quantity when food products must be discarded because they are not fit for consumption. However, quantitative loss is mostly the focus of PHL estimation ((Sheahan & Barrett, 2017).

In terms of quantitative losses, the share of food waste and loss (FWL) in developing countries is much higher at the production and post-harvest stages while in developed countries of North America, industrialized Asia, and Europe, FWL is higher at the consumer level, ranging from 45% to 60% of total losses (Gromko & Abdurasulova, 2019). It is recognized that such losses are not merely loss of food but also a corresponding waste of human efforts, farm inputs, financial investments, and scarce water resources. A reduction in PHL will translate into an increased food availability (Addo et al., 2015), and once more food is available, consumers would most likely pay lower prices for food stuff at the markets. The presence of these conditions through investments in PHL prevention will ensure food security (Sheahan & Barrett, 2017). This is because food security goes beyond availability to include accessibility, affordability, and utilization. From another perspective, in the absence of PHL prevention, the impact of food loss and waste (FLW) on the environment will be devastating. For instance, FLW has a higher impact of on land degradation and deforestation in developing countries (with 6.31 Gt of soil lost and 1.66 million ha deforested in 2013 alone) (Gromko & Abdurasulova, 2019). Investments in PHL thus occur with four objectives in mind; the need to improve food security, to improve food safety, to reduce waste of resources/unnecessary use of resources, and to increase profit margins for food value chain actors (Sheahan & Barrett, 2017). To meet these objectives in the Sub-Saharan African context, further studies is needed to understand the determinants of PHL, especially among smallholders. This is crucial because majority of farmers in Africa are smallholders (Altieri et al., 2012) accounting for about 75% of agricultural production in the continent (Salami et al., 2010).

4.3 Methods

4.3.1 Data collection

This study used data from a cross-sectional survey with smallholder farmers (n=1100) as part of a Social Science and Humanities Research Council funded project. The survey covered broader thematic areas of smallholder farmers including smallholder demographics, agricultural production, housing, household assets, household expenditure, gender relations, credit access, adaptive capacity, food security, livelihood activities and climate resilience. A multistage sampling technique was employed. First, a non-probability purposive sampling technique was used to select three districts (Nadowli-Kaleo, Lawra, and Wa west) in the region. This sampling technique was found more convenient because it allows researchers to select the most relevant population (in this case, smallholder farmers). At the District levels, a simple random sampling was used to select the study communities/villages in each of the three Districts. In each community, a systematic sampling of every fifth household as a unit was selected to participate in the survey. This gave all farming households an equal chance of being included in the research survey. The sample sizes of the selected Districts were arrived at based on their population sizes (Nadowli-Kaleo=367, Lawra=295, and Wa west=438). Ethical clearance for the study was granted by the Non-Ethical Research Board of the University of Western Ontario.

4.3.2Measures

The key dependent variable for this research is post-harvest food loss. This is derived from a question that asked smallholder farmers to estimate the proportion of the annual harvest they lost during post-harvest handlings (e.g., during shelling/threshing, winnowing, drying, storage etc.). Estimates were done on a continuous scale of 1-100 kilograms (Kg). Appendix C contain details on the measurement of PHL. Covariates were structured into individual level, household level and agricultural related factors. Individual level factors included: age (0 =18-25, 1=26-35, 2=36-45, 3=46-59, 4=60 and above); gender of primary farmer (0=male, 1=female); marital status (0=married, 1=single, 2=widowed/divorced); education (0=tertiary, 1= no formal, 2= primary, 3= secondary). Household level factors included: wealth (0 = richest, 1= richer, 2= middle, 3=poorer, 4= poorest); household decision making (0=sole decision, 1=joint decision); household size (0=1-4, 1=5-7, 2=8-11, 3=12 and above); access to credit (0=no credit, 1= formal source, 2=informal source); remittances (0=no, 1=yes). Agricultural related factors included: farm size; storage treatment (1=chemical, 2=traditional granaries), cropping type (22=mixed cropping, 23=sole cropping), livestock rearing (0=no, 1=yes), and source of climate information (1=personal experience, 2=local community, 3=external experts).

4.3.3 Analytical approach

The survey data was analyzed in Stata version 15. The analysis is structured in three main parts. First, a univariate analysis was employed to understand the distribution of the dependent variable (post-harvest loss), and the independent variables. Second, a bivariate linear regression was used to explore the relationship between each independent variable and post-harvest loss. Finally, while controlling for relevant theoretical factors, multiple linear regression analysis was conducted to understand how the independent variables influences the post-harvest food loss outcomes of smallholders. These analyses were conducted at three levels (consisting of model 1, model 2, and model 3). Model 1 comprised of only demographic variables, model 2 consist of both demographic and household socio-economic variables, and model 3 contain all the theoretically relevant variables included in the study (i.e., demographic, socio-economic, and farm-level factors). The three different models were run to gain insight on the relative influence of the demographic, socio-economic, and farm-related factors on post-harvest food loss in the study context. Analysis of data was conducted in Stata version 15. Both descriptive and inferential statistics were employed in the analysis. Multiple linear regression was more appropriate given that the outcome variable (post-harvest food loss) is a continuous variable with several predictors.

4.4 Results

4.4.1 Descriptive statistics

Table 2 below presents the descriptive statistics for all selected variables. The average post-harvest food loss recorded among study participants was 21.88 kilograms (kg). Out of 1100 respondents, 52% were males and 48% were females. This distribution is proportionate to the regional distribution of women in agriculture-where women in the Upper West region constitute about 42% of agricultural labor force (see Ghana Statistical Service, 2019). 82% of the study respondents were married couples, 6% were either widowed or divorced, and the remaining 12% were single in terms of marital status. Also, large proportion of the farmers (67%) had no formal education. Perhaps, this explains why majority (83%) of the respondents did not see the need to seek experts' knowledge for climate information but had to rely on either their personal experiences or local community. Table 2 below contains a comprehensive distribution of all relevant variables in the study.

Table 2: Descriptive statistics

Variable	Percentage
PHL	21.88kg(mean) SD (18.27)
Age	
18-25	8
26-35	20
36-45	35
46-59	31
60+	6
Gender	
Male	52
Female	48
Marital Status	
Married	82
Single	12
Widowed/Divorced	6
Religion	
Christian	61.45

Muslim	16.91
Traditional/Other	21.64
Education	
Tertiary	4
Primary	17
Secondary	12
No formal	67
Household decision making arrangement	
Sole decision-making	75
Joint decision-making	16
Household size	7.30(mean) SD (3.28)
Wealth	
Richest	19
Richer	17
Middle	22
Poorer	22
Poorest	20
Remittances	
Yes	4
No	96
Credit Source	
No Credit	54
Formal	36
Informal	10
Cause of PHL	
Other animals	3
Pests/insects	69
Rats/mice	17
Mold/spillage	11
Farm size	4.91(mean) SD (9.24)
Cropping type	
Sole cropping	46.67
Mixed cropping	53.33
Source of climate information	
Personal experience	21
Local community	62
External experts	17

4.4.2 Bivariate analysis

Table 3 shows results for the bivariate analysis. Farmers within the age groups 36-45 (α=-2.011; $p<0.05$) and 60+ (α=-3.559; $p \leq 0.01$) reported 2 times and 4 times less PHL respectively, compared farmers whose ages ranged from 18-25 years. In terms of marital status, single farmers (α=3.539; $p \leq 0.001$) reported about 5 times less PHL compared to those who were married. With regards to religious affiliation of farmers, those who were Muslims (α=-2.286; $p \leq 0.01$), also reported twice less PHL. Likewise, larger households (8-11 members) reported (α =-1.741; $p \leq 0.05$) about 2 times less PHL compared to smaller household (1-4 people). Households that practiced joint decision-making (α=-2.270; $p \leq 0.001$) reported 2 times less PHL compared to households that practiced unilateral decision-making. In terms of financial status, the poorer (α=1.816; $p \leq 0.05$) and poorest (α=2.838; $p \leq 0.001$) primary farmers about 2 times and 3 times more PHL respectively, compared to households belonging to higher wealth quantiles. Farmers who received remittances (α=-2.944; $p \leq 0.05$), reported about 3 times less PHL compared to those who did not receive remittance. Furthermore, farmers that reared livestock (α=1.896; $p \leq 0.05$) reported nearly 2 times more PHL compared to those who were not into livestock rearing. Also, farmers who relied on their own knowledge (α=2.681; $p \leq 0.01$) and those who relied on the local community for climate information (α=2.522; $p \leq 0.001$), all reported about 3 times more PHL compared to those who relied on external experts. With regards to the cause of PHL, mold infestation (α=8.243; $p \leq 0.001$) led to 8 times more with PHL compared losses caused by stray animals. Last but not least, farmers who practiced sole cropping (α=-1.739; $p \leq 0.001$) reported nearly 2 times less PHL compared to those who practiced mixed cropping.

Table 3: bivariate linear regression of PHL and covariates

Variable	Coef(SE)	95% Conf. Interval	
Gender of primary farmer (ref: Male)			
Female	-0.745(0.486)	-1.699	0.209
Age (ref: 18-25)			
26-35	-1.406 (.994)	-3.357	0.545
36-45	-2.011 (.927)*	-3.829	-.1927
46-59	-1.554 (.938)	-3.396	0.287
60 and above	-3.559 (1.27)**	-6.052	-1.066
Marital Status (ref: Married)			
Single	3.539 (0.754)***	2.059	5.019
Divorced/widowed	-1.031 (1.032)	-3.058	0.996
Religion (Ref: Christianity)			
Muslem	-2.286(0.665)**	-3.591	-.922
Traditional/other	-.620(0. 605)	-1.808	0.568
Education (ref: Tertiary)			
Secondary	1.134 (1.373)	-1.559	3.828
Primary	-0.181 (1.318)	-2.768	2.405
No formal education	0.767 (1.214)	-1.613	3.149
Household size (ref: one-four)			
Five-seven	-.684 (0.710)	-2.078	0.709
Eight-eleven	-1.741 (0.770)*	-3.253	-.231
Twelve and above	-0.771 (0.944)	-2.623	1.081
Household decision making (Ref: Sole)			
Joint decision making	-2.270 (0.659)***	-3.563	-0.978
Wealth (ref: Richest)			
Richer	-0.264(0.803)	-1.840	1.313
Middle	-.012(0.753)	-1.489	1.466
Poorer	1.816(0.760)*	0.325	3.308
Poorest	2.838(0.776)***	1.315	4.360
Remittances (ref: No)			
Yes	-2.944(1.188)*	-5.274	-0.613
Credit source Ref: No credit)			
Formal source	-.342(0.525)	-1.372	0.688
Informal source	-1.444(0.827)	3.066	0.179
Climate information (ref: External experts)			
Personal experience	2.681 (0.790)**	1.131	4.232
Local community	2.522 (0.664)***	1.219	3.826
Farm Size	-0.019(0.026)	-0.071	0.032

Livestock Rearing (Ref: No)			
Yes	1.896(0.793)*	0.340	3.452
Cause of Post-harvest loss (Ref: Pest/insects)			
Rats/mice	-0.514 (1.463)	-3.386	2.357
Mold	8.243 (1.519)***	5.262	11.224
Cropping type (Ref: Mixed cropping)			
Sole cropping	-1.739(0.487)***	-2.695	-0.784

* p<0.05, **p<0.01, ***p<0.001, Coef= Coefficients, SE = Standard Error, CI = Confident Interval

4.4.3 Multivariate analysis

Table 4 below presents the results for multivariate analysis at three levels. Model 1 consist of only the demographic characteristics of primary farmers in the farming households. Model 2 consist of both demographic and household socio-economic variables. Model 3 is the final model consisting of farm-related predictors in addition to the demographic and household socio-economic variables. Model 3 thus provide the collective impact of all predictor variables on smallholders' post-harvest loss outcomes in the study context. Models 1, 2, and 3 have adjusted R-squares of 0.0217, 0.1372, and 0.4551, indicating a 2%, 13% and 45% of model fit, respectively. This shows an improvement in the prediction accuracy from model 1 to model 3.

The gender of primary farmer became a significant determinant of post-harvest loss (PHL) as shown in model 3 (α=-1.063; $p \leq 0.05$) where female primary farmers reported less PHL compared to male primary farmers. In terms of marital status, single primary farmers at all the three levels of analysis reported more PHL compared to married farmers; model 1(α=3.702; $p \leq 0.001$), model 2 (α=3.337; $p \leq 0.001$), and model 3 (α= 2.081; $p \leq 0.05$). In both model 2 (α=-2.047; $p \leq 0.01$) and model 3 (α=-1.880; $p \leq 0.05$), primary farmers belonging to larger households (8-11 membership), reported less PHL compared to households with relatively fewer members (1-4 members). Also, both in model 2 (α=-1.622; $p \leq 0.01$) and model 3 (α=-1.257; $p \leq 0.05$), households that practiced joint decision-making reported less PHL compared to those who practiced unilateral decision-making. Household wealth became a significant determinant of PHL in both model 2 and model 3 whereby the poorer and poorest households reported more PHL compared to households in better wealth quantiles; model 2[poorer (α=1.934; p≤0.001); poorest (α=3.167; p≤0.01)] and model 3[poorer (α=1.006; p≤0.05); poorest (α=1.360; p≤0.01)]. Moreover, primary farmers who received financial remittances, reported 2.3 times and 2.6 times less PHL in model 2 (α=-2.335; p≤0.05) and model 3 (α=-2.622; p≤0.05) respectively, compared to those who did not receive remittances. Source of climate information also became a significant determinant of PHL but only in model 3 whereby farmers who relied on the local community for climate information (α=2.696; p≤0.001), reported 2.6 times more PHL than those that relied on external experts. Likewise, primary farmers who reared animals (α=1.851; p≤0.05) reported about 2 times more PHL than those who were not into livestock rearing. In terms of the cause of losses, consistent with results at the bivariate level, mold infestation (α=6.340; p≤0.05) led to 6 times more PHL compared to losses caused by stray animals.

Table 4: Results of multivariate analysis

Variable	**Model 1 (demographics)**			**Model 2 (Socio-economic)**			**Model 3 (Farm-related)**		
	Coef.(SE)	**CI(95%)**		**Coef. (SE)**	**CI(95%)**		**Coef. (SE)**	**CI(95%)**	
Gender of primary farmer (ref: Male)									
Females	-.582 (0.504)	-1.571	0.406	-.917 (0.523)	-1.94	0.108	-1.063 (0.518)*	-2.079	-.047
Age (ref: 18-25)									
26-35	.068(1.108)	-2.106	2.242	.047 (1.096)	-2.102	2.197	-.687 (1.059)	-2.765	1.391
36-45	0.000 (1.170)	-2.295	2.295	-.099 (1.158)	-2.373	2.173	-.168 (1.118)	-2.362	2.027
46-59	0.199 (1.183)	-2.122	2.519	.118(1.168)	-2.174	2.410	.527 (1.128)	-1.687	2.740
60 and above	-1.758(1.479)	-4.659	1.144	-1.378(1.465)	-4.253	1.497	-1.210 (1.433)	-4.113	1.513
Marital Status (ref: Married)									
Single	3.702 (0.950)***	1.838	5.566	3.337 (0.940)***	1.492	5.182	2.081 (0.916)*	0.283	3.879
Divorced/widowed	-.924 (1.104)	-3.091	1.243	-.060 (1.106)	-2.231	2.109	-.825 (1.105)	-2.993	1.343
Religion(Ref: Christian)									
Muslem	-2.198 (0.681)***	-3.534	-.862	-1.967(0.688)	-3.316	-.618	-1.456(0.685)	-2.801	-.112
Traditional/other	-.559(0.673)	-1.880	0.762	-.794(0.691)	-2.150	.561	-.547(.740)	-1.999	0.905
Education (ref: Tertiary)									
Secondary	0.887 (1.420)	-1.899	3.674	0.607(1.413)	-2.165	3.379	0.405 (1.388)	-2.319	3.130

Primary	0.504(1.329)	-2.103	3.111	0.626 (1.337)	-1.998	3.250	0.393 (1.313)	-2.185	2.972
No Formal	2.085 (1.261)	-.390	4.560	1.798 (1.260)	-.675	4.271	1.156 (1.246)	-1.289	3.600
Household size (Ref. 1-4)									
Five- seven	-.666 (0.723)	-2.084	0.752	-1.148 (1.727)	-2.57	0.277	-1.130 (0. .714)	-2.532	0.271
Eight-eleven	-1.464(0.808)	-3.049	0.121	-2.047 (0.820)**	-3.656	-.438	-1.880 (0.018) *	-3.878	0.116
12 and above	-.344(0.998)	2.303	1.615	-1.516(1.031)	-3.539	0.507	-1.88 (1.017)	-3.877	0.116
Household Decision Making (ref: Sole decision making)									
Joint decision making				-1.622 (0.666)**	-2.929	-.315	-1.257 (0.661)*	-2.554	0.039
Wealth (ref: Richest)									
Richer				-.1355 (0.805)	-1.714	1.443	-.483 (0.792)	-2.037	1.071
Middle				-.056 (0.766)	-1.560	1.448	-.892 (0.756)	-2.375	0.590
Poorer				1.934(0.793)**	.377	3.490	1.006 (0.799)*	-.561	2.575
Poorest				3.167 (0.851)***	1.498	4.836	1.360 (0.862)**	-.331	3.053
Remittances (ref; No)									
Yes				-2.335 (1.226)*	-4.742	0.071	-2.622 (1.219)*	-5.014	-0.230
Access to credit (ref: No credit)									
Formal				-.315 (0.598)	-1.489	0.859	0.811 (0.650)	-0.464	2.085
Informal				-.670 (0.839)	-2.316	0.977	-.939 (0.841)	-2.589	0.711
Climate Information (ref: External experts)									
Local community							2.696 (0.810)***	1.107	4.284
personal experience							1.248 (0.805)	-.332	2.828
Farm Size							-.017 (.025)	-.066	0.032
Livestock Rearing (Ref:No)									
Yes							1.851 (0.863)*	0.158	3.544
Cause of post-harvest loss (Ref: Other animals)									
Pests/insects							1.006(1.420)	-1.780	3.793
Rats/ mice / etc.							-.424(1.514)	-3.395	2.547
Mold spoilage							6.340(1.567)***	3.264	9.416
Cropping type (mixed)									
Sole							-1.696 (0.600)**	-2.874	0.518
Adj R-squared	0.0217			0.1372			0.4551		

* p<0.05, ** p<0.01, *** p<0.001, SE = Standard Error, CI = Confident Interval

4.5 Discussion

This study examined the determinants of post-harvest food loss among smallholder farmers in semi-arid northern Ghana. A number of theoretical relevant predictors including the demographic characteristics, household socio-economic conditions, and farm-related factors emerged as significant determinants of PHL.

Gender emerged as significant predictor of PHL whereby female primary farmers reported lower post-harvest losses when compared to male primary farmers. This finding may be explained by the fact that in this context and in similar traditional farming societies, constructed gendered farm roles results in women being typically responsible for harvesting and post-harvest handling processes (Sugri et al., 2021;Kansanga et al., 2019). As a results, women have a relatively very rich knowledge which may put them in a better position to manage PHL better than men. This finding points to the important insights women can bring to PHL management policy making in the Global South. It is however important to note that although women are mostly responsible for harvesting and post-harvest handling of food in this context, in most cases women may not have the freedom and level of empowerment to make appropriate adjustments on farm level decisions.

Consistent with the work of Abera et al (2020), primary farmers who were single, recorded higher likelihood of PHL than those who were married. This speaks to the challenging aspects of PHL in context of climate variability. In most smallholder contexts of Sub-Saharan Africa and in fact other developing countries, the prevalence of poverty and associated low technology adoption leaves smallholders with no choice than to carry out post-harvest handling activities manually (Kumar and Kalita, 2017). Consequently, post-harvest handlings such as thrashing, shelling, winnowing, drying, transportation, and storage can be very laborious and time-taking for single men and women who may not have other people around to help in harvesting and post-harvest handlings. Furthermore, the harvesting period for some crops can be very short and thereby leaving single farmers unable to rely on their social networks who may be engaged in their own farms. However, married couple may have the comparative advantage of shared labor and resources to manage post-harvest processes in a timely and effective manner, necessary for loss prevention. Besides, in typical farming communities of northern Ghana, having many children has been an age-long cherished social practice whereby children are considered a blessing and source of wealth in that context. Intrinsic within this social belief system is the fact that many poor smallholders in these contexts tend rely on their children for agricultural labor. A similar study (see Kansanga et al., 2019) shows that marriage and type of marital arrangement in smallholder farming household in the Upper West region has an influence on the burden of agricultural responsibilities and labor requirement in farming households. For instance, a disproportionate burden of farm labor was discovered between women in polygamous and monogamous family structures in the Upper West region where women in polygamous families with female children especially, enjoyed the privilege of lesser labor burden as children complimented their home responsibilities and farm labor (Kansanga et al., 2019). Primary farmers who are married with children in this context may thus utilize the services of their children to either complement extra-home responsibilities, or even speed up farm responsibilities on post-harvest handlings such as shelling and drying. This would particularly be the case of married couple with grown-up children. Moreover, even in post-harvest technology adoption, driven by their social responsibility, married couple are more likely to be responsive in order to cater for their family (Mujuka et al., 2021).

Consistent with earlier studies in Ghana including Aidoo et al., (2014), there is a significant association between household size and PHL. As expected, households with more available labor are able to reduce PHL. This is particularly crucial in semi-arid northern Ghana where rainfall variability is a major driver of PHL food loss. For example, in August 2021, heavy rains and floods fueled by the 'Bagre' dam discharge, resulted in the destruction of several hectares of crops as well as already harvested produce at affected farms during the harvesting season (Atanga and Tankpa, 2021). Moreover, farmers are usually challenged with the preservation of produce for early maturing crops given that the harvesting of such crops usually coincides with the rainy season during which the weather is mostly cloudy with little sunlight for drying of farm produce (Baral & Hoffmann, 2018; Hoffmann et al., 2018). Consequently, farmers must constantly be available to monitor farm produce during drying to prevent them from being beaten by rain. Given these challenges, households with more agricultural labor would stand a better chance of reducing PHL.

The traditional masculine nature of our study context points to the importance of household decision-making in the context of PHL. This indicated by the fact that households in which agricultural decisions were jointly made, had lower PHL compared to households where unilateral decisions tend to be made, most by male household heads. This could be due to the relative effectiveness of varied views, shared ideas, skills, and even resources that actors may collectively bring forth on the table of post-harvest management decision-making process. An earlier study in the Upper West region has uncovered that joint decision making facilitates problem solving (see Batung et. al, 2021). When household problems are collectively approached, it creates a sense of ownership and increases the willingness of household members to see to the effective and timely implementation of such decisions (Batung et. al, 2021). As highlighted earlier, in semi-arid northern Ghana where worsening climatic conditions exist, requires collective action for effective management of the complexities involved in PHL issues. Post-harvest handlings like drying and storage at the farm-level are largely labor intensive and must be conducted timely to prevent spoilage from post-harvest rains and extreme whether events, as well as from destruction by stray animals. But given the sense of willingness and collective ownership in joint decision-making arrangement, actors or members of the farming household will not only share their labor but also bring forth diverse ideas and resources to collectively address post-harvest challenges, hence the lesser likelihood of PHL in joint decision-making compared to sole decision-making in the study context.

As one would expect, poverty significantly influenced post-harvest loss, implying that in smallholder contexts, wealth mediates access to productive resources including the acquisition of equipment for post-harvest processing, transportation of produce, and storage. The absence of affordable agricultural credit facilities in the smallholder farming communities of northern Ghana further complicates the plight of poor smallholders. Undoubtedly, poor access to agricultural credit is a bottleneck to post-harvest technology adoption among smallholders, and therefore a reason for their inability to prevent post-harvest food loss (Delgado et al., 2021; Sheahan & Barrett, 2017). In the absence of financial resources, reinforced by poor road networks in most parts of Ghana's farming communities, transporting farm produce for storage, or even from home to the market centers, is highly problematic. As a result, large amounts of produce end up delaying in the farm, fully exposed to destructions by stray animals and summer rains that often prevent proper drying, and consequently causing the suitable conditions for mold and pest infestations.

The association between remittance and lower PHL speaks to the available resources for smallholders who may be racing against time during harvesting and immediately following post-harvest. This is in line with Tshikala et al (2019) observation of a positive relationship between financial remittances and technology adoption in agriculture; whereby remittance serve as a substitute that may enable smallholder farming households to overcome liquidity constraints and invest in new technologies and activities for loss prevention (Dedewanou and Kpekuo, 2021; Tshikala et al., 2019). This also aligns with work by Atuoye et. al (2017) who found a positive relationship between access to financial remittances and household food security related concerns.

A recurrent challenge in this context is the frequent lack of timely climate related information for farmers most of whom are in rural areas. It is therefore not surprising that access to timely agricultural and climate information is a strong predictor of PHL among smallholders. Households in which the primary farmer relied on the local community for climate information, recorded higher PHL compared to those who solely relied on external experts. Acquiring the right information through external experts provide farmers best practices of harvest and post-harvest handlings (Sheahan & Barrett, 2017). With the right information at hand, farmers can put the necessary precautionary measures in place to avert PHL. The notion that access to climate information through external experts may place farmers in a better position to anticipate changes in climatic variables such as rainfall, underlies existing inequities with regards to who can access relevant climate information. In most smallholder communities in northern Ghana, the lack of adequate local weather stations with trained agents that can translate this information to smallholders who may not be formally educated, makes it hard for these farmers to readily access climate information. Most smallholders are thus left with no choice than to either rely on their own knowledge and personal experiences, or other members of their local community.

The emergence of the relationship between livestock rearing and PHL is worth noting. Invariably, livestock rearing is frequently seen as a climate resilience strategy (Mulwa and Visser, 2020). Yet the findings here show that those who rear livestock were more likely to report PHL. In the Upper West region of Ghana, it is common among farming households to rear animals such as goat, sheep, and fowls. In fact, produce in storage sacks at home are occasionally consumed by these animals at home (Mustofa & Godar, 2017). Concomitantly, some farmers in this study context engage in extensive livestock farming at the farm-level, in most cases poultry and goats. In such instances, considerable quantities of harvested produce that are undergoing post-harvest processing at the farm-level, may be eaten by these animals on the field as they wonder around, and may be counted as losses by farmers in that regard. This perhaps explains why livestock owners in this context recorded higher PHL compared to those who were not into livestock rearing. Restrictions of livestock during the farming season has been a long-lasting traditional practice albeit challenging as most farmer are typically multitasking and unable to protect these animals from destroying their produce. This points to the need to work with farmers on livestock management especially during the harvesting and post-harvesting periods.

Furthermore, in terms of the cause of spoilage of harvested produce among smallholders, the study results showed that mold infestation significantly influenced higher PHL. This finding is consistent with work by Akumu et al (2020) who reported that in Uganda, mold significantly results in post-harvest losses during post-harvest handlings, and particularly in instances where drying is done on the bare ground. Similarly, working in the middle belt of Ghana Opit et al (2014) found that mold infection of harvested food produce is a problem that most famers face during the drying and storage stages of post-harvest handlings. There are a number of potential explanations related to the role of mold in PHL in the study context, and in fact, in similar contexts. First, with rapid climate variability that has resulted in frequent erratic rains, smallholders' ability to dry their crops may be challenging given that harvested crops usually contain high moisture content that create a suitable condition for mold infection, and therefore require longer drying time to prevent infection (Manandhar et. al, 2018). Second, with advent of erratic rains, reliability of climate and weather information would be required for smallholders to be able to manage their harvest. Unfortunately, the lack of such information means these farmers cannot plan for post harvesting management of their harvest. Also, the lack of access to appropriate post-harvest food management technologies for drying and processing of harvested crops is also a factor that influences the amount of food loss due to mold contamination. This relates to the huge amount of labor that is typically required for post-harvest management.

The study results further indicated that smallholders who practiced mono cropping, recorded lower PHL compared to those who practiced mixed cropping. Unlike mono cropping, mixed cropping is inherently more complicated given that majority of smallholders in this study context often cultivate legumes (such as groundnuts, beans etc.) and grains (e.g., maize, millet etc.) on the same plot of land. With these crops sometimes maturing at different stages (e.g., leguminous crops usually mature for harvest before the grains), farmers may be confronted with having to deal with different issues at the same time. This is especially the case of impoverished smallholders in the study context who tend lose substantial amount of their harvested produce on annual basis due to lack of capital or inability to hire the services of extra labor.

While this study provides useful insights on the determinants of PHL among smallholders in Northern Ghana, the findings should be interpreted with consideration of some noteworthy weaknesses. One limitation of this study is that there are possibilities of under reporting and over reporting of post-harvest losses by the participants given that this was a self-reported measure in the survey. However, as highlighted by Sheahan & Barrett, (2017), though a major challenge in estimating the magnitude of food loss is a question of methodological appropriateness, it is however reasonable to believe households self-reports based on well-organized questionnaire that follow standard survey protocols. Another limitation is that the survey data used in this analysis is cross-sectional, which limits the findings to statistical associations. Future research may benefit from longitudinal analysis.

4.6 Conclusions and recommendations

Despite the limitations of this study, it has made a significant contribution to literature on the determinants of PHL outcomes in smallholder contexts. This study thus concludes that among smallholder farmers in the study context and in similar contexts across the Sub-Saharan African region, PHL outcomes among smallholders is dependent on a variety of factors including access to credit and remittances, access to climate information, and household decision-making arrangements. Based on the findings in this study, it is important for agricultural policies that target smallholders, to prioritize and address their socio-economic (e.g., credit access) challenges since such challenges affect the PHL outcomes of smallholder farmers. Post-harvest rains are undoubtedly a major challenge to post-harvest loss prevention among farmers in Africa (Tefera, 2012), and particularly common among smallholders that lack financial resources to hire sufficient labor and utilize modern technologies for loss prevention. Agricultural policies should therefore prioritize the creation of affordable credit facilities in smallholder farming communities to help impoverished farmers overcome the financial barriers to loss prevention. Until the socio-economic constraints of smallholders in this context and similar contexts are addressed, food loss and waste will remain a major challenge to the attainment of food security, and to the achievement of Sustainable Development Goal 2 (Kaminski et.al, 2020). More importantly, for post-harvest loss interventions to be successful, they should be based on a holistic understanding of the local demographic and socio-economic conditions of farmers. Policy interventions in Africa at large must therefore ensure that the post-harvest loss concerns of smallholders-who account for about 75% of agricultural production in the continent (Salami et al., 2010), are reflected in policy design and implementation.

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Chapter 5

Title: Association between backyard gardening and resilience to climate change in Semi-arid Northern Ghana.

5.0 Abstract

Projections for future climate variability suggest that poor smallholder farmers' vulnerability to the adverse impacts of climatic stressors would continue to increase without appropriate context-based interventions. In developing countries like Ghana, smallholder farmers have long engaged in backyard gardening as a supplementary source of food production, and a risk spreading strategy. However, unlike community gardening and its role in urban resilience, very little is known about the role of backyard gardening in smallholder farmers' resilience to climatic stressors. Using data from a cross-sectional survey of 1100 smallholders in the Upper West Region (UWR) of Ghana, this study explored the association between rural backyard gardening and smallholder farmers' resilience to climatic stressors. Results from a logistic regression model showed that farmers who practiced backyard gardening (OR=9.105; $p<0.001$) were 9 times more likely to have good resilience than those who did not. Other covariates including livestock rearing (OR=9.928; $p<0.01$), crop switching (OR=2.056; $p<0.05$), and joint decision-making (OR=1.680; $p<0.05$), were also significantly associated with improved resilience to climatic stressors. Overall, backyard gardening has the potential to moderate the impacts (e.g., food insecurity) of climatic stressors on smallholder farmers in the study context. Since the UWR is characterized with semi-arid weather conditions and a single maxima rainy season, policies could be leveraged on dry-season backyard gardening as a key entry point for improving smallholder farmers' livelihood resilience to climate change impacts.

Keyword: Climate change; resilience; backyard gardening; smallholder farmers; semi-arid northern Ghana.

5.1 Introduction

There is now a consensus regarding the negative impacts of changing climatic conditions on agricultural production, particularly in Sub-Saharan Africa (SSA). In SSA and many parts of the world, rural livelihoods consist primarily of rain-fed family farms (Pelletier et al., 2016). With high reliance on natural resources and ecosystem services, rural livelihoods tend to be vulnerable to climatic shocks and stressors. In SSA, smallholder farmers are particularly vulnerable to the adversities of climate change due to their extensive reliance on rain-fed agriculture as well as their limited capacities to adapt (Mohammed et al., 2021). Efforts to reduce global food insecurity seem to have slowed down and SSA stands out as a region for which progress is slow **(**Burke and Lobell, 2010; IPCC, 2019). In Ghana, about 73% of the population are smallholder farmers whose livelihoods depend on rainfed agriculture (Mohammed et al., 2021; Dapilah and Nielsen, 2019), which makes them vulnerable to extreme weather events like floods and drought. Climate related livelihood disruptions are particularly rife in the semi-arid part of the country which experiences a single maxima rainfall regime with a long annual dry season. Empirical evidence shows that the annual rains are falling over a relatively shorter duration but with increased intensity, thereby producing shorter rainy seasons with relatively violent storms (Asante et al., 2021; Acheampong et al., 2014).

Given that climate change is adversely affecting smallholder farmers' livelihood, the adoption of climate resilient strategies has become a necessary mechanism for subsistence. Smallholder farmers are therefore constantly resorting to various coping and resilience building strategies to reduce food insecurity and famine, and backyard gardening has (re)emerged as one such resilience building strategy.

5.2 Backyard gardening

Backyard gardening with its underlying operations implicitly based on the principles of agroecology, involves the cultivation of crops and, or vegetable on a physically enclosed domestic space, usually for household consumption (Ayambire et. al, 2019). Historically, gardening came into being in response to food insecurity crisis (Okvat and Zautra, 2011). For instance, urban gardens emerged during periods of social and economic crisis to build local resilience (Camps-Calvet, 2015). Similarly, during the Great Depression, during and after World War I and World War II, community gardens were used to increase food supply (Okvat and Zautra, 2011). Recently, due to growing attention towards issues of food security, food justice, and urban sustainability, there has been a renewed interest in urban community gardening and its broader social and environmental benefits including urban resilience (Hou, 2020). The use of different forms of urban gardening to strengthen the resilience of cities has become a topic of global discussion especially in the Global North (see Gulyas and Edmondson, 2021; Langemeyer et. al, 2021; Taguchi and Santini, 2019). More recently, following the emergence of the recent COVID-19 pandemic, there has been a renewed interest in backyard gardens and home-grown foods (Mullins et.al., 2021) as gardening has the potential to mediate the food security challenges that came with lockdowns and related COVID restriction (Lin et al., 2021). However, unlike the role of urban gardening in urban resilience to climate change impacts, little is known about rural backyard gardening and its role in smallholder farmers' resilience to climatic stressors in the Global South. This is particularly the case in most SSA countries like Ghana where the main livelihood source (farming) for a larger proportion of the population is constantly under the threat of climate change and variability.

Resilience building is a priority given the climate induced challenges and stresses facing SSA (Kansiime and Mastenbroek, 2016; IPCC, 2019).

Backyard gardening is broadly practiced for meeting the competitive demand of households' consumption amid food insecurity. In SSA, backyard gardening is seen as a way of meeting the dietary needs of households (Hamad et. al, 2017; Galhena and Maredia, 2013; Subair and Siyana, 2003). In most parts of Ghana for instance, backyard gardening is practiced for the cultivation of vegetables, legumes, and cereals such as maize. Even though backyard gardening exists in both rural and urban settings of Ghana, it rarely receives government recognition as a potential moderator of the impacts of climate change, and therefore rarely spoken about in climate adaptation efforts. Unlike Ghana, Botswana has taken an exemplary step where backyard gardening is seen as a subsistent source of food production that protects the vulnerable in society against food price fluctuations (Moseley, 2016; Raditloaneng and Chawawa, 2015; Fehr and Moseley, 2019). Despite this understanding, in the UWR of Ghana, the association between backyard gardening and resilience to climate change remains unexplored. This paper contributes to the debate by examining the relationship between backyard gardening and farmers' resilience to climatic stressors in the UWR of Ghana.

5.3 The concept of vulnerability and resilience

Vulnerability is the state of being susceptible to harm due to stresses from environmental or social change (Adger, 2006). Within the context of climate change, vulnerability is defined as the function of exposure, sensitivity, adaptive capacity, and the characteristics of a system (Adger, 2006). Vulnerability to climatic stressors often manifest as food insecurity and malnourishment (Williams et. al, 2020). In developing countries like Ghana, smallholders are the most vulnerable to the adversities of climatic stressors largely because of their heavy reliance on rainfed-agriculture, depicting their lack of financial capacity to develop and utilize irrigation schemes for all year-round cultivation. This therefore makes smallholders more susceptible to the impacts of climatic stressors. However, amid such vulnerabilities, activities such as dry season backyard gardening can potentially augment and reinforce smallholder farmers' resilience.

Resilience in the literature of ecology, refers to an ecosystem's ability to withstand disturbances without changing its self-organized structures and processes (Gunderson, 2000). According to Adger, (2000), resilience is "the ability of groups or communities to cope with external stresses and disturbances as a result of social, political and environmental change" (p. 347). Although the concept is widely used in ecology, its meaning and measurement is highly contested (Adger, 2000). Resilience is variedly used in different disciplines within different contexts and has become a well-known research and policy concept in climate change and adaptation (Tanner et. al, 2015). Within the context of climatic stressors, Williams et. al, (2020) conceptualized resilience to mean the capacity to maintain elevated levels of food security during, and after a drought. Resilience is also conceptualized within the context of food security to mean the regular production of sufficient and nutritious food in the face of chronic and acute environmental perturbations such as drought (Bullock et. al, 2017). The concept is increasingly used to inform development initiatives that aim at building the capacity of rural households to cope, adapt, and transform in the midst of climatic shocks (Pelletier et. al, 2016). The application of the concept in human-environment interactions is termed as socio-ecological resilience, which refers to the ability of communities or social groups that depend extensively on ecological and environmental resources for their livelihood, to cope with external stressors (Adger, 2000). The dependence of communities on ecosystems influences their social resilience and ability to cope with external shocks (Marshall, 2010). Affected communities and groups usually exhibit different levels of resilience to environmental shocks. According to Mikulewicz and Taylor, (2020), for African countries to be able to withstand climate change and its impacts, resilience must be strengthened.

5.4 Methods

5.4.1 Data collection

This study used data from a cross-sectional survey with smallholder farmers (n=1100) as part of a Social Science and Humanities Research Council funded project at University of Western Ontario. Data was collected from July to August 2019. The survey covered broader thematic areas of smallholder farmers including their demographics, agricultural production, housing, household assets, household expenditure, gender relations, credit access, adaptive capacity, food security, livelihood activities and climate resilience. A multistage sampling technique was employed. First, purposive sampling technique was used to select study districts (Nadowli-Kaleo, Lawra, and Wa west) in the region. At the District levels, a simple random sampling technique was used to select the study communities/villages in each of the three Districts. In each community, a systematic sampling of every fifth household as a unit, was selected to participate in the survey. This gave all farming households an equal chance of being included in the research survey. Based on the 2010 Ghana population and housing census, the total population sizes of the three selected Districts were as follows: Nadowli-Kaleo (61,561), Lawra (54,889) and Wa West has 81,348 (GSS, 2010). The sample sizes of the selected Districts were arrived at based on their population sizes (Nadowli-Kaleo=367, Lawra=295, and Wa west=438). Ethical clearance for the study was granted by the Non-Ethical Research Board of the University of Western Ontario.

5.4.2 Measures

The dependent variable in this analysis is resilience to climate change. It was derived from a question that asked the primary smallholder farmer in each selected household the question "how would you rate your ability to handle flood/drought/ erratic rain related stress?". Responses were recoded into a binary outcome (0=poor, 1=good). See Appendix C for details on the measurement of climate change resilience. With regards to the main predictor variable (backyard gardening), farmers were asked to indicate whether they were practicing backyard gardening (0=no, 1=yes). Other predictor variables included respondent demographics such as age (0=18-25, 1 = 26-35, 2 = 36-45, 3= 46-59, 4= 60 and above), gender (0= male, 1= female), marital status (0= married, 1= single, 2= widowed/divorced), education (0= no formal education 1= formal education). Household level factors included: wealth (0= richest, 1= richer, 2 = middle, 3= poorer, 4= poorest), household decision making arrangement (0= sole decision, 1= joint decision), and remittances (0= no, 1= Yes). Agricultural related factors included: farm size, source of climate information (1= personal experience, 2= local community, 3 = external experts) source of water for crops (0=rainfed, 1=irrigation), livestock rearing (0=no, 1=yes), type of cropping (0=sole cropping, 1=mixed cropping), whether the farming household switched main crop of cultivation in response to climate variability (0=no, 1=yes), and whether the primary farmer borrowed seeds for cultivation (0=no, 1=yes). Stata version.15 was used for statistical analysis.

5.4.3 Analytical approach

The analysis of data is structured in three parts. First, descriptive analysis was conducted to understand the distribution of the study variables. Secondly, at the bivariate level, a logistic regression analysis was conducted to examine the relationship between the outcome variable and each independent variable. Thirdly, at multivariate logistic regression model was used to examine the association between the focal independent variable (backyard gardening) and the outcome variable (climate resilience), while controlling for individual, household, and farm level factors. Logistic regression was considered because the independent variable (climate resilience) is a binary outcome. The equation for logistic regression model is given below in table:

$$\pi(\mathrm{X}) = \frac{\exp(\beta 0 + \beta 1\mathrm{X}1 + \cdots + \beta k\mathrm{X}k)}{1 + + \exp(\beta 0 + \beta 1\mathrm{X}1 + \cdots + \beta k\mathrm{X}k)}$$

π = probability that an observation is in the category of the dichotomous Y value known as the success,

exp = the exponential function,

β0 = intercept

β1 = the coefficient of first predictor variable

βk = the coefficient of the last predictor variable.

5.5 Results

5.5.1 Descriptive statistics

As shown in table 5 below, 53% of the farmers reported poor resilience and 47% reported good resilience to the impacts of climatic stressors. Also, only 5% of the study participants were engaged in backyard gardening while the greater majority, representing 95%, were not. The survey also constituted 48% and 52% female and male respondents respectively. A noteworthy fact is that a greater proportion of the respondents (67%) had no formal education. Only 17% of respondents reported to have sought for climate information from external experts while 21% and 62% relied on their personal experiences and local community for climate information, respectively.

Table 5: Descriptive statistics for smallholders in semi-arid Northern Ghana

Variable	**Percentage**
Resilience	
Poor	53

Good	47
Backyard gardening	
Yes	5
No	95
Age	
18-25	8
26-35	20
36-45	35
46-59	31
60+	6
Gender	
Male	52
Female	48
Education	
Formal	32.82
No formal	67.18
Marital Status	
Married	82
Single	12
Widowed/Divorced	6
Household decision-making	
Sole decision-making	84
Joint decision-making	16
Household size	7.30(mean)
Wealth	
Richest	19
Richer	17
Middle	22
Poorer	22
Poorest	20
Remittances	
Yes	4
No	96
Farm size	4.91(mean)
Source of climate information	
Personal experience	21
Local community	62
External experts	17

5.5.2 Bivariate results.

The bivariate results are shown in table 6. Farmers who engaged in backyard gardening (OR=10.985: p<0.001) were about 11 times more likely to have good resilience than those who did not engage in backyard gardening. With regards to age, those who were between 46-59 (OR=0.408; p<0.001) were 40% less likely than farmers in the age bracket of 18-25 years to have good resilience. Also, those who were 60+ years (OR=0.354; p<0.01) were 35% less likely to have good resilience compared to those between 18-25 years. Single farmers (OR=2.118; p<0.001) were almost 2 times more likely to have good resilience than married couples, while those who were widowed/divorced (OR=0.540; p<0.05) were 54% less likely to have good resilience. Farmers who had formal education (OR=0.568; p<0.001) were about 57% less likely to have good resilience compared to those without formal education. Farmers belonging to traditional religious groups (OR=3.769; p<0.001) were nearly 4 times more likely to have good resilience. Household with between 8-11 membership (OR=1.689; p<0.01) were about 2 times more likely than household with less than 5 members to have good resilience. Also, households with 12 or more membership (OR=1.983; p<0.01) were about 2 times more likely to have good resilience than household with less than 5 membership. Moreover, households in which joint decision was practiced (OR=1.860; p<0.001), were about 2 times more likely to have good resilience than households that practiced sole decision making. Surprisingly, the poorer (OR=1.633; p<0.05) and poorest (OR=5.576; p<0.001) households were about 2 times and 6 times more likely to have good resilience, respectively. Also, farmers who reared livestock (OR=14.603; p<0.001) were about 14 times more likely than those who did not rear livestock, to have good resilience. Moreover, smallholders who were seed insecure (OR=0.148; p<0.001), were about 15% less likely to have good resilience compared to those who were seed secure or had their own reserved seeds for cultivation.

5.5.3 Multivariate analysis

The results for multivariate analysis are presented in table 6. At the multivariate level, all the relevant covariates were analyzed against resilience as the outcome variable using logistic regression model. Consistent with results at the bivariate level, farmers who practiced backyard gardening (OR=9.105; $p<0.001$) were about 9 times more likely to have good resilience than those who were not engaged in backyard gardening. Apart from backyard gardening, other covariates significantly predicted farmers' resilience to climatic stressors. With regards to religious affiliations, traditional religious believers (OR=2.967; $p<0.01$) were about 3 times more likely to have good resilience than those who identified as Christians. Also, households that practiced joint agricultural related decision-making (OR=1.680; $p<0.05$) were 1.6 times more likely to have good resilience than those that practiced unilateral decision-making. Surprisingly, but consistent with results at the bivariate level, the poorer (OR=1.870; $p<0.01$) and poorest (OR=4.639; $p<0.001$) households were 1.8 times and 4.6 times more likely to have good resilience than households in higher wealth quantiles, respectively. Farmers with an average farm size of 4.9 acres in the study context (OR=0.855; $p<0.01$), were 85% less likely to have good resilience compared to those with relatively larger farm sizes. Livestock rearing served as a buffer to climatic stressors, such that those who reared livestock (OR=9.928; $p<0.01$), were almost 10 times more likely to have good resilience than those who were not into livestock rearing. Smallholders who practiced sole cropping (OR=0.716; $p<0.05$), were 71% less likely to have good resilience compared to those who practiced mixed cropping. Moreover, farmers who reported changing the main crops they cultivated to drought tolerant varieties in response to changing climatic conditions (OR=2.056; $p<0.05$), were 2 times more likely to have good resilience than those who did not. Smallholders who borrowed seeds from other farmers for planting (OR=0.210; $p<0.001$), were 21% less likely to have good resilience compared to those who were seed secure. Generally, results from both the bivariate and multivariate analysis are indicative that backyard gardening has the potentials of building smallholder farmers' resilience to climatic stressors in Semi-arid northern Ghana.

Table 6: The association between backyard gardening and resilience

Variable	**Model 1 (Bivariate)**		**Model2 (Multivariate)**	
	OR(SE)	**CI(95%)**	OR(SE)	**CI(95%)**
Backyard Garden (Ref:No)				
Yes	10.985(4.781)***	4.681 25.778	9.105 (4.400)***	3.531 23.476
Gender (Ref:Male)				
Female	0.978 (0.118)	0.772 1.240	0.888 (0.140)	0.653 1.209
Age (Ref:18-25)				
26-35	0.607 (0.152)*	0.372 0.992	0.816 (0.259)	0.438 1.519
36-45	0.811 (0.190)	0.513 1.283	0.725 (0.245)	0.374 1.406
46-59	0.408(0.097)***	0.256 0.652	0.354(0.124)	0.178 0.702
60 and above	0.354 (0.116)**	0.186 0.673	0.448 (0.195)	0.1907 1.053
Marital status (ref:married)				
Single	2.118(0.415)***	1.442 3.109	2.305 (0.626)**	1.354 3.924
Widowed/Divorced	0.540(0.150)*	0.313 0.931	0.907 (0.310)	0.464 1.772
Education (Ref: No formal)				
Formal	0.568(0.075)	0.439 0.735	0.568 (0.105)	0.396 0.816
Religion (Ref: Christian)				
Muslem	1.35 (0.225)	0.974 1.873	1.319 (0.265)	0.889 1.955
Traditional/other	3.769(0.613)***	2.740 5.184	2.967 (0.650)***	1.931 4.558
Household size (Ref: one-four)				
Five-seven	1.235(0.221)	0.869 1.754	1.170 (0.254)	0.764 1.792
Eight-eleven	1.689 (0.237)**	1.156 2.468	1.196 (0.297)	0.735 1.945
Twelve and above	1.983 (0.470)**	1.246 3.156	1.175 (0.407)	0.596 2.316
Household decision making (Ref:Sole)				
Joint	1.860(0.311)***	1.341 2.580	1.680 (0.345)*	1.124 2.512
Wealth (Ref: Richest)				

Richer	0.951 (0.200)	0.631	1.435	1.089 (0.257)	0.685	1.729
Middle	1.066 (0.208)	0.727	1.563	1.098 (0.249)	0.705	1.711
poorer	1.633 (0.317)*	1.116	2.390	1.870(0.439)**	1.181	2.961
poorest	5.576(0.199)***	3.659	8.498	4.639 (1.313)***	2.664	8.079
Remittances (Ref: No)						
Yes	0.798 (0.239)	0.444	1.434	1.110 (0.411)	0.613	2.347
Farm size	0.956 (0.024)	0.911	1.004	0.855 (0.033)***	0.792	0.922
Source of water for crop (Ref: Rainfed)						
Irrigation	0.405 (0.238)	0.128	1.281	0.892 (0.577)	0.251	3.171
Livestock rearing (Ref: No)						
Yes	14.603(4.924)***	7.541	28.279	9.928 (3.916)***	4.582	21.510
Cropping type (Ref:Mixed)						
Sole cropping	1.137 (0.138)	0.896	1.443	0.716 (0.123)*	0.511	1.004
Changed main crop (Ref: No)						
Yes	1.643 (0.478)	0.928	2.907	2.056(0.701)*	1.053	4.012
Borrowed seeds (Ref: No)						
Yes	0.148(0.044)***	0.084	0.265	0.210 (0.069)***	0.111	0.400

*p<0 .05,**p<0.01,***p<0.001,OR=Odds Ratio, SE = Standard Error, CI = Confident Interval

5.6 Discussion

The findings in this study show that smallholders who were engaged in backyard gardening, exhibited higher level of good resilience to climatic stressors when compared to those who did not practice backyard gardening. Gardening has the potential of building the adaptive capacity of individual farmers and community resilience at large to climatic stressors (Nursey-Bray e. al, 2015; Ayambire et. al, 2019). Studies among smallholder farmers have indicated food insecurity as one of the immediate impacts of climate change (Atuoye et al., 2017), and the findings here show that backyard gardening, especially during the dry season, has the potential of providing all year-round access to food for households. This finding is consistent with earlier studies that reported backyard gardening as a potential medium of meeting the daily household nutritional needs (Lal, 2020; Musotsi et. al, 2008). More so, during critical periods such as the COVID-19 pandemic that disrupted the global food systems (Chenarides et.al., 2021), gardening emerged as having the potential of simultaneously mediating the impacts of food shortages and protecting consumers from hiking food prices (Lin et al., 2021; Mullins et al., 2021). The advantage of backyard gardening is that during periods of insufficient rainfall, backyard gardeners can use little water to keep plants alive. However, same cannot apply to the relatively long-distance farms partly because they are much bigger on acreage. Besides, backyard gardening in the study context and within similar contexts across the SSA region is inherently agroecological in nature and therefore relatively cost-effective. For instance, poor smallholders tend to employ agroecological practices such as green mulching, soil moisture conservation through tillage, and animal droppings from home. Such practices do not only promote crop growth and yield but are also enviro-friendly and should be promoted among smallholders.

Consistent with other studies, farmers that practiced joint decision-making were more resilient to climatic stressors than those that practiced sole decision making. For instance, Batung et. al, (2021) argued that in typical traditional households where decision making is the prerogative of only the male household heads, problem solving may not harness the valuable ideas of all household members. Decision making may not also receive immediate support of other household members. However, joint decision making facilitates cooperative problem solving and can therefore significantly improve household resilience. When household problems are approached collectively, there exist a sense of ownership and increased willingness among members of the household to see to the effective and timely implementation of such decisions (Batung et. al, 2021). Household members are then also able to implement necessary initiatives. For instance, in semi-arid northern Ghana where worsening climatic conditions exist, farming operations like land preparation, are largely labor intensive and must be conducted timely to maximize the benefits of early rains and avoid crop failure. A sense of collective ownership can facilitate household members working together to promptly execute such farming operations to maximize benefits and simultaneously reduce potential risk of crop failure. Joint decision can also result in household members bringing resources together to address the prevailing challenges presented by climate variability.

With regards to household wealth, the poorer and poorest farmers surprisingly exhibited more likelihood of good resilience. Strange as it may appear, poor households may be relying on deep-seated traditional ecological knowledge that mediates their understanding of environmental changes, thereby facilitating their capability to be proactive in response to climatic shocks based on accumulated knowledge. Influential members of poor households could also provide them with the financial support needed during periods of climatic stressors to boost their resilience (Mohammed et al., 2021). Invariably, smallholders who practiced traditional religion were significantly more resilient to climatic stressors. This finding was also consistent with the results of other studies. According to Mohammed et al., (2021), aside making use of the rich traditional knowledge and belief systems that are well adapted to the local environment, traditional religious believers and societies also benefit from social norms like labor sharing that promote climate adaptation. In typical traditional societies of semi-arid northern Ghana, communal labor is offered during periods of land preparation, seed sowing, weed removal, and harvesting. For instance, a poor or sick member of a typical traditional community can leverage on the social capital of communal labor for harvesting and transportation to prevent the spoilage of produce from impacts of climatic stressors (e.g., erratic rainfalls and floods). This is a common and effective way of escaping the severity of impacts of climatic stressors in the study context.

The higher likelihood of good resilience associate with livestock rearing is perhaps because livestock provides an extra source of income that can mediate farmers' vulnerability to the adverse impacts of climatic stressors. The sale of livestock during drought is an effective strategy among rural dwellers as it moderates the severity of impacts and increases the resilience of rural farmers to climatic shocks (Keshavarz and Moqadas, 2021; Asare-Nuamah et al., 2021). To this effect, IPCC (2019) highlighted livestock rearing as an option for enhancing the adaptive capacity and resilience of rural communities, particularly, smallholders and pastoralists, to the impacts of climate change and variability. Another interesting finding is that farm size was significantly associated with farmers' resilience. Smallholders that cultivated an average land size of 4.9 acres in the study context, were found to be less resilient to climatic stressors. In similar studies, it is argued that during climatic stressors like drought, the size of farm is a significant factor because a unit increase in farm size amount to a potential increase in returns, given that larger farm sizes are more likely to be diversified to spread the risks presented by climate variability (Gebrehiwot and Van Der Veen, 2013; Olanipekun and Kuponiyi, 2010).

Also, practicing mixed cropping have a positive influence o farmer resilience to climatic stressors. There are complementary benefits that come with mixed cropping. For instance, empirical studies shows that mixed cropping improves soil fertility through nitrogen fixation (Eichler-Löbermann et al., (2020); Okereke and Ayama, 1992), and by extension promote crop growth and yield. Given the benefits that accompany mixed cropping, farmers that practice mixed cropping stand the chance to reduce the risk of crop failure through soil moisture retention and nutrient generation. More so, smallholders who changed their major crop of cultivation to drought tolerant varieties as a response to the changing climatic conditions, were found to be more resilient to the impacts of climatic stressors. Given the ever-changing pattern of climatic variables (e.g., rainfall and temperature), farmers are changing the crops they cultivate to crops that thrive under the prevailing climatic conditions (Bawayelaazaa et. Al, 2016). Depending on the climatic conditions of an area, farmers may switch their major crops of cultivation to meet their household food needs, and by so doing, reduce the risk of poor harvest. Due to the worsening weather conditions in semi-arid northern Ghana, coupled with poor smallholders' inability to afford irrigation, the use of drought tolerant crops is a crucial mechanism for reducing the risk of crop failure from fluctuating rainfalls and the increasing trend of atmospheric temperatures in the area.

Expectedly, seed insecurity and seed borrowing were associated with poor resilience to climatic stressors. Seed borrowing and, or seed sharing, is still a common practice among smallholders in rural Ghana where farmers tend to rely on other farmers and relatives to have access to seeds for planting. This practice is indicative of the prevalence of seed insecurity among poor smallholders particularly in semi-arid northern Ghana. However, seed security is fundamental to achieving higher productivity, food security, and for building good resilience among smallholders (Madin, 2020; Katrin and Yuan, 2016). In Ghana, the informal seed sector is the dominant system, serving the majority (80%) of farmers across all major food crops (USDA, 2020). Within this informal seed sector, farmers produce, save, maintain, market, and distribute or share seeds amongst themselves from one growing season to the next (Ghana Brief, 2017). Majority of smallholder farmers in Ghana rely on this system due to several factors including limited exposure or non-proximity to improved seed varieties, limited access to agro-dealers, and farmers' inability to purchased improved varieties. Consequently, smallholders tend to select and preserve the best varieties of seeds from their harvest in preparation for the next planting season.

Hence, smallholders who are seed secure, tend to hold onto the best selected seed varieties, and may only share or sell the less climate resilient varieties to others.

Though this study portrays the potential of backyard gardening in building farmers' resilience to the impacts of climatic stressors, interpretation of the findings should be done with consideration to some noteworthy limitations. A major limitation is that the survey data used in this analysis is a cross-sectional data which limits the findings to statistical association. Future research could benefit from longitudinal studies. Regardless of such limitations, this study makes a major contribution to the literature on the role of backyard gardening in moderating the severity of impacts of climatic stressors among vulnerable smallholder farmers in semi-arid northern Ghana, specifically the Upper West Region.

5.7 Conclusions and recommendations

Based on the findings, agricultural development agencies (both governmental and non-governmental) need to incorporate traditional complementary farming practices like backyard gardening into climate change adaptation policies. The promotion of dry season backyard gardening in the study context may enhance food security in smallholder farming households, and simultaneously protect them against the fluctuating prices of food items in the market. Ghana and other Sub-Saharan African countries should follow the example of Botswana where gardening projects are initiated as a pro-poor activity to reduce the vulnerability of poor farmers to climate change impacts. The availability of irrigation for dry season gardening will reduce reliance on rain-fed agriculture, improve household food security, and alleviate poverty (Fagariba et. Al, 2018). To create an enabling environment for dry season gardening, and to build smallholders' resilience to climatic stressors like drought, it is imperative upon governments to carry out nationwide irrigation projects. Overall, amid climate change and variability, effective backyard gardening programs may play a crucial role in enhancing the livelihood of poor and vulnerable smallholder farmers in the study context, and in similar contexts across SSA.

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Chapter 6

6.0 CONCLUSIONS

6.1 Introduction

This thesis explored two complementary topics within the context of food security and climate change resilience among smallholder farmers in the Upper West Region (UWR) of Ghana. First, it explored the determinants of post-harvest loss (PHL) within the context of food security in UWR. Secondly, it explored the association between backyard gardening and smallholder farmers' resilience to climatic stressors in the region. Chapter 6 thus summarizes the main findings of this thesis. It also presents the contribution of this thesis to the existing literature on PHL, and climate change resilience through backyard gardening. The policy implications of the findings are further summarized in this chapter. Also, the chapter presents the limitations of the thesis as well as directions for future research.

6.2 Summary of findings

6.2.1 Objective one: Determinants of post-harvest loss

Results from the multivariate analysis showed that some demographic characteristics (gender of primary farmer, household size, and marital status) and socio-economic conditions (household decision-making arrangement, wealth, livestock rearing, financial remittances, etc.) were significant determinants of post-harvest loss among smallholder farmers. Given that agriculture in Ghana is predominantly rain-fed and labor intensive, to a larger extend the socio-economic conditions of smallholder farmers shape their PHL outcomes and food security concerns amid climate variability. The findings of this study highlight the urgent need for agricultural policies to target and address the socio-economic barriers that smallholders face in PHL prevention and management processes. This is crucial for PHL prevention, and for improving food security among smallholder farmers in the study context, and similar contexts across SSA.

6.2.2 Objective two: Association between the practice of backyard gardening and smallholder farmers' resilience to climatic stressors

In semi-arid northern Ghana, the prevalence of climatic stressors (e.g., erratic rainfalls, drought, severe windstorms etc.) threatens the major livelihood (agriculture) of smallholders. Consequently, poor farmers in most part of Semi-arid Northern Ghana are at the risk of experiencing crop failure and food insecurity. As a result, though rarely given any government or policy intervention, a cross section of smallholder farmers are actively engaged in backyard gardening as a supplementary farming practice to spread the risk associated with increasing climatic stressors. In order to understand the role of backyard gardening in climate change resilience, I examined the association between backyard gardening and smallholder farmers' resilience to climatic stressors in the UWR of Ghana. Backyard gardening is the key predictor variable and climate resilience is the outcome variable. Given that climate resilience was a binary outcome, I used a logistic regression model to examine the association between the predictors and the outcome variable. The results showed that smallholders who were engaged in backyard gardening, had good resilience than those who were not engaged in backyard gardening. Details of the findings are in chapter five. Consistent with other studies (Camps-Calvet, 2015; Okvat and Zautra, 2011) backyard gardening has the potential of promoting community resilience during crises. In fact, it is also considered a pro-poor activity with the potential of alleviating poverty and promoting food security (Moseley, 2016; Raditloaneng and Chawawa, 2015; Fehr and Moseley, 2019). With the ongoing climatic stressors, complementary farming activities like backyard gardening has the potential of not only spreading the associated risks, but also building poor smallholder farmers' resilience to such stressors. Hence, policies that create opportunity for all-year round backyard gardening will go a long way to reduce smallholder farmers' vulnerability to climatic stressors like drought, and by extension improve food security in smallholder farming households.

6.3 Synergies between the two manuscripts

Within the context of food security and climate change, the two manuscripts examined a twin challenge of post-harvest food loss and climate resilience among smallholder farmers. The first manuscript (Chapter 4) examined the determinants of post-harvest loss (PHL) within the context of food insecurity. The chapter illustrated that amid the devastating impacts of climate variability in Northern Ghana, a region that has been hit hardest by both colonial and current political neglect in terms of development policies, addressing the PHL challenges (e.g., lack of agricultural credits for post-harvest management) of smallholder farmers will go a long way to reduce food insecurity in most smallholder households and build their resilience to climate change. The second manuscript (chapter 5) examined a related challenge within the context of climate change. The association between backyard gardening and climatic resilience as examined in chapter 5, aligns the need to find climate resilience strategies in the study context. In an enabling policy environment (e.g., organized irrigation schemes), farming practices like dry season backyard gardening can reduce the vulnerability of smallholders to the impacts of climatic stressors (e.g., drought and erratic rainfalls). Within the context of climate change and food insecurity in northern Ghana, collectively, the two manuscripts explored smallholder farmers' resilience to climatic stressors and the prospects for PHL prevention, both of which are relevant for attaining food security.

6.4 Contributions of the study

This study contributes to the literature on post-harvest loss (PHL), and backyard gardening as a climate change resilience strategy in the smallholder farming contexts. It demonstrates the need for agricultural policy intervention to address the challenges of impoverished farmers in their PHL prevention efforts. This study extends the literature by demonstrating that the socio-economic conditions of smallholder farmers are significant determinants of their PHL outcomes. The findings of this study suggests that by addressing the underlying challenges of smallholder farmers in the study context, they stand the chance of significantly reducing PHL, relevant for ensuring food security in northern Ghana and SSA at large. Given that post-harvest handlings are to a larger extent conducted manually in Semi-arid Northern Gnana due to farmers' inability to adopt modern mechanized technologies, I argue that PHL can be significantly reduced by tackling the socio-economic challenges of smallholders in post-harvest management processes. For example, the creation of affordable credit facilities in smallholder farming communities will increase smallholder farmers' ability to afford necessary equipment for effective post-harvest handlings, processing, and storage.

Also, this study is a contribution to the broader literature on resilience to climatic stressors in the study context and in similar contexts across SSA. Existing works on gardening as a supplementary food source and climate resilience strategy have mostly focused on urban settings (see Mullins et al., 2021; Lin et al., 2021; Lal, 2020; Fehr and Moseley, 2019; Nursey-Bray et al., 2015; Galhena et. al, 2013; Okvat and Zautra, 2011; Musotsi et.al., 2008). This study expands the literature by taking into consideration the smallholder context in rural agricultural settings. This is crucial because nearly 3.4 billion people resides in rural areas across the globe, of which many are smallholders, and highly vulnerable to climate change impacts (IPCC, 2022). Besides, knowledge on the association between backyard gardening and smallholder farmers' resilience to climatic stressors could inform policy decisions that can positively reinforce climate resilience among smallholders. Therefore, I argue that with appropriate policies, backyard gardening can mediate the impacts of climatic stressors on smallholder farmers in the study context and similar contexts across SSA. Given that backyard gardening is a pro-poor activity that enable smallholder farming households to mee their food requirement (Moseley, 2016; Raditloaneng and Chawawa, 2015; Fehr and Moseley, 2019), policies that promote dry season backyard gardening among smallholder farmers, will go a long way to increase their resilience to the impacts of climatic stressors on their livelihoods. Overall, this study provides a major contribution to literature on post-harvest loss, and resilience to climatic stressors through backyard gardening in the smallholder context.

6.5 Policy recommendations

In semi-arid northern Ghana, specifically the in Upper West Region (UWR) and similar contexts across SSA, the effectiveness of post-harvest management depends largely on the socio-economic conditions of smallholder farmers. Therefore, policies must take into consideration the underlying social-cultural factors (e.g., household agricultural decision-making arrangement) and economic conditions (e.g., household wealth, access to agricultural credit etc.) of smallholder farmers in order to fully target and address their pressing challenges in an effective and holistic manner. For instance, agricultural policies should take into consideration the creation of affordable credit facilities in smallholder farming communities to promote effective post-harvest handling and storage among farmers for loss reduction. Also, given that joint decision-making and gender (the female primary farmer) were significantly associated with lower likelihood of PHL in the study context, policies ought to promote joint agricultural decision-making in farming households, as well as the creation of participatory learning spaces for gendered knowledge transfer on post-harvest management. Agricultural responsibilities in Northern Ghana are highly gendered with women mostly responsible for post-harvest management (e.g., winnowing, shelling, drying etc.), hence empowerment of the female gender is crucial in this context for PHL prevention. Moreover, in the study context and similar patriarchal contexts in Ghana, women have unequal access to productive resources like land and agricultural credit. Therefore, existing policies such as the Livelihood Empowerment Against Poverty (LEAP) program in Ghana, should give priority to marginalized groups like female primary farmers in the study context. Training programs could also be organized periodically educate farmers on best practices in post-harvest handling. These are areas of critical concern that need urgent policy intervention in the study context. Such policies will be crucial in finding a long-lasting solution to post-harvest food loss and food insecurity in smallholder communities in SSA at large.

Also, the findings from this study suggest that traditional adaptation strategies like backyard gardening should be integrated into policies and programs that aim at building smallholder farmers' resilience to climatic stressors. Due to financial limitations, most farmers in smallholder farming communities of Northern Ghana and similar contexts across SSA are unable to afford irrigation and other necessary agricultural inputs to offset the impacts of climatic stressors like drought. Therefore, in the Ghanaian context, existing policies like the 'one village one dam' policy initiative which is intended to promote dry season farming in the country, though a political party's manifesto project, should be adopted as a national policy. Solar powered drip-irrigation schemes could be incorporated into the program to harness its fullest potential in enhancing dry season backyard gardening in Semi-arid Northern Ghana in particular. Drip-irrigations are cost effective and have a proven potential to increase food supply and sustain the livelihood of smallholder farmers in SSA (Assefa et. al., 2019). Given that the UWR and other parts of Northern

Ghana are characterized with a single maxima rainy season and semi-arid conditions, the promotion of dry season gardening in the area is crucial for improving food security in smallholder farming households. Besides, backyard gardening in the study area is based on indigenous knowledge systems and farm management practices (e.g., use of green manure, animals' droppings, compost, soil moisture conservation techniques, mulching, etc.) which are environmentally friendly and should be encouraged.

Climate change and food policies have over the years been mainly focused on technology adoption and improved modern farming practices without taking into consideration the poor financial conditions of majority of farmers in SSA countries like Ghana. I therefore suggest that focus should be shifted towards addressing the socio-economic constraints (e.g., lack of access to affordable credit facilities) of smallholder farmers in their PHL prevention efforts. Also, context specific climate resilience strategies such as backyard gardening should be integrated into national climate change policies.

6.6 Study limitations

Despite the contributions of the study as highlighted above, there exist some noteworthy limitations. First, that this study used a cross-sectional survey which makes it impossible to establish a cause-effect relationship. The methods used thus limit the findings to statistical associations. Also, the study relied on a self-reported measures to capture post-harvest loss, and climate change resilience. With self-reported measures, there exist the likelihood of response biases. For instance, the question on post-harvest loss was constructed on a continuous scale that allowed respondents to provide estimates of losses recorded, hence the likelihood of both underestimation and overestimation. Also, the survey could not capture the intra-household differences in perceptions regarding climate change resilience given that survey questions were administered to only the primary farmers in the farming households. It is therefore important to note that the perceptions of primary farmers may not be an accurate representation of individual household members' perceived resilience.

Notwithstanding the afore highlighted limitations, findings from the study offers a significant insight on the determinants of post-harvest loss, and backyard gardening as a climate change resilience strategy in the smallholder context. The statistical associations that were found between various variables offer insights on; (i) the socio-economic determinants of post-harvest food loss among smallholder farmers; and (ii) how backyard gardening affects smallholder farmers' resilience to the impacts of climatic stressors. Findings from this thesis thus remain relevant for policy directions in smallholder contexts in northern Ghana and across similar contexts in SSA at large.

6.7 Implication for future research

Given the inherent limitations of this study, I propose some opportunities and directions for future research. This study utilized quantitative methods to examine the determinants of post-harvest loss among smallholder farmers, as well as the association between backyard gardening and smallholder farmers' resilience to the impacts of climatic stressors. The use of the household as the unit of analysis limits the understanding of individual household members' perceptions and experiences of post-harvest loss, and resilience climatic stressors. Hence, qualitative methods could be used in future research to unearth the in-depths and potential differences in perceptions and experiences of individuals involved in harvesting, to fully understand the issues that may need policy attention. More so, the use of a cross-sectional survey limits the findings to statistical association. Therefore, future research may employ a longitudinal study design to facilitate a better understanding on the determinants of post-harvest loss among smallholder farmers, as well as how backyard gardening affects farmers' resilience to climate change impacts.

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Appendices

Appendix A: Research Ethic Approval: Farmer Livelihoods and Agricultural Production (FLAP)

Western Research

Date: 2 July 2019

To: Dr. Isaac Luginaah

Project ID: 114075

Study Title: Using participatory scenario planning to understand community seed systems resilience to climate change in Ghana and Malawi Region

Short Title: Climate change and seed security in Ghana and Malawi

Application Type: NMREB Initial Application

Review Type: Delegated

Full Board Reporting Date: August 2 2019

Date Approval Issued: 02/Jul/2019

REB Approval Expiry Date: 02/Jul/2020

Dear Dr. Isaac Luginaah

The Western University Non-Medical Research Ethics Board (NMREB) has reviewed and approved the WREM application form for the above mentioned study, as of the date noted above. NMREB approval for this study remains valid until the expiry date noted above, conditional to timely submission and acceptance of NMREB Continuing Ethics Review.

This research study is to be conducted by the investigator noted above. All other required institutional approvals must also be obtained prior to the conduct of the study.

Documents Approved:

Document Name	Document Type	Document Date	Document Version
FLAP Survey Ghana June 13, 2019	Online Survey	13/Jun/2019	2
FLAP Survey Malawi June 13 2019	Online Survey	13/Jun/2019	1
Focus Group Letter of Information and Consent Ghana June 25 2019	Verbal Consent/Assent	25/Jun/2019	2
Focus Group Letter of Information and Consent Malawi June 25 2019	Verbal Consent/Assent	25/Jun/2019	1
Ghana Participatory Scenario Planning Activities May 24 2019	Focus Group(s) Guide	24/May/2019	1
Letter of Invitation Farmers Ghana June 25 2019	Recruitment Materials	25/Jun/2019	2
Letter of Invitation Farmers Malawi June 25 2019	Recruitment Materials	25/Jun/2019	2
Malawi Participatory Scenario Planning Activities June 25 2019	Focus Group(s) Guide	25/Jun/2019	1
PSP Participants Characteristics Data Collection Sheet Ghana Malawi June 25 2019	Other Data Collection Instruments	25/Jun/2019	1
RA_Confidentiality Agreement Ghana and Malawi - June 25 2019	Verbal Consent/Assent	25/Jun/2019	2
Recruitment Letter of Invitation Focus Groups Ghana June 25 2019	Recruitment Materials	25/Jun/2019	2
Recruitment Letter of Invitation Focus Groups Malawi June 25 2019	Recruitment Materials	25/Jun/2019	2
Verbal Letter of Information and concent Farmers Ghana June 25, 2019	Verbal Consent/Assent	25/Jun/2019	2
Verbal Letter of Information and consent Farmers Malawi June 25 2019-1	Verbal Consent/Assent	25/Jun/2019	1
Written Letter of Information and concent Farmers Ghana June 25, 2019	Written Consent/Assent	25/Jun/2019	1

Written Letter of Information and consent Farmers Malawi June 25 2019	Written Consent/Assent	25/Jun/2019	1

No deviations from, or changes to the protocol should be initiated without prior written approval from the NMREB, except when necessary to eliminate immediate hazard(s) to study participants or when the change(s) involves only administrative or logistical aspects of the trial.

The Western University NMREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the Ontario Personal Health Information Protection Act (PHIPA, 2004), and the applicable laws and regulations of Ontario. Members of the NMREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB. The NMREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000941.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Kelly Patterson, Research Ethics Officer on behalf of Dr. Randal Graham, NMREB Chair

Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).

Appendix B: Survey topics and number of item/questions

Survey Topic	Number of Questions (Sub-questions)
Background information	10
Household demographics	10
Agricultural production and practices	45
Household food security	1(14)
Household expenditure	1(10)
Livestock	2 (6)
Livelihood activities and other income	3
Access to credit	5
Household assets	1
Housing and amenities	6
Household gender relations	17
Adaptative capacity and resilience	5

Source: FlAP survey, Upper West Region 2019

Appendix C: Survey Instrument

A FARMER LIVELIHOOD AND AGRICULTURAL PRODUCTION (FLAP) SURVEY

INTRODUCTION

Informed Consent. ENUMERATOR, PLEASE READ THE FOLLOWING TO THE RESPONDENT

My name is _____. I am working for the Department of Geography at the Western University in Canada and University of Denver and Cornel University in the United States of America. We would like to understand more about your family and farming practices. I would like to ask you if I might interview you, and I'd like to explain more about what will be involved. Please feel free to ask any questions at any time. The results from this study will be used to inform future initiatives aimed at improving farmers' food security and agrobiodiversity.

If you agree to participate in this part of this study, we want to learn from your knowledge and how you are farming. We will be spending about an hour asking you questions about your cropping practices, your diet and other information that affects your family's food security. There is no right or wrong answer to our questions. If you feel uncomfortable at any moment or would prefer that I not participate/observe certain activities, you can refuse my presence at any time.

There is no direct benefit to you for participating in this part of research; however, it will help you to get to know us and become familiar with our study and provide an opportunity for you to express any concerns that you have regarding your life as a farmer. Additionally, the knowledge gained in this study will benefit your community indirectly. We will share what we learn from your farming practices with local, national and international institutions such that it can be used to inform initiatives for improving food security for smallholder farmers. You will not incur any costs by participating in part of the study other than about an hour spent discussing things with us. You will not receive any payment for this time.

Your participation in this study is completely voluntary and you may refuse to participate or leave the study at any time. Your name will only be recorded to document that you have agreed to participate in this research. It will not be put in any of the project documents to be prepared from this research. Only the research team will have access to the data provided and records will be kept safely in a locked cabinet to which only the research team will have a key, to ensure no one apart from the study investigators can have access to them. The survey will take about an hour.

Do you agree to continue with the survey? ☐ YES ☐ NO

You are encouraged to ask me questions at any time during or after this study, Thank you for all your help and cooperation with this study.

1.1 Name of Enumerator: ______________________________

1.2 Date of assessment: ______________________________

1.3 Village name ______________________________

BACKGROUND INFORMATION

Respondent Information

1.1 . Respondent number:

1.2 . Age: ____________ (years)

1.3 Gender (Sex): ☐ Male (1) ☐ Female (0)

1.4 Relationship: ☐ Household head (1) ☐ Spouse (2) ☐ Son/daughter (3) ☐ Other living in HH (4)

1.5 Education ☐ No formal (1) ☐ Primary school (2) ☐ Secondary (3) Tertiary (4) ☐

1.6 Marital status ☐ Single (1) ☐ Married (2) ☐ Divorced (3) Widowed (4). ☐

1.7 . If married, what is your marital structure ☐ Monogamous ☐ Polygamous

1.8 . Religion ☐ Christian (1) ☐ Muslim (2) ☐ African Traditional Other ☐ (4)…………………

1.9 . Ethnicity ☐ Dagao (1) ☐ Sisaala (2)

Household Demographics

1.10Which of the following best describes the structure of your household?

a	Female centered (No husband/male partner in household, may include relatives, children and friends)	
b	Male centered (No wife/female partner in household, may include relatives, children and friends)	
c	Nuclear (Husband/male partner and wife/female partner with or without children)	
d	Extended (Husband/male partner and wife/female partner with or without children and relatives	
e	Child centered (Child-centered)	
f	Other	

1.11Gender of household Head (HH).

☐ Male (1) ☐ Female (0)

1.12. Residential status of the household (HH). To be revised or omitted if there is no distinct category

☐ Resident (1) ☐ Returnee (2) ☐ Refugee (3)

1.13 For how long have you continually lived in this area?________(years)

1.14 Household size: How many people live in this household? Specify the number under each age group below

Age group→	< 5 years	5-17 years	18-35 years	36-60 years	>60 years

1.15. How many household members are involved in Agricultural activities?

Module A: AGRICULTURAL PRODUCTION AND PRACTICES

The next questions ask about the land your household uses for agriculture. I mean all the land that your household used for agriculture in all the agricultural seasons in which your household planted crops during the **[season].**

Crop Production/ Seed System Profile

A.1 What crops did you plant last season? (Retain/add/remove crop(s) based on most likely one to be found in the target areas. Modify the codes as well)

Cereals	☐ Sorghum =1	Maize=2	Rice=3	
	☐ Finger millet =4	☐ millet =5 (pearl)	☐ Wheat=6	☐ Teff = 7
Oilseed	☐ Groundnut=8	☐ Sesame=9	☐ Sunflower =10	
	☐ French beans = 14	☐ Pigeon peas = 15	☐ Soya = 16	☐ Dolicos = 17
RTB	☐ Cassava=18	☐ Sweet potato=19	☐ Potato=20	
	☐ Cocoyam = 21	☐ Yams = 22	☐ Banana =23	
Vegetables	☐ Local	☐ exotic		

A2. Should be asked only if the household indicated that they planted vegetable:

A.2a for what Main purpose do you cultivate vegetables?

☐ Domestic (1) ☐ Commercial (0)

A.2b. If commercial, who decides on how the money is used?

Men (1) ☐ Women (2) ☐ Both (3)

A.3 Name the three most important crops you cultivate

1)

2)

3)

A.4 Did you change the main crop you used to produce in the last few years?

A.5 Main reason for change of area if yes (see codes below): For statistical analysis, var can be grouped into structural: logistics, environmental …

1 = Lack of land;

2 = Access to more land; 3 = Lack of labor force

4 = Access to more labor force; 5=Lack of seed

6=Better access to seeds

7=Free seed

8=Increase in seed prices

9=Decrease in seed prices

10=Decrease of produce price

11=Guaranteed selling price produce

12=Secure market

13=Increased need at household level

14 = Lack of tools and equipment

15= Replanting of seed

Crop production parameters				
		a	b	

A6	What is the total amount of land your household owns?	Quantity | | | |. | | |	Units | |	**B1b: Units codes** 1 = hectares 2 = acres -8 = Not applicable
A7	During the **[season]** , how much land did your household use for agriculture (including land that is owned, rented/leased in, and borrowed, i.e., used without payment)?	Quantity | | | |. | | |	Units | |	

A8.	Was the land your household used for agriculture during the **[season]** more, less, or about the same as the amount of land your household used for agriculture during the **[previous season]**? **(If "More", go to question B3) (If "Less", go to question B4)** **(If "About the same", go to question B5)**	| |	1 = More 2 = About the same 3 = Less

		a	b
A9.	What were the two most important reasons you used more land? **(Go to question B5)**		

		a	b
A10.	What were the two most important reasons you used less land?		

B3a /b: Codes for planting more land	**B4a /b: Codes for planting less land**
1 = Wanted to increase production because of increased need (e.g., for increased	1 = Reduced production because of reduced need (i.e., smaller household, lower

household consumption increased expenses/income, etc.)

2 = Wanted to increase production to meet new demand (for existing or new crops)

3 = Had more own capital (not borrowed) to

were less expensive or more subsidized

9 = Higher prices for crops encouraged you to plant more

10 = More of the land you use for agriculture was useable (less damage from floods/weeds,

land, buy inputs, buy/rent equipment or drought power, etc)

5 = Had access to more land that you didn't have to pay for

6 = Had access to more labor you didn't have to pay for

7 = Had access to more drought power you did not have to pay for

8 = Could afford more inputs because they

expenses/income, etc.)

2 = Reduced production because you lost markets

3 = Had less own capital (not borrowed) to invest in agriculture (hire labor, rent/buy land, buy inputs, etc)

4 = Had access to less credit (cash or in-kind) to invest in agriculture (hire labor, rent/buy land, buy inputs, etc.)

5 = Did not have access to as much land that you didn't have to pay for

6 = Less household labor available (due to illness, smaller household, etc.)

7 = La ck of access to as much drought power that you did not have to pay for

8 = Could not afford as many inputs because of higher prices or lower subsidies

9= Lower prices for crops discouraged you from planting as much

10 = Land became unusable

(Flood/drought/Invasive weeds, etc.) 11 = Wanted to leave land fallow

12 = Other

-8 = Not applicable/no other reason

A11. With which source of drought power did you cultivate the most land during the past 12 months?	| |	1 = Tractor 2 = Donkeys/Horses 3 = Cattle (cows & bulls) 4 = Other -8 = Not applicable/none

A12. I'd like to know how you divide agricultural work among household members and whether men and women have different responsibilities. Do the men or the women of the household do most of______**[name of task from rows]** or is the work shared about equally among men and women?

		Crops kept for household consumption	Crops sold for cash income
		a	b
1	Ploughing		
2	Hoeing		
3	Planting		
4	Weeding		
5	Applying fertilizer/pesticides		
6	Irrigation		
7	Harvesting		
8	Shelling/threshing maize/beans/ groundnuts/rice		

B6a/b: Codes for source of labor:
1 = Female household members
2 = Male household members
3 = Shared among male and female household members 4 = Hired labor 6 = Other
-8 = Not applicable

9	Post-harvest cleaning and sorting			
10	Marketing decisions (selling, transport to market, negotiating, etc.)			

The following questions ask about the crops your household planted or harvested during the **[season]**.

A13.	Season					How much______did you harvest?			Of the seed you used to plant <u>this crop</u>, how much had you retained from your own production?	If you had had to buy this seed, what would it have cost?	How much improved/certified seed did you <u>buy</u> to plant <u>this crop</u>?	How much indigenous seed did you <u>buy</u> to plant <u>this crop</u>?	**(Do not ask if j & k are both "0")** Considering cash and in-kind payments, what was the total amount you spent on indigenous and improved seed to plant <u>this crop</u>?
	Enter names of (or codes for) the seasons	Which crops did you plant or harvest?	Did you intercrop this crop with another crop?	How much area did you plant to this crop?	**Record area units**	Quantity	**Weight units**	**Weight of "other" in kg**	0 = None -7 = Don't know	-7 = Don't know	0 = None -7 = Don't know	0 = None -7 = Don't know	
		See codes below	1 = Yes, 0 = No			**0 = None**			Quantity (kg)	Local currency	Quantity (kg)	Quantity (kg)	Local currency

	relevant to the country												
		a	b	c	d	e	f	g	h	i	j	k	l
	[first season] - if only one season, name it here and ask specifically about planting in this season.												
0	**the second crop.**												
1													
2													
3													
4													
	[second season] - if more than one season, name them in separate sections and ask specifically about planting in each season.												
5													
6													
7													
8													
9													

A14	For crops that are intercropped with other crops, record common expenses in the row	What was the cost of pesticides, herbicides, and spraying services you bought for this crop?	How much did you spend on non-labor expenses incurred to plant, tend, and harvest this crop (for example, e.g., leasing land or irrigating,)? **(Enter "0" if none)**	Did you hire any labor for this crop that you paid based on the amount of time they worked? **(If "No" or 'don't know", go to next row/ crop)**	How many days of labor did you hire for preparing land, weeding, and harvesting for this crop? **(If "0", go to column r)**	Considering cash, and the value of in-kind payment, what was the total amount you paid for this labor?	How many days of labor did you hire for other tasks for which you paid by the time spent for this crop? **(If"0", go to next crop)**	Considering cash, and the value of in-kind payment, how much did you pay for this labor?
		0 = None, -7 = Don't know	0 = None	1 = Yes 0 = No -7 = Don't know	Days of labor	Local currency	Days of labor	Local currency

	m	n	o	p	q	r	s
	[first season] - if only one season, name it here and ask specifically about planting in this season.						
0							
1							
2							
3							
4							
	[second season] - if more than one season, name them in separate sections and ask specifically about planting in each season.						
5							
6							
7							
8							
9							

__ __ __ __ __ __ __ __ __ __ __ __ __ __ __ __ __ __ __

__ __ __ __ __ __ __ __ __ __ __ __ __ __ __ __ __ __ __

Season codes	**Crop codes**	**area unit codes**	**weight units**
Develop codes for each of the seasons using "1"	Insert codes for all staple and cash crops relevant to the country from the list of crop codes in the Data Collection Manual.	1 = hectares 2 = acres	**codes** 1 = grammes 5 = 50 kg bags 6 = metric tonnes 2

for the main season, etc.		8 = Not applicable	= kilogrammes 3 = 100 kg bags = 90 kg bags	7 = quintals 8 = Other 4

A`16. Considering c ash and the value of in-kind payment, how much did you p ay for all these tasks?	Local currency	
A15. During the **[season]**, did you pay any labor based on the <u>task</u> (for example, ploughing or transporting crops from the field to your house)? **(If "No" or "Don't know", go to question A17)** **(If "Yes", go to B9)**	|__ |	1 = Yes 0 = No -7 = Don't know

A17.		Weight units		Considering both cash and in-kind payments, what was the total amount you p aid for this fertilizer?

		Quantity (bags)	See c odes below	Weight of " other" units (kg)	Local currency
		a	b	c	d
	How much chemical and natural fertilizer did you <u>buy</u> for all the crops you planted last season?	| | | | |	| |	| | | | |	| | | | | | | |

: weight units codes

2 =	kilogrammes	5 =	50 kg bags
3 =	100 kg bags	6 =	metric tonnes
4 =	90 kg bags	7 =	quintals
		8 =	Other

The following questions ask about your sales of crops during the **[season]**.

A18		Which crops did	How much of the quantity that you harvested have you sold,	What is the main reason you did not sell any of this	Considering c ash, the value of in-kind goods, and the	Which		Did you have any difficulty selling	

	Season	you harvest or sell during [season]? **(Include all crops listed in question B7a plus any other crops the respondent sold)**	bartered, or used to repay loans?			crop?	value of what you bartered or used to repay loans, what was the total amount you received for what you sold?	member of the household made the decision about how (timing, buyer, price, etc.) to sell this crop?	What was the total value of all costs (both cash and in-kind) you incurred to sell this crop (e.g., transportation, storage, cleaning, drying, market fees, commissions, taxes, etc.)	this crop?	What were the two most significant problems you had selling this crop?	
	Enter names of (or codes for) the seasons relevant to the country	Use codes from B7	Quantity **(If "0", go to e, Otherwise, complete c and d and then go to f)**	**Weight units**	**Weight of "other" in kg**	**(Go to next row/ crop or question)** See codes below	Local currency	See codes below		**(If "No", goto next row or next question)** 1 = Yes, 0 = No	See codes below	
	a a	a	b	c	d	e	f	g	h	i	j	k
	[first season] - if only one season, name it here and ask specifically about planting in this season.											
0												
1												
2												
3												

4												
	[second season] - if more than one season, name them in separate sections and ask specifically about planting in each season.											
5												
6												
7												
8												
9												

A19: Season codes	**B11c: weight units codes**		**B11e: Reasons for not selling**	
Develop c odes for	2 =	kilograms	1 =	No surplus to sell
each of the seasons	3 =	100 kg bags	2 =	Had surplus but did not need/want to sell
using “ 1” for the main	4 =	90 kg bags	3 =	Wanted to sell but price not attractive
season, etc.	5 =	50 kg bags	4 =	Had surplus, but no-one to sell crops to/no affordable access to markets
	6 =	metric tonnes	5 =	Tried to sell but crop rejected due to poor quality
	7 =	quintals	7=	Have surplus to sell but waiting to sell it later
	8 =	Other	6 =	Other

A19g: Decision maker codes	**A19j/k: Problems selling crop**
1 = Household head 2 = Spouse of household head 3 = Joint decision of household head and spouse 4 = Other	1 = High cost of transport to market 2 = Low prices in acaccessible markets 3 = High market fees/taxes 4 = Poor transportation infrastructure 5 = Trade restrictions (for example, restrictions on cross-border trade or restrictions on traders buying particular ccommodities) 6 = Not able to meet quality requirements of buyers 7 = Unpredictable prices 8 = Lack of price information 9 = Difficult/unable to find buyer 10 = Farmers' organization not effective at selling your commodities 11 = Late or slow payment from buyers 12 = Other -8 = Not applicable (no other problem)

The following questions ask about how your household used the [staples] commodities you harvested during the **[season]**.

A20.	Crop (list all [staples] commodities harvested from question A13a)	Considering all the______[name of crop] that you harvested during the [seasons], about what proportion did you… (Use proportional piling if necessary) (Ensure that columns b through f sum to 100)					What was the main cause of loss during storage?	How did you store the portion of this crop that you consumed in your household? (Indicate up to two types of storage)		How did you store the portion of this crop you sold (immediately or later on)? (Indicate up to two types of storage)		How did you usually dry this commodity?
		Sell, barter, use to repay loans, or give away?	Retain for sale later on	Lose to spoilage or pests during storage or use for other than its intended use because of spoilage?	Retain for consumption in your household?	Retain specifically for seed or animal feed?						
		Percent	Percent	Percent	Percent	Percent	See codes below	See codes below	See codes below	See codes below	See codes below	See codes below
	a	b	c	d	e	f	g	h	i	j	k	l
1												
2												

3												
4												
5												

A21.					Considering all the______**[name of crop]** that you <u>sold</u> during the [seasons], about what proportion did you … **(Use proportional piling if necessary)** **(Ensure that columns p through r sum to 100)**			Of the portion of the _____ **[name of crop]** that you sold, about what proportion did you … **(Ensure that columns s and t sum to 100)**				
	Did you dry this commodity adequately to reduce spoilage during storage?	Did you store the commodity in a structure that kept out rats, mice, and moisture?	Did you treat the commodity with chemicals during storage to control insect pests?	**Continue only for crops reported sold in column b**	Sell to or through a farmers' organization?	Sell yourself at your farm gate?	Sell yourself somewhere other than at your farm gate?	Sell within four weeks of harvest?	Store and sell at a later date?	**(Ask only if s > "0")** What was the main reason you sold some of this crop within four weeks of harvest?	Was there a market for a better quality than what you sold (i.e., lower moisture, less foreign matter, fewer small/ broken grains)? **(If "No", go to next row)**	What was the main reason you did not improve the quality for this buyer/ market?
	1 = Yes 0 = No	1 = Yes 0 = No	1 = Yes 0 = No		Percent	Percent	Percent	Percent	Percent	See codes below	1 = Yes 0 = No	See codes below

	m	n	o		p	q	r	s	t	u	v	w
1	|__|	|__|	|__|									
2	|__|	|__|	|__|									
3	|__|	|__|	|__|									
4	|__|	|__|	|__|									
5	|__|	|__|	|__|									

A21a: Crop codes	A21g: Storage loss codes	A21h/ i / j / k: Storage options	A21l: Drying methods
	1 = Mould /spoilage 2 = Pests/insects 3 = Rats/mice/etc. 4 = Other animals 5 = Other -7 = Don't know	1 = In traditional granaries 2 = Indoors – in basket/bags 3 = Indoors – open storage 4 = Outside – open storage 5 = In certified warehouses for which you received a receipt specifying the quality and quantity deposited 6 = In other warehouses/stores 7 = Metallic home silos (Latin America) 8 = Other	-8 = Not applicable / did not store

1 = On the ground

2 = On tarpaulins or iron sheets 3 = On concrete / grain yards

4 = Mec hani c al dryer 5 = Crib

6 = Hanging

7 = In the field (standing or stacked)

8 = Other

-8 = Not applicable/did not dry

Reasons for selling at harvest

1 = Needed immediate c ash 2 = Could not store

3 = Offered a good price 4 = Other

Reason for not improving quality

1 = Normal practice meets buyer specifications 2 = No increase in price to justify cost

3 = Increase in price not enough to justify cost 4 = Farmers’ organization provided this service

5 = Do not have ability to dry, clean, or sort to buyer specifications 6 = Other

A22.		During the past 12 months, where did you get information about prices of staple commodities? **(Mark all that apply and prompt if necessary)**	**(Ask only if B13a = 1)** Did thisinformation help you in your selling decisions?
		1 = Source of information 0 = Not a source of information -8 = Not applicable	1 = Yes 0 = No
		a	b
1	Radio/TV	|_ |	| |
2	Direct contact with traders	|_ |	| |
3	Farmers' organizations	|_ |	| |
4	Newspapers	|_ |	| |
5	Extension workers	|_ |	| |
6	SMS system/mobile phone	|_ |	| |
7	Neighbors/friends/relatives	|_ |	| |
8	Information boards at local agricultural offices	|_ |	| |
9	Personal knowledge of the market	|_ |	| |
10	Information from food reserve agency (country-specific name)	|_ |	| |

11	NGOs	|_ |	| |
12	International development organizations	|_ |	| |

A23. Did you cultivate any cash crops last season?

No (1) Yes (2)

A23a. Did you grow crops in a backyard garden this past dry season?	Yes	1
	No	2
A23b. If yes, what was the size of the garden?	Area cultivated:	
A24. What crops did you grow in the garden? *Enumerator: Probe for all possible crops…*) Green leafy vegs, tomatoes, onions, potatoes, carrots, pumpkins, beans, maize, sweet peas, sweet potatoes, yams, sugar cane, cassava…	Crops:	
A25. What methods do you use to water the garden crops?	Diesel pump	1
		2
	Hand watering	3
	Gravity canals	4
	Deep planting/ residual moisture	5
	Other	97
A26. Did you grow any cash crops last season?	Yes	No
A27a. Did you receive a fertilizer coupon?		
A27b. If yes what quantity (specify in bags)?		
A28a. Did you apply any herbicide to your fields last season?		
A28b. If yes, what quantity?		
A29. Which of the following did you do to improve soil fertility		

Strategy		**Yes**	**No**
Planted legumes			
Buried crop residue			

	Agroforestry			
	Mulching			
	Prepared box ridges			
	Planted vertiva grass			
	Applied compost manure			
	Crop rotation			
	Other (specify)			
	Applied chemical pesticides/herbicides/ fertilizers			
	Other (specify)			

A30. Did you do any of the following to control pests and diseases?	**Strategy**	**Yes**	**No**	
	Intercropped			
	Crop rotation			
	Improve soil fertility			
	Applied botanical sprays (e.g. tephrosia, chisoyo)			
	Planted repellant plants			
	Physical killing			
	Smash or burn beetles to apply to field			
	Adjust planting time			
	Applied chemical pesticides/herbicides/ fertilizers			
	Other (specify)			

A31a. Have you shared any seeds in the last planting season?	☐ Yes	☐ No
A31b. if yes, check all of the crops which	Crop	Quantity

you have shared and indicate what amount	1.	
	2.	
	3.	
	4.	
	5.	
	6.	
A32a. Have you received or borrowed any seeds in the last planting season?	☐ Yes	☐ No

A32b. If yes, specify source and quantity	Crop	Quantity	Source
	1.		
	2.		
	3.		
	4.		
	5.		
	6.		

Module B: HOUSEHOLD FOOD SECURITY

Instructions to the Enumerators: For each of the following questions, make sure that you refer to the past four weeks. If the answer is 'yes', explain whether: sometimes (once or twice), often (3-10 times), frequently (more than 10 times).

#	Question (Check only one response). Each of the following questions applies to past 4 weeks.	Never	Rarely (1-2 times)	Sometimes (3-10 Times)	Often (More than 10 times)
	In the past 4 weeks, were you ever worried that you may not have	☐	☐	☐	☐

#	Question (Check only one response). Each of the following questions applies to past 4 weeks.	Never	Rarely (1-2 times)	Sometime s (3-10 Times)	Often (More than 10 times)
B1	enough food in your household?				
B2	In the past 4 weeks was there anyone in this household unable to eat the kinds of foods you preferred because of a lack of resources?	☐	☐	☐	☐
B3	In the past four weeks did you or any household member have to eat a limited variety of foods due to a lack of resources?	☐	☐	☐	☐
B4	In the past four weeks was there any household member who had to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of food?	☐	☐	☐	☐
B5	In the past four weeks was there anyone in this house hold who ate less amount of food [or a smaller meal than you felt you needed] because there wasn’t enough food?	☐	☐	☐	☐
B6	In the past four weeks was there any household member who ate fewer times per day because there wasn’t enough food?	☐	☐	☐	☐
B7	In the past four weeks was there ever no food to eat of any kind in your household because of lack of resources?	☐	☐	☐	☐
B8	In the past four weeks, did you or any household member go to sleep at night hungry because there wasn’t enough food	☐	☐	☐	☐
B9	In the past four weeks was there any household member who had spent a whole day and night without eating because there wasn’t enough food?	☐	☐	☐	☐
B10	Have you or any household member had to do ‘byday’ for food in the past 4 weeks because you have run out of your own food sources?	☐	☐	☐	☐

#	Question (Check only one response). Each of the following questions applies to past 4 weeks.	Never	Rarely (1-2 times)	Sometime s (3-10 Times)	Often (More than 10 times)
	Have you or any household member had to do ganyu for food in the past 4 weeks because you have run out of your own food sources?				
	Enough clean water for home use?	☐	☐	☐	☐
	Enough fuel to cook your food?	☐	☐	☐	☐
	A cash income?	☐	☐	☐	☐
B11	Did you run out of food last year?	Yes or no			
B12	At what month after harvest did last season's produce finish and your household started struggling with finding food?	Indicate in months (July to September is the harvest season)			
B13	Does your household harvest/process shea to support household food provisioning?	Yes/no			
B12	What quantity of shea did your household harvest last year	________			

Dietary Diversity

B13. Now I will ask you questions about food stuffs and drinks that any household member ate or drank yesterday from the time he/she woke up until he/she went to bed *[Do not include food or drink taken elsewhere].* Did any household member eat or drink any of the following yesterday?

Food group	**Examples**	**Yes**	**No**
a) Cereals	Any food such as TZ, porridge, bread, spaghetti, scones, biscuits, rice, boiled whole maize grain, pito/sweet beer, or any food made from finger millet,	1	0

	sorghum, bulrush millet, maize and wheat?		
b) Vitamin A rich tubers & vegetables	Any food such as: pumpkins, carrots or sweet potatoes having yellow pigment, including local orange maize? *[please check here if they indicate that they ate local orange maize]*	1	0
c) White tubers and roots	Any food in the group of: white sweet potatoes, coco yams, cassava, Irish potatoes, yams or any white roots and tubers?	1	0
d) Dark green leafy vegetables	Relish of dark green leafy vegetables as well as the indigenous vegetables including, Cat's whiskers leaves, cassava leaves, sweet potato leaves, mustard, rape, local rape, pumpkin leaves, cow peas leaves, bean leaves, black jack leaves	1	0
e) Any other vegetables)	Any kind of relish from leafy vegetables e.g. Chinese cabbage, okra, cabbage, egg plants, tomatoes, onions, green pepper and green beans?	1	0
f) Vitamin A rich fruits	Any fruits like papaya (pawpaw	1	0
g) Other fruits	Any other fruits including the indigenous wild fruits e.g. oranges, tangerines, lemons, tamarind, elephant fruits, avocado pears, bananas and baobab fruits?	1	0
h) Meats	, pork, goat meat, rabbit meat, mice, wild game, poultry duck, flying insects e.g. guinea fowl or any other bird, liver, kidney, heart, offal or any other meat.	1	0
i) Eggs	Eggs of any kind?	1	0
j) Fish	Fresh or dried fish	1	0
k) Legumes, nuts & seeds	Any type of beans and peas e.g. beans, cow peas, pigeon peas, nkhungudzu, peas, ground beans, soya beans, ground nuts, green gram, custard apple, Nseula, chick peas?	1	0
l) Milk and milk products	Milk and Food made from milk e.g. yoghurt, sour milk?	1	0

m) Oils and Fats	Any type of fats or oils e.g. cooking oil, animal fats and margarine used for cooking or added to food?	1	0
n) Sweets	Any sweet, sugar, honey, soft drinks such as Fanta, Coca-Cola, sprite, and other drinks to which sugar was added or sugary foods e.g. chocolate, sweets?	1	0
o) Coffee/tea	Any tea or coffee?	1	0

Module C. HOUSEHOLD EXPENDITURE

C1.	About how much did your household spend on________for domestic consumption **<u>during the last 30 days</u>.** **(If "Don't know", go to next item)**				
1	Maize		9	Milk and dairy products	
2	Beans		10	Sugar/Salt	
3	Bread		11	Milling	
4	Rice		12	Alcohol & Tobacco	
5	Fruits & vegetables		13	Household items (soap, batteries, etc.)	
6	Fish/Meat/Eggs/ poultry		14	Transport and fuel	
7	Oil, fat, butter		15	Cooking & lighting fuel (wood, paraffin, etc.)	

8	Water		16	Soda/drinks (including tea)	

C3.		About how much did your household spend on_______**during** **<u>the last 12 months</u>**.
		(If "Don't know", go to next item) 0 = None
	Medical expenses, health care	**-7 = Don't know**
	Education (books, school fees, uniform, etc.) Clothing, shoes	
	(excluding those required for school) Equipment and tools	
1	(including for agriculture) Construction, house repair	
2		
3	Debt repayment	
4	Celebrations, social events (funerals, weddings, etc)	
5	Remittances/gifts	
9	Raising crops (includes the cost of inputs – excluding equipment and tools - and labor)	__ __ __ __
10	Raising livestock (includes the cost of buying livestock, feed, and labor)	__ __ __ __

Module D. LIVESTOCK

D1. During the past 12 months, did your household raise any livestock, either for sale or for your own consumption? **(If "No", go to next section)**	|__ |	1 = Yes 0 = No

D2.	What types of livestock has your household owned during the past 12 months?	How many	How many of [animal type] did you buy during the past 12	Considering both c ash and the value of in-kind payments, how much did you spend	How many of [animal type] did your household consume or give aw ay	How many of [animal type] did you sell or barter during the	Considering c ash and the value of in-kind payment, what is the total amount you received	During the past 12 months, did you earn any money renting this animal or selling products from this animal? **(If "No", go to j)**	In total, how much did you earn (in c ash and the value of in-kind payment) from renting these animals or selling their produces	Considering c ash and the value of in-kind payment, how much did you spend on feed for these animals	Considering c ash and the value of in-kind payment, how much did you spend on othercosts for these animals such as veterinary supplies, taxes, and hired labor

		of [animal type] do you have now?	months? **(If "0",go to e)**	purchasing these animals?	during the past 12 months?	past 12 months? **(If "0", go to h)**	for the sale of these animals?	**Yes=1, No=0**	during the past 12 months?	during the past 12 months?	during the past 12 months?
	a	b	c	d	e	f	g	h	i	j	k
1											
2											
3											
4											
5											
6											
7											
8											
9											

Module E. LIVELIHOOD ACTIVITIES AND OTHER INCOME

E1	Other than agriculture and livestock that you've already told me about, **(mentioned in Modules Band D)**, what other sourcesof cash and in-kind income did your household have during the past 12 months? **(List top three livelihood sources first)**	How many members of your household worked at this activity during the past 12 months? **(Enter "not applicable" for remittances or gifts or other types ofincome that did not require work)**	What was the total amount the entire household or household members earned during the past 12 months from this activity considering both cash payments and the value of in-kind payments? **(Enumerator: ask about number of household members who worked how many**	Did the household incur any expenses with this activity? **(Probe about hired labor, purchasing items to sell, renting market space, transportation, etc.)**. __ __ **(If "No", go to next row/** __ __ **activity)** __ __	About how much were these expenses during the past 12 months?
		-8 = not applicable		1 = Yes 0 = No	

__ __

__

			days/ months worked, payment, etc. to arrive at the answer)		
	a	b	c	d	
1					
2					
3					
4					
5					
6					
7					
8					
9					
1 0					

E1a /E3: Livelihood activity codes

Cash or in-kind income from...	7 = Petty trade	14 = Cash, food, or other assistance
1 = Remittances staple commodities or	8 = Pension/social grants 2 = Trading 9 = Formal salary/wages	15 = Gathering natural products for sale
cash crops	10 = Fishing	e.g. medicinal herbs, mushrooms, etc.
19= Production & sale of staple	11 = Vegetable /fruit crops production/sales	16 = Collecting scrap / waste material for re-sale
3 = Trading in livestock sale of cash	12 = Small scale mining/ 20= Production & /quarrying/brick-making	-8 = Not applicable (No other source) 18 = Other

E3. Which of your household's livelihood activities was most responsible for the change **(reported in E2)**?	| | |	Use codes from **E1a/E3**

Module F: ACESS TO CREDIT

F1. Has any member of your household borrowed any cash or goods during the past 2 years? **(If "Yes", go to question F2)** **(If "No", go to question H1)**	| |	1 = Yes 0 = No

E2. Was your household's total income from all sources (including agriculture and livestock) during the past 12 months higher, lower, or about the same as in the 12 months prior to that time? **(If "About the same" or "Don't know" go to Module F)**	| | |	1 = Higher 2 = About the same 3 = Lower -7 = Don't know

F2.		Has any member of your household borrowed any c ash or goods for____in the p ast2 years? **(If multiple loans of the same type/category, enter information for most recent)** **(If "No", go to next row)** 1 = Yes 0 = No	What amount did you ask for? **(If loan was in-kind (i.e., goods or services instead of cash), enter the monetary value of the goods or services requested)**	What amount did you receive? **(If the loan was in-kind (i.e., goods or services instead of cash), enter the monetary value of goods or services received)**	Which household member signed for the loan? 1=Female 0 = Male 2 =Joint loan	What was the source of the loan?	In what form (did you/will you) rep ay the loan?
		a	b	c	d	e	f
1	To purchase agricultural	|__ |			|__ |	|_ |	|__ |

	inputs (seed/fertilizer/ chemicals)						
2	To invest in agriculture (e.g., buy tools, equipment, livestock, buy or rent land, etc.)	|__ |			|__ |	|_ |	|_ |
3	To start or invest in a non- agricultural business	|__ |			|__ |	|_ |	|_ |
4	To pay school fees/sup plies	|__ |			|__ |	|_ |	|_ |
5	To purchase staple food for household consumption	|__ |			|__ |	|_ |	|_ |
6	To pay for health care / medic al expenses	|__ |			|__ |	|_ |	|_ |
7	To pay for social event	|__ |			|__ |	|_ |	|_ |

	(funerals, wed dings)						
8	To build or add on to a house	|__ |			|__ |	|_ |	| |
9	Other	|__ |			|__ |	|_ |	| |

F2e: Codes for sources of credit			**F2f: How credit was/will be repaid**
1= Friend/relative	8 =	Government/Rural Credit fund	1 = In c ash
2 = Money lender	9 =	International development organization	2 = In kind
3 = Commercial bank	10 =	NGO	3 = Both c ash and in kind
4 = Informal savings group	11 =	Micro-credit institutions	
5 = Farmers' organization	12 =	Other	
6 = Local trader/ shopkeeper			
7 = Buyer/ trader (contract farming)			

Module G. HOUSEHOLD ASSETS

H1. How many of each of the following assets that are in working order does a member of your household own? **(If an asset is not owned or belongs to a non-household member, write 0)**

		a			a
1	Chair (excluding traditional stools and benches)		15	Hand Mill	
2	Table		16	Bicycle	
3	Bed		17	Harrow	
4	TV/ satellite dish/DVD		18	Plough	
5	Radio		19	Sewing machine	
6	Fishing nets		20	Hammer mill	
7	Canoes		21	Mobile phones/ landline	
8	Axe		22	Maize thresher	
9	Machete		23	silos	
10	Backpack sprayer		24	Tricycle motor/motorking	
11	Hoe		25	Vehicle (car/pick up/motor cycle)	
12	Ox Cart		26	Stove (electric or gas)	
13	Tractor		27	Fridge	
14	Generator		28	Water pump/ treadle pump	

Module H. HOUSING AND AMENITIES

H1. Please indicate the major material of the roof, floor and walls of the main house? **(based on observation – Don't ask)**			**Roof**	**Floor**	**Walls**
1	Roof		1 = Thatch 2 = Iron sheets 3 = Tiles 4 = Plastic	1 = Dirt/ mud/sand 2 = Wood 3 = Concrete 4 = Asbestos	1 = Concrete/fired brick 2 = Mud or mud brick 3 = Mud/wattle
2	Floor				
3	Walls				

H2. What is the main source of drinking water for your family? **(If "Piped into dwelling", go to question H5)**		1 = Piped into dwelling, yard or plot 2 = Public tap/neighboring house 3 = Well/spring	4 = Pond, lake, river, or stream 5 = Tanker 6 = Borehole 7 = Rain water 8 = Other

H3. On a typical day, what is the total number of trips all members of your household make to fetch water for household use?	

	a		b	
H4. Including waiting time, about how much time does one trip to fetch water for household consumption usually take?		**Record units for**| |		1 = Minutes

	(Enter "-7" for "Don't know")	**time**		2 = Hours

H5. What type of toilet facility does your household use?		1 = Flush/ pour flush 2 = Ventilated Improved Pit latrine (VIP)	3 = Pit latrine (unimproved) 4 = None (bush or field)

H6. What type of cooking fuel does your household use		1 = Charcoal 2 = Firewood 3 = Kerosene/paraffin	4 = Gas cylinder 5 = Electricity 6 = Other

H7. What type of lighting fuel does your household use?		1 = Kerosene/paraffin, oil, or gas lantern 2 = Generator/ car battery 3 = Candles, firewood	4 = Solar panel 5 = Electrical network 6 =Torch 7 = Other

Module I: HOUSEHOLD GENDER RELATIONS

I1	In your household who is considered to be in charge of decision making?	Everyone contributes equally	1
		Male Head/Father	2
		Female Head/Mother	3
		Male relative	4
		Female relative	5
		Both female and male	6
		Other (Specify)	7
		Don't Know	8
		Refused	9
I2	In your household who makes decisions about making large household purchases? (Example: Vehicle, furniture etc.)	Everyone contributes equally	1
		Male and Female Heads decide together	2
		Mostly the Males	3
		Mostly the Females	4
		Other (Specify)	7
		Don't Know	8
		Refused	9
I3	In your household who makes decisions about making household purchases for daily needs?	Everyone contributes equally	1
		Male and Female Heads decide together	2
		Mostly the Males	3
		Mostly the Females	4
		Other (Specify)	7
		Don't Know	8
		Refused	9
I4	In your household who makes decisions about visits to	Everyone contributes equally	1

	distant families and relatives?	Male and Female Heads decide together	2
		Mostly the Males	3
		Mostly the Females	4
		Other (Specify)	7
		Don't Know	8
		Refused	9
I5	In your household who makes decisions about what food to eat each day?	Everyone contributes equally	1
		Male and Female Heads decide together	2
		Mostly the Males	3
		Mostly the Females	4
		Other (Specify)	7
		Don't Know	8
		Refused	9
I6	In your household, who contributes most of the income?	Children	1
		Male Head/Father	2
		Female Head/Mother	3
		Male relative	4
		Female relative	5
		Other (Specify)	7
		Don't Know	8
		Refused	9
I7	In your household who contributes **THE SECOND MOST** of the income?	Children	1
		Male Head/Father	2
		Female Head/Mother	3
		Male relative	4

		Female relative	5
		Other (Specify)	7
		Don't Know	8
		Refused	9
I8	In your household who usually makes decisions on paying for any health-related expenses?	Everyone contributes equally	1
		Male and Female Heads decide together	2
		Mostly the Males	3
		Mostly the Females	4
		Other (Specify)	7
		Don't Know	8
		Refused	9
I9	Who usually decides what and where to plant?	Everyone contributes equally	1
		Male and Female Heads decide together	2
		Mostly the Males	3
		Mostly the Females	4
		Other (Specify)	7
		Don't Know	8
		Refused	9
I10	Who usually decides what farm products to sell?	Everyone contributes equally	1
		Male and Female Heads decide together	2
		Mostly the Males	3
		Mostly the Females	4
		Other (Specify)	7
		Don't Know	8

		Refused	9
I11	Who usually decides whether you can participate with different local organizations?	Everyone contributes equally	1
		Male and Female Heads decide together	2
		Mostly the Males	3
		Mostly the Females	4
		Other (Specify)	7
		Don't Know	8
		Refused	9

I12 Can your wife (*or you if it is woman*) ever decide to plant crops on own?	Yes	No
I13 Can your wife (*or you if it is the woman*) ever decide to sell crops on her own?	Yes	No
I14 Can your wife (*or you if it is the woman*) ever decide on her own to join an organization such as a village bank?	Yes	No
I15 Can your wife (*or you, if it is the woman*) ever decide to visit family or friends outside the village on her own?	Yes	No
I16a. Do you (*or your husband*) ever help with child care?	Yes	No
16b.1 If yes, how often per month? (circle response) (write any details provided):	Daily	
	Frequently	
	Rare Occasions	
	Never	
I17 Would you (*or your husband*) be comfortable with your wife being in a leadership position in an organization that led her to travel away from home?	Yes	No
I18a. Do you (*or your husband*) ever help with food preparation?	Yes	No
I18b.1 If yes, how often per month? (circle response)	Daily	
	Frequently	
	Rare Occasions	

	Never	
I19a. Do you (*or your husband*) ever do the laundry?	Yes	No
I19b. If yes, how often? (circle response) (write any details provided):	Daily	
	Frequently	
	Rare Occasions	
	Never	
I20. Does anyone in the household drink alcohol?	Yes	No
I21 If someone drinks Can you estimate how often per week this person usually drinks?	Daily	
	Frequently	
	Rare Occasions	
	Never	

Module J: ADAPTIVE CAPACITY AND RESILIENCE

Now I would like to ask you about what you do to manage or cope during drought, flood events and storm surges.			
J1	Which of these events have you experienced in the past 12 months?	Drought	0
		Flood	1
		Storm Surge	2
		Erratic rainfall	3
		None	4

		Other	5
J2	Do you have any coping strategies?	No	0
		Yes	1
		Don’t	8
		Refused	9
J3	What specific things did you do to manage the most recent drought/flood/ storm/ other climate event you experienced?	Nothing	0
		Relocate	1
		Sand filling	2
		Drain water	3
		Rely on family or friends	4
		Rely on social network	5
		Rely on government	6
		Rely on humanitarian aid	7
		Sell crops or livestock	8
		Sell assets	9
		Don’t know	97
		Refused	98
		No	99
J4	In the past 12 months have you received early warning information about drought, flood/storm events?	No	0
		Yes	1
		Don’t know	8
		Refused	9
J5	From whom would you get this early warning information?	Friends, neighbors, and	1

	(Circle as mentioned)	family	
		Community leader/ lead farmer	2
		Social networks	3
		Media	4
		Local government	5
		Central government	6
		Private organization	7
		NGOs	8
		Don't know	98
		Refused	99
J6	What changes (if any) in your household have you made because of drought/flood/storm/ erratic rainfall?	None	0
		Relocation out of flood/storm prone area	1
		Change job	2
		Change school for children	3
		Construct flood/storm barriers	4
		Clearance of drainage channels	5
		Change planting times	6
		Changing cultivation methods	7
		Others (specify)	8

J7	How would you rank drought/flood/storm / erratic rain problems relative to other problems in your area?	Low	2
		At par (same)	3
		High	4
		Top priority	5
		Don’t know	8
		Refused	9
		Very poor	1
J8	How would you rate your ability to handle flood/drought/ erratic rain related stress?	Poor	2
		Satisfactory	3
		Good	4
		Very good	5
		Don’t know	8
		Refused	9

Appendix D: Curriculum Vitae

Educational attainments

Jan. 2021- August 2022	M.A. Candidate, Department of Geography and Environment University of Western Ontario, Canada Dissertation: Aspects of food security and climate change resilience in Semi-arid northern Ghana.
Sep. 2015 to May 2019	B.A. (Honours), Geography and Rural Development, Kwame Nkrumah University of Science and Technology (KNUST), Ghana. Dissertation: The Socio-economic impacts of Climate Change on Smallholder Maize and Groundnut farmers in Northern Ghana.

Professional Experience

Teaching Assistant University of Western Ontario Jan. 2021 to August 2022	Facilitates tutorials and lab sessions, moderates online classes, holds office hours, proctor and grades undergraduate assessments. Courses TA'ed Include Introduction to Human Geography, Geography of Hazard, Animal Geography.

Research & Teaching

Assistant, KNUST.

Sep. 2019 to Aug. 2020

Hosted tutorial sessions and assisted undergraduate students in their research projects. Assisted my supervisor in research data collection, analysis and reporting.

Publications

In progress

Sulemana Ansumah Saaka1*. Kamaldeen Mohammed1. Evans Batung1. Moses Kansanga2. Isaac Luginaah1. Determinants of post-harvest loss in Semi-arid Northern Ghana.

Sulemana Ansumah Saaka1*. Kamaldeen Mohammed1. Evans Batung1. Moses Kansanga2. Isaac Luginaah1. Association between backyard gardening and smallholder farmers' resilience to climate change impacts.

Conferences

Apr 2021

Canadian Association of Geographers-Ontario Division (CAGONT 2021)

Presentation title: Does Gender matter in post-harvest loss prevention? A cross-sectional study in semi-arid Ghana

Mar 2022

Environment and Sustainability Conference (EnviroCon)

Presentation Title: Does Gender matter in post-harvest loss prevention? A cross-sectional study in semi-arid Ghana

Honours and Awards

Jan. 2021 Western Graduate Scholarship, Western University -$32,000 (minimum) per year for two years.

June. 2022 Michael Troughton Bursary Award ($1,500).

Jun. 2019 Kwame Nkrumah University of Science and Technology (KNUST), Faculty of Social Sciences Dean's Award. Kumasi-Ghana.

Software Skills

ArcMap, Stata, SPSS, Microsoft Office

References

Graduate Supervisor

Professor Isaac Luginaah

Department of Geography and Environment, Western University, Canada

Professor Godwin Arku

Department of Geography and Environment, Western University, Canada