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Climate Change and Seed Security Among Smallholder Farmers in Northern Ghana

Michael Biwalib Madin
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Smallholder agriculture is highly susceptible to climate variability and change. According to recent projections by the Intergovernmental Panel on Climate Change, this sensitivity would likely increase in the coming decades, with more erratic rainfall, prolonged dry periods, shorter growing seasons, and seed germination failures. In the African context, the mechanisms through which these ecological stressors would affect seed security are poorly understood. Drawing upon a case study of semi-arid Ghana, this study examines climate change impacts on seed security among smallholder farmers. It adopts a mixed-methods approach with intensive fieldwork in two farming communities. Conceptually, the study uses a political ecology framework to understand the environmental, historical, and political factors that shape seed systems under changing climatic conditions. Methods of data collection included a household survey (n=429), focus group discussions (n=2), and in-depth interviews integrated with human-environment timelines (n=20). Overall, the findings show that the significant determinants of seed security in semi-arid Ghana include village remoteness, mobile phone ownership, accessibility to credit, and access to tractor plowing services. The results further show that seed security is often disrupted by factors other than climate change, including ethnic conflicts, farmer-herder conflicts, and the use of synthetic farming inputs. Other non-climatic factors include the lingering impacts of neoliberal policies such as structural adjustment programs. In terms of adaptation to seed insecurity, farmers adopt a variety of measures, including the geographical expansion of their seed networks during times of stress. This adaptation strategy was however gendered. More specifically, female-headed households were less willing to procure seeds beyond a distance of 60 km. Ultimately, the study argues that in the quest to enhance seed security, an overemphasis on climate change impacts alone may be inadequate. Such an approach could detract attention from equally important socio-political factors that reinforce farmers' struggle to access healthy and desirable seeds.

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Title: CLIMATE CHANGE AND SEED SECURITY AMONG SMALLHOLDER FARMERS IN NORTHERN GHANA
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List of Acronyms

CIDA	Canadian International Development Agency
CIA	Central Intelligence Agency
EGM	East Gonja Municipality
FAO	United Nation Food and Agriculture Organization
HH	Household
IPCC	The International Panel on Climate Change
IRB	Institutional Review Board
LEAP	Livelihood Empowerment Against Poverty
MADU	Municipal Agriculture Development Unit
NADMO	National Disaster Management Organization
NNM	Nanumba North Municipality
NGO	Non-Government Organizations
PF&J	Planting Food and Jobs

CHAPTER ONE

INTRODUCTION

1 Introduction

Over the past two decades, agricultural production, food, and nutrition security have been under significant stress. Although food production has been projected to increase globally over the next few decades, production would decline in sub-tropical regions where food security[1] is already a problem (IPCC, 2018; Richardson et al., 2011). These production trends would be shaped by intensified climate change, in combination with socio-economic and political factors (Gil et al., 2017; IPCC, 2018; Papaioannou, 2016; Leichenko & O'Brien, 2008). According to the Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2018), Sub-Saharan Africa is among the regions with the highest risks to the impacts of global climate change.

The population in Africa at a disproportionately higher risk of climate change include smallholder farmers. Based on an assessment by the IPCC (2012), most smallholder farmers have already experienced deteriorating food security. There is over 50% projected reductions in crop yields by 2020, and a corresponding fall in net crop revenues of 90% by 2100 (Etwire et al., 2017; Boko et al. 2007). Climate change impacts

[1] Food security is when 'All people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life.' (FAO, 2002: 4–7).

on crop yields, coupled with human-caused disasters (e.g., wars and civil conflicts)[2] are reported to have had increasingly devastating effects on the livelihoods of smallholder farmers (FAO, 2010, 2016; Leclerc et al., 2014; Sperling, 2008). These impacts have resulted in a situation where most African farmers are predisposed to seed insecurity (Gil et al., 2017).

The United Nations Food and Agriculture Organization (FAO) defines seed security as when farmers "have sufficient access to quantities of available good quality seed and planting materials of preferred crop varieties at all times in both good and bad cropping seasons" (FAO, 2016, p.16). Seeds are defined broadly to include not just grains that are sown, but also cuttings, tubers, and other agricultural planting materials required by farmers (Sperling, 2008). It is also viewed as crop improvement and the delivery of high-quality germplasm for ensuring improved crop production (McGuire & Sperling, 2013). Adequate access to healthy and desired seeds is critical for smallholder agriculture. Yet, improved seeds available in Africa are adopted by only 35% of the farmers, in contrast to over 80% in South America and over 60% in Asia (Byerlee & Bernstein, 2013). Risks such as possessing poor quality seeds continue to serve as a barrier to climate change adaptation and food security in Africa (Niang et al., 2014).

There is a large body of research examining smallholder farmers' seed availability, networks, and security. For instance, some case studies have examined the socio-cultural factors determining seed circulation networks (e.g., Nyantakyi-Frimpong

[2] Conflicts in Northern Ghana, involved resource marginalized ethnic groups and dominant neighbors, power and supremacy request, and the rejection by regarded powerful and superior ethnic groups (Talton, 2003b).

& Kerr, 2015; Ricciardi, 2015; Kawa et al., 2013; Alvarez et al., 2005; and Zimmerer, 2003). Others have also focused on how socioeconomic status or wealth affects seed access (e.g., Wencélius et al., 2016; Poudel et al., 2015; Samberg et al., 2013; and Alvarez et al., 2005). Reyes-García et al. (2013) and Calvet-Mir et al. (2012) have assessed ecological dimensions that influence seed networks and agrobiodiversity. Similarly, Waldman et al. (2017), Violon et al. (2016), and Leclerc et al. (2014) have studied climate change and seeds, while Tripp & Mensah-bonsu (2013) and Shiva et al. (1999) have focused on how globalization and other political processes affect seed security. In this growing literature, however, very few studies have investigated how climate change interacts with other factors to affect seed security. As well, McGuire & Sperling (2013) have stressed that whereas seed security remains key to climate change resilience, concrete means for building this resilience remain unexplored in both research and practice.

Given these knowledge gaps, this study seeks to assess the experiences of seed security among smallholder farmers, with a case study in northern Ghana. Overall the study objectives are to:

1. assess smallholder farmers' experiences of seed insecurity and how these experiences differ by age, gender, crop diversity, income levels, and household structure;
2. understand the temporal nature of seed insecurity experiences; and
3. critically evaluate farmers' adaptation strategies used to improve seed insecurity.

This case study is timely because by answering the above questions, the findings would add to the limited existing literature on seed security. It would also provide lessons for improving seed policies in Africa and elsewhere. The research results would also ensure that seed security efforts are made more context-specific, carefully targeted, farmer-oriented, and ultimately more sustainable in their delivery.

The thesis is organized into five chapters. After this introduction, Chapter Two provides a literature review on seed security and seed networks in smallholder farming systems. Chapter Three describes the research methodology and provides a background to the case study area. Chapter Four presents empirical evidence from primary fieldwork. Chapter Five discusses the empirical findings and concludes with recommendations to help improve seed security under a changing climate.

CHAPTER TWO

LITERATURE REVIEW

2.1 Definition of Terms

Before presenting the conceptual framework for this study, it is essential to define some key terms. Smallholder farmers are defined as farmers who cultivate marginal pieces of land, often less than 1 hectare, with lower levels of market orientation (Chamberlin, 2007). They rely on rain-fed agriculture, without adequate access to technology (Haggblade, 2010). Most of these farmers depend primarily on family labor (Morton, 2007). It is essential to understanding seed acquisition practices among these farmers because over 80% of the food consumed in Africa is produced by smallholders (Chandra & Mcnamara, 2017) and accounts for nearly 20% of the Gross Domestic Products (CIA, 2017). In the development studies literature, a household is defined as a group of individuals who share the same house-keeping arrangements (Ghana Statistical Service, 2014c). In most cases, it is comprised of a man, his wife, children, and some other relatives.

2.2 The Seed Security Framework

Despite decades of research and development interventions, smallholders' productivity across sub-Saharan Africa is still relatively lower than in other regions (Poku et al., 2018; Etwire et al., 2017; Waldman et al., 2017). Some of the interventions implemented in this regard included the Green Revolution policies and investments in improved seed cultivars, especially for staple crops (Spielman & Kennedy, 2016; Waldman et al., 2017). The efforts are premised on the basis that the challenges facing African smallholders result mainly from climate-induced stresses. Ensuring seed security is critical for building farmers' resilience to climate change (FAO, 2010; Coomes et al., 2015; Kansiime & Mastenbroek, 2016). For example, Sperling (2008) indicated that adequate access to desired seeds enables farmers to produce for their consumption and sale; hence, lack of desired seeds poses a threat to livelihoods.

For the past two decades, the FAO has continued to support efforts toward ensuring adequate access to healthy and desirable seeds for different crops among smallholder farmers, particularly in the developing world (Sperling et al., 2008; FAO, 2005, 1998). As defined in the first section of chapter one, seed security has three dimensions, including seed availability, access, quality and varietal suitability (FAO, 2016; McGuire & Sperling, 2011). Seed availability means having enough quantities of seed within reasonable proximity to farmers (spatial availability) and offered in time for critical sowing periods. Seed access refers to farmers' capacity to produce their seed or have adequate resources to otherwise obtain seeds through cash, loan, barter, or gift. Seed quality involves seeds of acceptable health and desired physiological attributes, while varietal suitability indicates the extent to which crop varieties are preferred and adaptable to the farmer's microclimate conditions (FAO, 2016).

Seed security could serve as an indicator of food security among smallholder households (FAO, 2010; McGuire & Sperling, 2011; Coomes et al., 2015; Kansiime & Mastenbroek, 2016). Yet, research evidence shows mixed results of efforts toward achieving seed security in Africa through policies and investments. For instance, Byerlee and Bernstein (2013) found that improved seed varieties made available in Africa are adopted by only 35% of the farmers, in contrast to over 80% in South America and over 60% in Asia. Among the possible explanations for these results is the challenge faced by the farmers in selecting or obtaining seeds that are suited to their local climatic conditions (Niang et al., 2014; Waldman et al., 2017). Also, well established in the literature includes the influence of farmers' perceptions and uncertainties on seed varietal suitability given changing climatic conditions (Gaffney et al., 2016; Mucioki et al., 2016; Spielman & Kennedy, 2016). Likewise, Almekinders et al. (2019) and Poku et a., (2018) found that most of the interventions are designed without an understanding of farmers' seed needs.

2.3 Overview of Smallholder Seed Security

2.3.1 The Smallholders Seed Systems

Seed systems refer to the various channels from which farmers obtain seeds and other planting materials (FAO, 2016). Farmers' seed systems are grouped into 'informal' and 'formal' sources (FAO, 2016). The informal sources consist of channels from the farmers' harvest or friends, relatives, and neighbors obtained either through barter, gift, or purchase from local markets (FAO, 2010, 2016; Sperling, 2008). The formal source consists of seed companies, input dealers, government channels, NGOs, and international aid agencies (FAO, 2010, 2016; Sperling et al., 2008).

There is a contentious debate on which of these two seed systems is more resilient or needs to be promoted in Africa (McGuire & Sperling, 2013; Shiva et al., 1999). For instance, Shiva et al. (1999) argued that informal seed systems should function free of external interference along with firm community control and formal systems participation. Likewise, Chrys et al. (2013) contended that foreign interference would inhibit smallholder farmers from re-using, sharing, and storing indigenous seeds, and thereby create dependency on improved seeds produced and supplied externally. Also, McGuire & Sperling (2011) found that even in cases of repeated seed distributions from formal seed sources to address gaps in seed availability, farmers have still obtained the majority of seed sowed from informal seed sources.

Sperling and McGuire (2013) recognized that it is essential that formal seed systems play a complementary role, but the resilience response emphasis should be placed within the informal networks. This is primarily because the smallholders possess the knowledge and skills that can enhance farmer productivity and mitigate climate risks (Mucioki et al., 2016). Also, informal sources are embedded in indigenous farming systems, reliant on traditional methods of seed production, preservation, and multiplication (Kansiime & Mastenbroek, 2016). If adequately understood and transformed, informal seed systems possess the potentials to help smallholder farmers to adapt effectively to climate risks. Nevertheless, FAO (2016) continues to maintain that the two systems are part of one overall system, whose components interact with each other to determine the opportunity to switch between sources so that if one source dries up, another source can be used. As such, this study takes into consideration how seed security could be enhanced through both informal and formal seed systems.

2.3.2 Stressors of Seed Security

The stressors of seed security are the shocks, a series of drivers operating within an agricultural setting, or the macro level, that adversely affect seed systems. According to Sperling et al. (2008), seed security stressors operating within an agricultural setting are usually manifested by effects on crop production, seed supply, and local market functionality. On the other hand, those emanating from the macro-level include factors such as market regulation, labor supply, seed policies, and public demand.

2.3.3 Impacts of Climate Change on Seed Security

Consistently, research evidence has identified climate change as a significant stressor of seed security. For example, extreme climatic events such as droughts and floods have been reported to have caused an increasingly devastating impact on seed systems (FAO, 2010; Kansiime & Mastenbroek, 2016; Waldman et al., 2017). The impacts of climate change have also been noticed for halting crop production, destroying agricultural assets, and hindering access to farm inputs, which further diminish seed security (FAO, 2010, 2016; McGuire & Sperling, 2013; Sperling, 2008; Sperling et al., 2008).

Seed availability is affected when extreme climatic events disrupt farmer-saved seeds and the effective operation of local markets, such that seeds are not available within a reasonable distance from any source. For instance, farmers could experience limited saved seed for planting, coupled with dried up social network sources due to flood, drought, and bushfires (Kansiime & Mastenbroek, 2016). Seed access may also be constrained by the depletion of social capital, assets, and income needed to purchase seeds (FAO, 2016; Violon et al., 2016). The later occurs when farmers experiencing extreme climatic events turn to diminish their assets and income sources and thereby reduce their purchasing power. Households with depleted assets and social networks tend to have insufficient seed for planting. Hence, they might need to acquire seeds from local markets, but they have limited economic resources to barter or purchase seed due to their diminished purchasing power.

Seed quality covers seed attributes such as germination, physical purity, moisture content, seed health, and varietal purity for some crops (FAO, 2010, 2015). However, most seeds have an optimum germination temperature alternating between 20 °C and 30 °C, which is quickly deteriorated by extreme temperatures below or above this range (FAO, 2010). The deteriorated seeds typically lose their vital physiological functions and essential quality attributes such as vigor and germinating ability. In this case, farmers may have access to seed, but it may be of poor quality due to high moisture content or rapid deterioration during storage (FAO, 2010; McGuire & Sperling, 2013). The quality dimension could also be affected if the farmers' perception and preference on seed qualities aligned with the varieties that are not adaptable to the impacts of the local climate conditions (FAO, 2016; Gaffney et al., 2016).

The most cited desirable seed attribute include appearance, taste, cooking quality, storability, ability to produce fodder, high-income potential, high production potential, disease, and pest resistance (Almekinders et al., 2019; FAO, 2010). Unsuitable climatic conditions affect this dimension when the varieties farmers possess, know, trust, or prefer are not adaptable to the current local climate conditions (Almekinders et al., 2019; FAO, 2016). For instance, farmers may have millet varieties that take too long to mature, but with the apparent shortening of the rainy season, shorter duration varieties may rather be suitable.

2.3.4 Impacts of Conflicts on Seed Security

Quality seeds of appropriate varieties are considered essential for smallholders to attain food security and climate resiliency. However, human-induced disasters, such as wars and ethnic conflicts, have had an increasingly devastating impact on farmers' access to quality seeds. These impacts are manifested through halting crop production, destroying agricultural assets, and hindering their access to agricultural inputs (FAO, 2010). For example, Sperling (2008) indicated that in a prolonged war context, farmers' social relationships usually are strained such that the routine networks of gift or exchange of seeds are markedly impeded. Similarly, Samberg et al. (2013) found that conflicts weaken social ties within communities because of the fracturing effects of tensions and violent destructions, which increase the dependence of farmers on outside sources for seed. In most cases, formal seed sources are found to break down when conflicts arise (FAO, 2016; McGuire & Sperling, 2013; Sperling, 2008; Sperling et al., 2008).

Since the 1980s, a series of conflicts has engulfed almost all parts of Northern Ghana (Debrah et al., 2016; Talton, 2003b). In each of the disputes, a historically non-centralized, politically and resource marginal groups engaged in protracted fighting with one or several of their historically centralized and dominant neighbors (Pul, 2004; Talton, 2003a, 2010; Tonah, 2012). The conflicts are reported to be mainly fueled by the struggle for resources (e.g., farmlands), power and supremacy, and the rejection of these requests by groups regarded powerful and superior (Debrah et al., 2016; Mahama & Longi, 2013; Talton, 2003a, 2010). The consequences included violent clashes, loss of lives and properties (Mahama & Longi, 2013). As a result, climate change vulnerability among smallholders in Northern Ghana is reported to have been intensified by these protracted conflicts and thereby having adverse effects on seed security (Antwi-Agyei et al., 2012; Michalscheck et al., 2018; Musah-Surugu et al., 2018; Papaioannou, 2016; Talton, 2003b).

Therefore, studying the effects of conflict on natural resources (i.e., farmland and seeds that smallholders require for survival) has become necessary in Northern Ghana, where over 70% of the population is directly engaged in agriculture. Likewise, Taylor (2007) argued that conflicts that restrict access to land and natural resources of these kinds, have significant effects on smallholder production systems, and required research to inform interventions adequately.

2.3.5 Impacts of Macro-Level Stressors

There is evidence of explicit social and ecological costs linked to the globalization of smallholder seed production and distribution systems, which have been experienced in the form of making genetically improved or nutrient fortified crops available in the global south. According to Shiva et al. (1999), whereas seeds and chemical corporations enjoy the benefits of globalization through expanded markets, the cost and risks are exclusively born by the farmers who have little control over the process. Likewise, Sperling et al. (2008) indicated that direct seed delivery, through foreign interventions such as seed aid, is unsuitable for many situations and distort sustainable seed production and distribution.

For example, in Ghana, Lyon & Afikorah-Danquah (1998) found that the economic reforms of the 1980s structural adjustment policies have resulted in the emergence of numerous international enterprises, dealing in and marketing seeds locally. The privatization of seed production and distribution resulted in an increase in the cost of transactions partly due to limited information and demand (Lyon & Afikorah-Danquah, 1998).

Seasonal migration of farmers, from north to urban areas in southern Ghana, in search of jobs and income opportunities, is also reported to have adverse effects on farming. For instance, in localized studies, Schraven & Rademacher-schulz (2016) found that temporary migration in the rainy season, which is undertaken in the search for higher income-earning opportunities in cities, reduces labor availability in smallholder households and leads to missed farming season upon return. Bawakyillenuo et al. (2016); Kumasi et al. (2017) and Assan (2018) also established similar findings that seasonal migration of households members in search of alternative livelihoods resulted in more food insecurity and impoverishment—if the returnee came back with little income and also missed the farming season. Returning with little or no income and missing the farming season increases the likelihood of consuming own-saved seeds and the inability to replenish those seeds in the next season. In other areas, Kansiime & Mastenbroek (2016) found that farmers were more likely to sell all their harvests, including seeds, immediately after harvest due to high demand and better prices from urban areas coupled with an immediate need for cash for other livelihood needs.

2.4 Conceptual Framework: Political Ecology

Different conceptual ideas from human geography (e.g, cultural ecology, political ecology) can be used to explain seed security and climate change impacts. Among them, the political ecology framework serves as a more suitable approach. Political ecology framework has unique potentials of identifying broader systems, rather than blaming proximate and local forces, such as the farmers' socio-economic context and their natural systems (Robbins, 2012). The approach provides a broader and better understanding of factors underpinning smallholder seed security, particularly in the case of Northern Ghana. A political ecology approach offers an opportunity to include analysis of environmental issues, political power struggles (conflicts), historical contexts, government policies, and other macro-level political-economic factors that influence access to and utilization of resources. In so doing, the framework helps to identify and examine the linkages between ecology, politics, and seeds as a resource.

For instance, McGuire & Sperling (2013) and Sperling (2008) conducted seed security assessment among farmers in the contexts of political and civil conflicts coupled with adverse ecological conditions to illustrate seed systems resiliency amid crisis. Similarly, Zimmerer (2003, 2010) used political ecology to provide a comprehensive understanding of seed networks, exchange, and approaches to agrobiodiversity conservation among Andean peasants. Taylor (2007) also used the approach to illustrate how the civil war in Guatemala created and destroyed community cohesion, which, in turn, influenced land use practice and access to productive lands. Papaioannou (2016) employed historical micro-level analysis of the impact of climate shocks and recurrent civil conflicts as an ecological approach to explaining differential climate vulnerability among farmers in Nigeria. The present study builds upon and contributes to this field of scholarly research.

CHAPTER THREE

THE STUDY AREA AND RESEARCH METHODOLOGY

3.1 The Study Area

Fieldwork for this study was conducted from July to August 2019 in two farming villages located 120 km apart (Figure 3.1). These two villages, Buma and Makayili, were purposefully selected for comparative analysis. While both villages are similar based on farming practices, they also differ based on socio-political characteristics (Table 3.1). Buma was selected due to vulnerability to climate risks, while Makayili was selected because of climate risks and protracted ethnic conflict. All the two villages are highly remote and impoverished. Public transportation is limited and unreliable, with bicycles and motorcycles being the primary mode of transportation. The limited availability of transportation poses a significant challenge to accessing seeds outside the villages. In both villages, smallholder farming and livestock herding are the main livelihood activities. Farming is typically more oriented towards household consumption than for commercial purposes. The main staple crops include yam, maize, cassava, groundnut, beans, and millet. Households' livestock holdings include cattle, sheep, goats, chickens, and guinea fowls.

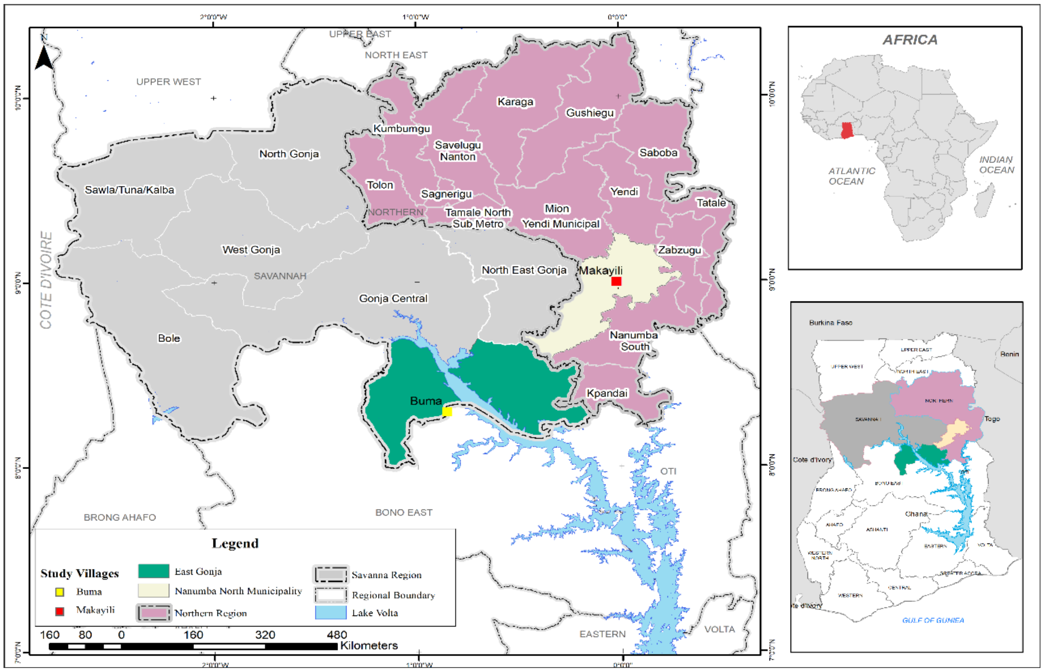

Figure 3.1: Location of Study Setting. *Source:* Map Drawn by Charles Asare Bamfo Jnr, GIS Department, Ghana Statistical Service, Accra.

The soil type in Buma is alluvial, consisting of gleysols found around the Volta Lake (Adjei-Gyapong & Asiamah, 2002). These alluvial soils are low in nutrients, especially nitrogen and phosphorus. The soil type in Makayili is savannah ochrosols, developed from voltanian sandstone materials. They are concrete-like (Adjei-Gyapong & Asiamah, 2002) and easily become impoverished through continuous cropping. These soils also have severe erosion problems, especially in low-lying farmlands. The soil types in both study villages require nutrient-efficient seeds in the traditional farming system.

Table 3.1: Characteristics of the Two Case Study Villages

Main points of comparison	Buma	Makayili
Geographic location	8.5^{o}N 9.25^{o} N, 0.57^{o}E 0.5^{o}E.	8.5^{o}N9.25^{o}N, 0.57^{o}E0.5^{o} E
Estimated population	2,355	5,035
Total households (HH)	336	607

Main points of comparison	Buma	Makayili
Average HH size	8.2*(7.1)*[a]	*7.7(8.2)*[b]
Sampled households		
Quantitative Survey	n (189)	n (240)
Qualitative Interviews	n (10)	n (10)
Main ethnic groups	Konkomba, Gonja	Konkomba, Dagomba
Average farm size	2.28 (ha)	2.35 (ha)
NGO presence	CIDA, since 2014	None
Political conflicts	No conflicts	Protracted ethnic conflict since the 1980s
Distance to the nearest town	24.5 km (Yeji)	20km (Bimbilla)
Road conditions	Unpaved road	Unpaved road
Access to market	No market –24 km to the nearest market	Market Available

Source: Compiled from Ghana Statistical Service (2014a, 2014b) and fieldnotes, July to August 2019.
a= data from East Gonja Municipality.
b= data from Nanumba North Municipality.

The two study sites fall within Ghana's savannah agro-ecology, which is among the poorest parts of the country. The population living below the poverty line is above 65% (Amuzu et al., 2014). The annual mean temperature in this zone ranges between 20.9^{o}C and 35.4^{o}C (Figure 3.2A). The region has a drier climate, marked with a single rainy season that begins in May and ends in October. Total annual rainfall ranges between 631 mm and 1734 mm (Figure 3.2B). The Savanah zone of Ghana is the most susceptible to severe climatic variations, with persistent droughts, recurring floods, and a higher degree of crop failures (Nyadzi et al., 2018; Antwi-Agyei et al., 2012; Nyantakyi-Frimpong, 2020). Limited attention and investment by the central government are also argued to be exacerbating the region's vulnerability to climate change (Madin & Peprah, 2018; Yaro et al., 2015; CARE International, 2013;). These vulnerability contexts made

Ghana's northern region a suitable locale to study how climate change affects seed security.

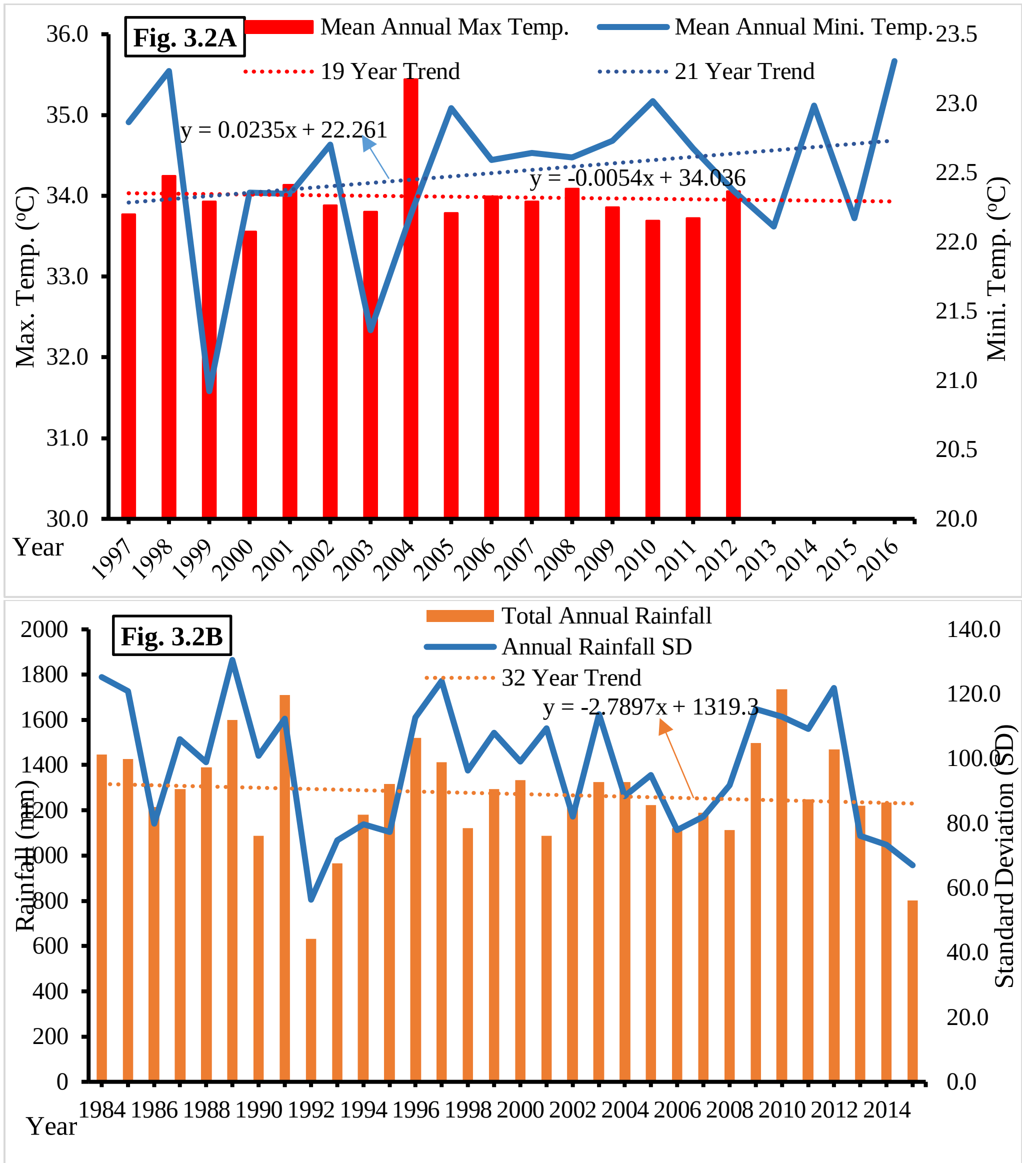

Figure 3.2: Temperature and Rainfall Records from the Meteorological Station (Salaga) closest to the study villages. *Data Source:* Ghana Meteorological Agency, Accra, (2019).

3.2 Methodology

This study adopted a mixed-methods approach using an explanatory sequential research design (Creswell & Clark, 2017). A combination of quantitative and qualitative data collection techniques was used. Since there is no formal census on seed security in northern Ghana, a quantitative survey was needed to identify general patterns of seed access, seed availability, and seed utilization in the study area. The multi-faceted and contextual nature of seed insecurity (FAO, 2015) also required qualitative data collection to understand farmers' lived experiences. This study received research ethics approval from the University of Denver [IRB Protocol # 1428173-1]. Data collection was implemented in three stages, as explained below.

Table 3.2: Sampling Technique and Quantitative Survey Sample Size

Population Projections	**Sample size**
Projected Population (in 2019) = $P_o e^{rt}$	Sampling = n = $\frac{N}{1+N(\alpha)^2}$
P_o = Base year population (in 2010)	
e = Euler's constant (2.71828)	Where n = sample size
r = Growth rate (2.7%)	N = Sample Frame or Total number of Households.
t = period (9years)	1 = Constant
	α = error margin = 5%

Source: Yamane (1965)

3.2.1 Stage 1: Quantitative Survey

A structured questionnaire was prepared and pre-tested in the field before the actual data collection. This questionnaire was designed following the FAO's seed security assessment guidelines (FAO, 2015). Walking along village footpaths and streets, every third household was selected for the survey until the required sample size was obtained. A random sample of 429 households was surveyed, with 189 in Buma and 240 in Makayili (Table 3.1 & Table 3.2). Survey questions included household socio-economic characteristics, food security status, current crops cultivated, and seed systems profile. There were additional questions on seed sources, indicators of seed security, farmer social networks, and perceptions of climate change.

The survey was conducted using the KoBo app. The KoBo app offers tools for conducting surveys on a digital platform using smartphones (Pham, 2019). The Harvard Humanitarian Initiative developed this app in such a way that questions and indicators can be modified and analyzed in the field. The app presents a quick summary of emerging data trends in descriptive statistics, tables, and figures, as the data is being inputted. This rapid analysis of descriptive statistics helped in quickly formulating questions for follow-up qualitative research.

3.2.2 Stage 2: In-depth Interviews and Focus Groups

In the second stage of fieldwork, qualitative data collection was used to delve deeper into emerging findings from the quantitative survey. This stage of fieldwork involved conducting in-depth interviews and focus groups. The in-depth interview participants were selected purposefully from the survey sample. The participants were selected using maximum variation sampling (Miles et al., 2014). Maximum variation was achieved by considering ethnic groups, crops cultivated, methods of farming, and gender. As part of the in-depth interviews, respondents were also asked to illustrate their seed security experiences by using human-environment timelines. The timelines were structured according to the political regimes in Ghana to help the respondents adequately situate and recollect their experiences and perceptions over the years. Qualitative interviews continued until a point where no new issues were emerging from additional fieldwork (Miles et al., 2014). Overall, 20 farmers were interviewed. After the interviews, separate focus group discussions (FGDs) were organized with twelve men in Buma and eight women in Makayili. These FGDs were meant to understand gender-related issues around seed security. The qualitative interviews were transcribed verbatim and added to fieldnotes for analysis.

3.2.3 Stage 3: Secondary Data Collection

Secondary data were also collected from government institutions. Ghana Meteorological Agency provided climate records for the Salaga station, Savannah Region. The data consisted of monthly rainfall totals from January 1984 to December 2015, minimum mean monthly temperature data from January 1984 to December 2016, and maximum mean monthly temperature data from January 1984 to December 2012. These periods of climate data were long enough to examine temporal variability. There were no maximum temperature data from January 2016 to August 2019, and minimum temperatures for the entire of 2017 to August 2019. Rainfall data were also missing from January 2016 to August 2019. The Ministry of Agriculture provided information on fall armyworm records, as well as the government's supply of subsidized improved seeds.

3.2.4 Data Analysis

The households survey data were analyzed using descriptive statistics and regression analysis. Chi-square (χ^2) and Cramer's V statistics were used to establish the bivariate relationship and statistical significance between the dependent variable and independent variables. A multivariate regression analysis was then performed to ascertain the combined relationships between selected independent variables and dependent variable categories (see Table 4.3). The dependent variable was the households' rating of their vulnerability to seed insecurity. The response categories of the dependent variable included; (1) not vulnerable, (2) not sure, and (3) vulnerable to seed insecurity.

The independent variables included age, gender, education, income level, income sources, mobile phone ownership, migrant status, household size, and the number of households member engaged in agriculture. Others included access to credit, crop diversity, type of crops cultivated, and access to tractor plowing service. These variables were selected based on the FAO's seed security assessment framework (FAO, 2015) and relevant literature. For example, smallholder farmers' age and gender are said to significantly influence their access to desired seeds (Almekinders et al., 2019; Alvarez et al., 2005). Likewise, household wealth and social also influence access to seeds (Wencélius et al., 2016). Farmers' accessibility to desired seeds also differs based on farm characteristics (crop diversity and type of major crops) and community remoteness (Kawa et al., 2013; Zimmerer, 2003). Lastly, smallholder households' accessibility to climate and seeds information (e.g., via mobile phone) determines their access to preferred seed and its circulation (Fisher et al., 2015; Ricciardi, 2015; Waldman et al., 2017). Table 4.1 and Table 4.2 provide a detailed description of the independent variables.

Logistic regression was used to predict the determinants of seed insecurity. Logistic regression is most appropriate for predicting categorical outcomes from continuous or categorical predictors or fitting models of the relationships between categorical variables (Field, 2013, p. 2176). However, conducting multivariate logistic regression in SPSS offers different options (i.e., Binary, ordinal, and multinomial) to analyze the dataset. Binary logistic regression was not an option because it required dichotomous dependent variables. The ordinal logistic regression was also not an ideal option since the outcome categories cannot be ordered. The 'Not Sure' category of the dependent variable could be interpreted differently to include either uncertainty in the form of vulnerability (see Kleemann, 2017) or lack of climate information and seed security knowledge, which may not necessarily translate into vulnerability. This interpretation makes it challenging to order the outcome categories in order of vulnerability. Therefore, multinomial logistic regression was found most appropriate for analyzing the dataset.

Three multivariate models were fitted to the referenced outcome variable category. The models were developed based on Wald's ratio significance (p <10%) and theoretical relevance. Although some of the independent variables in Table 4.2 were not statistically significant, they were still included in the models for theoretical relevance. In Model-1, all the independent variables were added using the stepwise method to retain only variables that met the Wald's ratio significance. In Model-2, households' wealth and farming characteristics were controlled to help ascertain socio-demographic variables that could significantly predict vulnerability to seed insecurity. In the final Model-3, social characteristics were controlled to help identify significant wealth and farm typology predictors.

Qualitative data analysis followed the methods outlined by Miles et al. (2014), and Patton (2014). Hand-coding was used to ensure deep and continued immersion in the qualitative data, including in-depth interviews and focus group transcripts. Firstly, a coding scheme was developed using key themes from the literature review. Secondly, codes or labels were assigned to segments of transcripts to help catalog key concepts while preserving the context in which these concepts emerged. After reaching theoretical saturation in the coding process (i.e., when no new concepts emerged from successive coding), I developed emerging themes. Themes represented patterned responses or meanings within the dataset (Miles et al., 2014). Key themes were identified according to criteria that included: (1) relevance to the research objectives; (2) frequency that the theme was mentioned; and (3) the predominance of the same theme across different types of participants (Miles et al., 2014; Patton, 2014). In the results section, verbatim interview quotations have been included to give voice to respondents' own views. These quotes have been carefully selected based on the following criteria: the ability to represent divergent perspectives, typical views expressed by many respondents, and the depth or clarity with which the idea was conveyed (Miles et al., 2014; Patton, 2014).

CHAPTER FOUR

RESULTS

4.1 Socio-Demographic Characteristics of the Sample

Before moving into the analysis, it is necessary to describe the socio-demographic characteristics of the respondents. The survey was conducted with 401 male household heads and 28 female household heads. Fourteen males and six females were also purposefully recruited for in-depth interviews. The mean age of the in-depth interview respondents was 40 years, with a range of 30 to 84. The characteristics of the survey respondents are illustrated in Table 4.1.

Table 4.1: Descriptive statistics of the household survey (n=429)

Characteristics	Survey
Mean age of household heads (years)	40
The age range of sampled household heads (years)	56
Male headed households	(93.5%) *(89.2%)*[a]*(91.3%)*[b]
Female-headed households	(6.5%) *(10.8%)*[a]*(8.7%)*[b]
Household heads who never attended school	(62.9%) *(59.2%)*[a]*(66.2%)*[b]
Households that owned farm tractor	2
Average farm size (Hectares)	2.3
The major cultivated crops	
Maize	381(88.8%)
Yam	373(86.9%)
Cassava	211(49.2%)
Groundnut	46(10.7%)
Access to tractor plowing service	
Fully accessible	135(31.5%)
Partial access	67(15.6%)
Not accessible	227(52.9%)
Households sources of income	
Sale of crop produce	421(98.1%)
On-farm labor	68(15.9%)
Sale of charcoal	74(17.2%)
Sale of livestock	113(26.3%)
Remittances	51(11.9%)
Mobile phone ownership of household heads	
Yes	319(74.4%)
No	110(25.6%)
Means of household seeds acquisition	
Purchase with money	214(73.3%)[c]
Barter	7(2.4%)[c]
Exchange with labor	3(1.0%)[c]
Gift	68(23.3%)[c]

Source: Compiled from Ghana Statistical Service (2014a, 2014b) and fieldwork, July to August 2019. c= only households that acquired seeds aside own saved seeds.

4.2: Determinants of Vulnerability to Seed (In)Security

For the univariate analysis, the null hypothesis (H_o) states that there is no relationship between each variable in Table 4.2 and vulnerability to seed insecurity; hence, any observed pattern is a result of randomness in sampling. The alternative hypothesis (H_A) states that there is a relationship between the variables and vulnerability to seed insecurity, and that the observed pattern cannot be attributed to random in sampling. The study results show that vulnerability to seed insecurity was significantly different between the two villages with a 0.2 effect size. Farmers in Buma rated themselves as being more seed secure compared to their counterparts in Makayili. This finding corroborates that of other studies in northern Ghana, showing statistically significant variations in seed security based on village location (Ricciardi, 2015). In this study, these differences can largely be explained by the dissimilar micro-characteristics of the two villages and the adaptative strategies employed by the farmers (see Figure 4.2).

Table 4.2: Correlation matrix of the determinants of households seed security

Variable	**df**	**χ^2 (Cramer's V)**	**P-Value**
1. Location of respondent *a. Buma b. Makayili*	4	12.831(0.200)	.012**
2. Age of the household head	244	252.844(0.384)	.335
3. Education attainment	20	16.024(0.097)	.715
4. Mobile phone ownership	4	10.987(0.160)	.027**
5. Gender of the household head	4	1.361(0.056)	.851
6. Years lived in the village	264	247.577(0.380)	.758
7. House size	92	99.118(0.241)	.288
8. Number of household members in agricultural	52	65.703(0.391)	.096*
9. Number of income sources	24	31.028 (0.270)	.153
10. Accessibility to credit and savings	4	14.038(0.181)	.007**
11. Number of crops grown (crop diversity)	44	122.591 (0.267)	.000***
12. Types of the three major crops	152	203.994(0.345)	.003***
13. Access to tractor plowing service	28	75.884(0.200)	.000***
14. Total annual income	600	700.798(0.680)	.003***

Source: Quantitative Household Surveys, July to August 2019. **Note:** * Significant at 90% confidence interval, ** Significant at 95%, and *** Significant at 99%.

Secondly, the number of persons engaged in agriculture activities in a given household was found to be strongly correlated with seed security. The established relationship showed that households with some of its members engaged in off-farm activities were less vulnerable to seed insecurity. This finding is explained by the crucial role of non-farm income sources and remittances during times of stress. Households with members engaged in non-agricultural activities (mostly working in cities) turned to demonstrate greater resiliency during climate shocks because of financial support during stress (see also Antwi-Agyei et al., 2018; Azumah et al., 2017). These households can readily replenish lost seeds during shocks such as floods, dry spells, bushfires, and destruction during conflicts. This finding is justified by the fact that only 21.9% of the interviewed households reported having ever accessed credit and loans in times of stress.

Access to credit and savings correlated significantly with perceived vulnerability to seed insecurity. Households who reported having access to credit were also found to be more seed secure. The farmers explained during focus group discussions that the ability to raise money from April to August is critical for acquiring seeds, should a household need to acquire seeds besides its own saved seeds. For instance, a 48-year old respondent summarized a persistent concern raised among most participants:

> *"We used to clear the farmlands with our hand tools, but now we've switched to the use of Condemned [herbicides]. The use of herbicides has increased the cost of farming. Resorting to buying herbicides, fertilizer, and the Agric [improved] seeds has become a huge financial burden on us. I think we need credit to buy seeds"* [**Kenneth, Male, 30 years of farming experience, Makayili]**.

The need for access to desired seeds on credit, as illustrated by *Kenneth*, is necessitated by the fact that current climate variabilities have resulted in a situation where the lean period is gradually coinciding with the planting season in the study villages. Since the true-planting rains have shifted from March to June, the period of April to August served as the lean season (known among the farmers as '*likpaasiil'*). During this period, the sale of harvested farm produce, which serves as the primary source of income, runs out (see Table 4.1). Thus, about 38.2% of the sampled households derived their income solely from the sale of farm produce, which reinforces those households' vulnerability to seed insecurity at the lean season.

The type of crops grown among the farmers also affected household seed security. The analysis showed that households cultivating yam, groundnut, and maize as their major crops tend to be more susceptible to seed insecurity. This finding is consistent with similar studies in other countries (Jarvis et al., 2011; Papaioannou, 2016). Interactions with farmers in the field revealed two reasons explaining why seed insecurity is shaped by the type of crop cultivated. The farmers explained that the germination rate of yam and groundnut is highly dependent on the time and amount of rainfall, as well as a suitable temperature. For example, one farmer mentioned that:

> *"The recent lack of rainfall for planting is a worrying situation. My main crops are groundnut, pepper, and maize, and if I don't get sufficient rain latest by June for planting, then forget, it would be a very poor harvest this year. I normally wait until the soil is sufficiently wet before I plant the groundnut and transplant the pepper. If not, the whole farm would wilt without rain within the next two weeks"* [**Judith, Female, 32 years of farming experience, Makayili]**.

Also, the farmers mentioned that maize tends to be more susceptible to drought during the flowering and maturity period. Given these reasons, prolonged dry spells and unsuitable temperatures during planting and maturity tend to exacerbate vulnerability to seed stresses.

Moreover, the farmers further explained that yam seeds are bulky and costly to transport home. Hence, these seeds are usually kept on the farms for planting in subsequent seasons. The seeds stored on the farm, however, were said to be prone to bushfires, damage by livestock, as well as targets for destruction during ethnic conflicts. One farmer explained this problem by saying:

> *"The recurring tensions [conflict] in this community is a worrying situation. In the recent clashes three months ago, people from the other faction went to the farm undercover and cleared our yam farms with a cutlass. They cut-off all the yam shoots from the yam mounds. It's a common practice here during conflicts in this community. We're even lucky the seeds were planted. They would've set the whole seed barns on fire"* [**Kenneth, Male, 30 years of farming experience, Makayili]**.

Another household head lamented during the interview that:

> "*Cattle rearing by the Herdsmen poses risks to crop farming. Our seeds are frequently being eaten and destroyed by the cattle. However, the traditional authority is always supporting the herdsmen. I understand it's due to the royalties the herdsmen pay to him; he wants to maintain them on the land to sustain the royalties. This makes it difficult to fight the problem. As such, some crop farmers have moved out of this community to safer places"* [**Suleman, Male, 28 years of farming experience, Buma**]**.**

Politics in the form of ethnic conflicts affect seed security, particularly in rural northern Ghana. Illustrations from the above quote reveal how recurring ethnic disputes undermine households' seed security in the study villages. Indeed, these findings show how politics and resource struggles could undermine seed security among smallholder farmers.

Mobile phone ownership and total household annual income also emerged from the analysis to have a statistically significant correlation with vulnerability to seed insecurity. The study results showed that households owning mobile phones are less likely to be vulnerable to seed insecurity because they can access climate and seed information before the planting season begins (Table 4.3). Earlier studies indicate that most parts of northern Ghana have limited access to inputs and climate information services (Assan et al., 2018; Nyantakyi-Frimpong, 2019a; Nyantakyi-Frimpong and Bezner Kerr, 2015). Hence, the only reliable access to climate information and desirable seeds hinge upon mobile phone ownership and usage. Further analysis showed a strong positive correlation between households' mobile phone ownership and total income earning (Likelihood Ratio= 182.490, Cramer's V= .601, p= .036). This relationship buttresses the fact that households earning higher annual income have a greater likelihood to acquire seeds even in the lean season.

Access to tractor plowing services was also significantly correlated with vulnerability to seed insecurity. For instance, households who could afford tractor plowing services to prepare all their farmland (full access) were found to be less vulnerable to seed insecurity than those who could not plow all their farmlands with a tractor (partial access), or those with no access at all. The interviews with farmers revealed that access to tractor service is influenced by strong social networks, relations, and money in the two villages (see also Nyantakyi-Frimpong, 2019b). Some of the respondents expanded on their experience, as illustrated below:

> *"Tractor service in this community is difficult to access. Last year, I couldn't even farm maize because of the difficulties in accessing tractor service. I waited for the tractor to plow my land, but the time it reached my term, it was late to plant, so I stopped. The issue here is that the tractor owners tend to render services first to their relatives"* [**Suleman, Male, 28 years of farming experience, Buma]**.

The above experiences align with earlier findings on the critical role of social networks and household wealth in shaping smallholder farmers' access to tractor plowing service (Antwi-Agyei et al., 2017; Kansanga, 2017; Fagariba et al., 2018). It further illuminates the usefulness of social networks and diverse relations in ensuring adequate seed accessibility and circulation among farmers (Violon et al., 2016; Zimmerer, 2003).

The limited number of tractors further worsens the challenge of accessing plowing services in the study area. Inadequate access to tractor plowing services tends to affect vulnerability to seed insecurity through delayed land preparation for planting. This problem is mainly because the two villages have a tractor each, serving all farming households. Hardly do tractors from neighboring towns come to the villages to provide services. This situation could largely be explained by the removal of government subsidies on tractor services during Ghana's structural adjustment era in the early 1980s (Kansanga, 2017). Limited access to tractors has resulted in farmers having to queue to get their farmland plowed. The tractor owners take advantage of the excess demand to increase prices. The farmers alluded that the seasonal increases in prices make it difficult to buy improved seeds and fertilizer. The time tractor services are needed also coincides with the lean season—the periods most of the households make decisions on whether they would purchase additional seeds. Besides, queuing for tractors results in excessive delays in plowing, and thereby makes planting riskier in case of rainfall variability.

Vulnerability to seed insecurity also emerged to be dependent on the extent of crop diversity. Households cultivating less than three different crops, mostly yam, maize, and groundnuts, were less likely to rate themselves as being seed secured. On the other hand, those growing more than four crops were more likely to be seed secure. Similarly, studies by FAO (2016) indicated that households growing multiple crops were less likely to experienced whole crop failure or be impacted disproportionally by extreme climate events or variabilities.

The results of the multinomial logistic regression models are illustrated in Table 4.3 output[3]. The analysis indicated that mobile phone ownership, access to credit and savings, and access to tractor plowing service are the main significant predictors of seed security (Model-1). The households without mobile phones have lower odds of rating themselves as vulnerable and not vulnerable to seed insecurity compared to reporting as not sure (OR= 0.227 and 0.128, p <5%). The higher likelihood of responding uncertainty on seed security status is because of the lack of mobile phones as a medium of accessing the information on seeds and climate change limit the ability of those households to make

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3 Note that an OR ≥ 1.100 and p > 10% implies that the households are more likely to rate themselves as either *vulnerable* or *not vulnerable* to seed insecurity than reporting as *not sure*. In other words, if we consider only *not vulnerable Vs. Not Sure* categories of the dependent variables in each model, then households were more likely to rate themselves as not vulnerable to seed insecurity compared to reporting as not sure of their vulnerability if OR ≥ 1.100 and p > 10%. Similarly, households were more likely to rate themselves as *not vulnerable* compared to reporting as *vulnerable* to seed insecurity if OR ≥ 1.100 and p > 10%.

informed decisions. Also, households without access to credit and tractor services were associated with lower odds of being vulnerable to seed insecurity relative to those with access to these resources (OR = 0.834, p< 5% and 0.001, p< 1%). Thus, households with no access to credit and savings were 16.6% (0.834 - 1*%) less likely to rate themselves as not vulnerable to seed insecurity compared to those with access, while households without access to tractor plowing service were 99.9% less likely to rate themselves as not vulnerable to seed insecurity compared to those with mobile phones. These results are indicative of the crucial role of information, wealth, and social networks in ensuring adequate seed accessibility and circulation among smallholder farmers.

Model-2 shows that when the social characteristics of households alone are considered, village remoteness, educational attainment, age, and the number of years a farmer has lived in a village, significantly predict vulnerability to seed insecurity. Households in Buma were more likely (OR= 1.955, p <5%) to be vulnerable to seed insecurity. This result demonstrates that in general, there is lower seed security uncertainty among households in Buma compared to those in Makayili. Compared to households in Makayili, those in Buma are associated with a 21.8% chance of being vulnerable to seed insecurity. For educational attainment, household heads without education appeared to be more likely to report uncertainties in their seed insecurity status. Household heads with secondary education or higher had higher odds of not reporting experiences of seed insecurity.

From Model-2 again, household heads aged 40 years or older were found to have higher odds of being rated as not vulnerable to seed insecurity (OR=1.062, p<10%).

Additionally, households who have lived in the villages for five years or less were less likely to rate themselves as not vulnerable to seed insecurity (OR=0.936, p<10%). The later finding corroborates with Abu et al.'s (2014) result that migrant households in northern Ghana are usually challenged in responding to climate-related impacts because they have limited attachment to the community, inadequate access to land, and weak social relations than indigenous households. Migrant status and age of household heads emerging as significant predictors in the multivariate regression contradict the univariate analysis in Table 4.2 and the in-depth interview findings. For example, a 75-year old farmer shared this experience in the interviews:

"I'm old; I've farmed throughout my entire life [...] but I've lost hope in farming recently because of my past 3 years experience. I don't understand why I can't harvest anything from my farm, while some people in this community are getting better yields. Meanwhile, I even planted earlier than they did".

[**Interviewer**]: But don't you think it could be because you planted earlier?

[**Respondent**]: *"Oh yes, it's true, I noticed I'd an abnormal reduced germinating rate. My concern for planting earlier was because I finished preparing yam mounts earlier in October and harvested the yam sets in December. So, I had the fear that I could lose them if I left the seeds too long on the farm"* [**Ramani, Male, 55 years of farming experience, Makayili**].

The findings above show how even the most experienced farmers are admitting to the inability of their longtime gained indigenous knowledge to help them effectively adapt to climatic variations. It further points out the intersection of climatic and non-climatic factors in determining vulnerability to seed insecurity. Thus, the decision of the 75-year-old farmer to plant earlier was based on his experience on how yam seeds left on the farm become vulnerable to high temperatures in March-April, bushfires, and target of destruction during conflicts. Nevertheless, it emerged that his effort could not tackle these factors together with the recurring dry spells and shifting planting season. This particular concern was shared by most of the elderly respondents in Makayili. The results in Model-2 and Table 4.2 show that a farmer's age alone cannot explain climate resiliency unless it is analyzed with other relevant factors.

Table 4.3: Multivariate determinants of households seed security

Independent variables	VULNERABLE TO SEED INSECURITY [a]			NOT VULNERABLE TO SEED INSECURITY [a]			NOT VULNERABLE TO SEED INSECURITY [b]		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
	All variables	Social characteristics	wealth and Farming characteristics						
	OR(SE)	OR(SE)	OR(SE)	OR(SE)	OR(SE)	OR(SE)	OR(SE)	OR(SE)	OR(SE)
Location of respondent *(Ref: Buma)*		1.955(0.820)**			4.479(0.930)**			1.218(1.041)**	
Age of the household head *(Ref: #≥40)*		0.954(0.023)			0.988(0.028)			1.062(0.031)*	
Education attainment *(Ref: none)*		0.001(1.087)***			0.110(2403.554)				
(Ref: #≥Secondary education)								6.550(0.001)***	
Gender of the household head *(Ref: female)*		8.798(1943.497)			1.517(3128.861)			0.636(1.120)	
Years lived in the village *(Ref: #<5 years)*		1.006(0.022)			0.982(0.027)			0.936(0.033)*	
House size *(Ref: #>4)*		0.974(0.090)			0.971(0.113)			0.996(0.076)	
Number of household members in agriculture *(Ref: #< 3)*		0.951(0.205)			0.974(0.254)			1.024(0.167)	
Mobile phone ownership *(Ref: no)*	0.227(0.656)**		0.116(0.585)***	0.128(0.902)**		0.069(0.786)**	0.473(0.655)***		0.881(0.634)*
Number of income sources *(Ref: #< 3)*			1.240(0.397)						
(Ref: #>3)						1.507(0.426)			1.320(0.316)
Accessibility to credit and savings *(Ref. no access)*	5.304(0.259)***		0.284(1.016)	0.001(0.648)***		0.283(0.960)	0.834(1.150)**		1.020(1.152)
Access to tractor plowing service *(Ref. no access)*	6.246(1.497)***		6.753(11.055)			0.281(13.124)	0.001(1.175)***		0.981(7.010)**
Total annual income *(Ref: # < Gh 11,500)*			1.000(0.001)						
(Ref: #> Gh 11,500)						1.000(0.000)			1.00(0.00)
Crops diversity *(Ref: #< 4)*			1.143(0.166)						
(Ref: #>4)						1.158(0.195)			1.166(0.215)
Types of the three major crops *(Ref: yam, maize, and groundnut)*			3.932(13.129)			0.115(13.068)			0.844(15.293)
Goodness-of-fit-test									
Model intercept	(0.558)***	(1.370)***	(15.598)	(1.131)***	(3522.373)	(18.486)	(0.558)***	(0.928)***	(9.634)
Log Pseudo-likelihood=X^2(df)	94.009(36)***	56.011(44)	6.604(100)	94.009(36)***	56.011(44)	6.604(100)	94.009(36)***	780.202(44)	746.607(200)
Pearson	1.000	0.619	0.000	1.000	0.619	0.000	1.000	0.619	0.000
Deviance	1.000	1.000	1.00	1.000	1.000	1.00	1.000	1.00	1.000
R^2 = Cox and Snell	0.199	0.123	0.015	0.199	0.123	0.015	0.199	0.123	0.200
Adjusted R^2 = Nagelkerke	0.231	0.142	0.024	0.231	0.142	0.024	0.231	0.142	0.232

OR= Odds Ratio, SE= Standard error, * P< 10%, ** P< 5%, *** P< 1%, Ref:# = Reference category of the independent variable, $\chi 2$ = Chi-Square statistic, df = degree of freedom,
R2 = Regression coefficient. a= Reference category of the dependent variable is Not Sure of Seed Security Status. b= Reference category of the dependent variable is Vulnerable to Seed Insecurity

In Table 4.3, the results of Model-3 considered wealth and farming characteristics while controlling for the social characteristics of the households. Taking the collective effect of all the variables in Model-3 into account, it emerged that mobile phone ownership alone is a significant predictor. Although access to credit was a significant predictor in Model-1 when the stepwise entering method was used, collinearity and cofounding effects eradicated its statistical significance when all household economic variables were maintained in Model-3. Thus, households without mobile phones were less likely (OR=0.116, $p < 1\%$) to be vulnerable to seed insecurity. Likewise, households without mobile phones were 11.9% less likely to rate themselves as not vulnerable to seed insecurity compare to those who owned mobile phones. Those without access to tractor plowing service were also found to be less likely to be vulnerable to seed insecurity (OR=0.981, $p< 5\%$).

Mobile phone ownership and access to tractor plowing service emerged as the only significant predictors in Model-3. This finding is also supported by the fact that mobile phone ownership, as an indicator of wealth, consistently emerged as a significant predictor of vulnerability to seed insecurity whenever it was included in a model. Monetary wealth is essential for ensuring seed security in the study sites because 73.3% of the households who reported having acquired seeds, besides own saved seeds, did so through purchasing with cash (see Table 4.1).

4.3 Human-Environment Timelines in the Context of Seed Insecurity

This section adds more depth to the preceding results by exploring the human-environment timelines associated with experiences of seed insecurity over the past three decades. The survey showed that most of the households (51.1%) were making adaptative efforts mainly by altering either their crop type or quantity of seeds planted during the last season. Further inquiry during the in-depth interviews revealed that these decisions are mostly influenced by more than one factor, which is indicative of the multifaceted nature of seed security. It is worth noting that some of the respondents recalled these timelines with exact years. For example, a 52-year old respondent recounted his experience of the dry spell and shifting raining season in 2012 and 2013, saying:

> *"Frequent dry spells have become a big problem for us here, and it all started in the 2012 farming season. So, in 2013 some of us subscribed to climate insurance in order to safeguard the poor germination rates"*
> [**Clifford, Male, 32 years of farming experience, Buma].**

Other elderly respondents specifically mentioned that the 1983, 1993, and 2006 farming seasons were the worst they have experienced in their lives, in terms of dry spells and recurring rainfall variabilities (see Figure 4.1).

Based on the human-environment timelines, socio-economic and political factors are those that have long affected seed security. Examples of these factors included seed subsidies, seed destruction by Fulani Herdsmen and their cattle, and agricultural restructuring that has affected tractor plowing services. In terms of climate change, higher temperatures were also reported as being historically recurring. Factors that appeared to be more recent were mainly related to soil fertility, land degradation, and pest infestation.

Figure 4.1: Human-Environment Timelines (*n*=20)**.** Timelines split according to gender and village location.
Data Source: Compiled from Fieldwork, July to August 2019.

Whereas the timelines indicated in Figure 4.1 may be attributed to respondents recall bias at first-sight, analysis of meteorological data largely confirmed the household experiences. For instance, temperature data from the meteorological records showed that the minimum temperature is increasing at an annual rate of 2.4% (see Figure 3.2A). The trendlines in Figure 3.2A equally showed a steady rise of both minimum and maximum temperature after 2012, which corroborated what farmers reported. Earlier studies in the savannah ecological zone also confirmed increasing dry spells during the planting season as a recurring phenomenon in the study sites (see Badmos et al., 2018). According to Laux et al. (2008), the recurring dry spells adversely affect the onset date of the optimum growing period. The optimum growing period is considered critical for ensuring good seed germinating rate and survival after planting (Nyantakyi-Frimpong & Bezner-kerr, 2015). As such, when seeds are planted too early before this period, there is a high likelihood of losing planted seeds in the event of prolonged dry spells. This finding is so because the local maize varieties require consistent rainfall over four months for a good yield. To a large extent, this finding underscores the need for making improved seeds available to ensure both seed and food security.

Also, while the total rainfall trend is not too explicit in earlier studies, Figure 3.2B suggests a gradual decline in the total rainfall in the study villages. Rainfall in the study area tends to occur in heavy torrents and is concentrated in a few months, mostly between August to October. This phenomenon results in substantial flooding of farmlands. A 47-year old farmer recounted his experience of perennial flooding by stating:

> *"The floods were very destructive [...]. After the floods, some of us have to hunt for our yam on top of trees [laughter]. I mean, when the floods came, it uprooted yams and carried them away, but as the yams still with shoot get to shrubs, they got trapped and hangs on top. So, we followed the paths of the floodwaters to pick the hanging yams, but we lost most of the yams"* **[James, Male, 30 years of farming experience, Makayili]**.

Farmers consistently noted that perennial flooding has resulted in crop failure and destruction of farmlands. The complaint about low crop yields and total crop failure was mostly among households engaged in maize and groundnut farming. These households explained that when farmlands are flooded, it takes several weeks for the floodwaters to drain due to the impervious, poor soils, thereby affecting crops in the field. Records from the National Disaster Management Organization (NADMO) also indicated substantial numbers of reported flood cases by the past few years. The official data shows that 41 hectares of farms were affected by floods in 2016, while 685 hectares and 33 hectares were destroyed respectively in 2017 and 2018. Government officials at the NADMO Unit indicated that bushfires had destroyed 7,000 yam seedlings, 500 yam tubers, and 120 hectares of rice farm in the municipality between 2015 and 2019. According to the farmers, though the annual occurrence of bushfires is not new, the shifting rainfall patterns and seasonality are making it more challenging for them to adapt effectively.

From Figure 4.1, it is interesting how the farmers linked the use of herbicides with land degradation and loss of soil fertility. For instance, a 52-year old respondent expressed a persistent concern raised among most of the participants:

> *"The loss of soil fertility and land degradation issues started with the use of condemned [herbicides]. The first time I applied it was in the 2009/2010 season. I noticed that whenever I applied condemned, it kills the grass together with the roots and some insects in the soil. I think these make the soil loose when it rains. Furthermore, it quickly gets dry too and hardens when it stops raining for a few days. These cause poor germination of seeds."* [**Frances, Male, 32 years of farming experience, Makayili]**.

Grainger-Jones (2011) has noted that the excessive use of agrochemicals such as herbicides, pesticides, and fertilizers has resulted in land degradation, diminished soil nutrients, and loss of biodiversity in Africa. These findings point to the need for making nutrient-efficient seed varieties accessible among farmers. It was also revealed during interviews with the farmers that the yam seeds tend to rot quickly and faster than normal if herbicide was applied on the farm. They explained that under normal circumstances, yam seeds could be left for about six months without a significant loss. Conversely, however, farmers pointed out that, due to the recent use of herbicides, about two-thirds of their yam seeds rot six months after harvest. While this concern from the farmers is currently limited in literature, most of the respondents insisted that the herbicide was responsible for the high incidents of yam seeds deterioration. This concern needs further research to substantiate the farmers' claim since it could also be attributed to the recent rise in minimum temperatures (see figure 3.2A).

Moreover, the farmers indicated seasonal fluctuation and hike in seed prices as a significant constraint on seed security. This phenomenon is specifically particular in rural settings where most of the farmers grow on a subsistence basis. Rural northern Ghana further presents a unique constraint to the farmers because of its prolonged dry season characteristics. This problem is mainly because agricultural activities are highly dependent on rainfall. Also, the sale of farm produce serves as the primary source of household income (about 98.1%) in the study sites. The limited availability of farm produces and seeds, on sale in the lean season, results in price hikes. As a result, it is difficult to raise money to buy seeds. These challenges reinforce vulnerability to seed insecurity.

The respondents further illustrated that frequent changes in government agricultural subsidy programs over the years has also affected the prices of improved seed. For instance, unlike in 2017, where the farmers obtained improved seeds under a government subsidy, from the year 2018 onward, the farmers were compelled to purchased improved seeds from retail shops with full payment. Similarly, the withdrawal of government subsidies on tractor plowing services during structural adjustment programs in the 1980s has made it increasingly difficult for the farmers to afford the full cost of plowing their farms (Fagariba et al., 2018; Kansanga, 2017). Moreover, Kansanga (2017) indicated that the removal of the subsidies had created an avenue for private sector entry into the tractor service market, which has resulted in exploitation and price hikes.

4.5 Households Adaptation to Seed Insecurity

4.5.1 Government Support

The field interactions and interviews revealed that central and local government institutions provide critical roles in building households' coping and adaptation strategies to seed insecurity. Likewise, Yaro et al. (2015) noted that local institutions offer a valuable framework within which individual capacities of the rural farmers can be fostered to adapt to climate impacts effectively. Most of these government and institutional supports have been executed through the planned adaptation of national efforts such as the Livelihood Empowerment Against Poverty (LEAP) program and the national disaster management initiative. The later involves giving material and cash aids to households affected by disasters such as flooding and bushfires. The LEAP program comprises cash payments to affected households via funds provided by the central government into the Municipal LEAP account. Besides, the government of Ghana, through other funding agents, provides subsidized improved seeds of selected crops to local farmers to help adapt to climate variabilities. The improved seeds are mainly supplied under the Planting for Food and Jobs (PF&J) program. Also, the municipal officers routinely pay visits to the communities to sensitize and educate the households on early disaster mitigation and adaptations. These government interventions are considered necessary in reducing vulnerability to seed insecurity.

However, some of the interviewed households reported discontent with institutional support in building their resiliency to seed insecurity. For example, a 47-year female household head in Makayili expressed one of the concerns shared by most of the interviewers, saying:

> *"We all wrote our names for support after the fall armyworm infestations. However, only a few privileged people received compensation. Even some of those who received the aid wasn't affected by the armyworm pests"* [**Naomi, Female, 32 years of farming experience, Makayili]**.

These negative concerns with institutional support have created a situation where farmers affected by climate disasters to not report to government officials for help. This problem affected planning efforts to support vulnerable households.

4.5.2 Geographical Expansion of Seed Acquisition Networks

The study further revealed that the farmers resort to the geographical expansion of their seed networks during times of stress as an adaptative strategy. However, the distance covered in accessing seeds, through these extra-community networks, was significantly different between the two villages ($p = 0.012$). This finding was established via the aggregate network of all seed sources utilized by the respondent households. The result indicates a more outward spatial interaction among households in Buma and a limited spatial interaction of repeated seed acquisition among households in Makayili (see Table 2 and Figure 4.2). The red rectangle represents the study village. The black dot indicates places where seeds were acquired mainly through social networks. The green diamond shows places were seeds were acquired from both social networks and the local market. The first circle (in yellow) indicates that seeds acquisitions occurred within less than a 20 km radius. The second circle (in blue) indicates that seed acquisitions occurred within less than a 60 km radius. The third circle (in red) indicates that seeds acquisitions occurred beyond a 100 km radius.

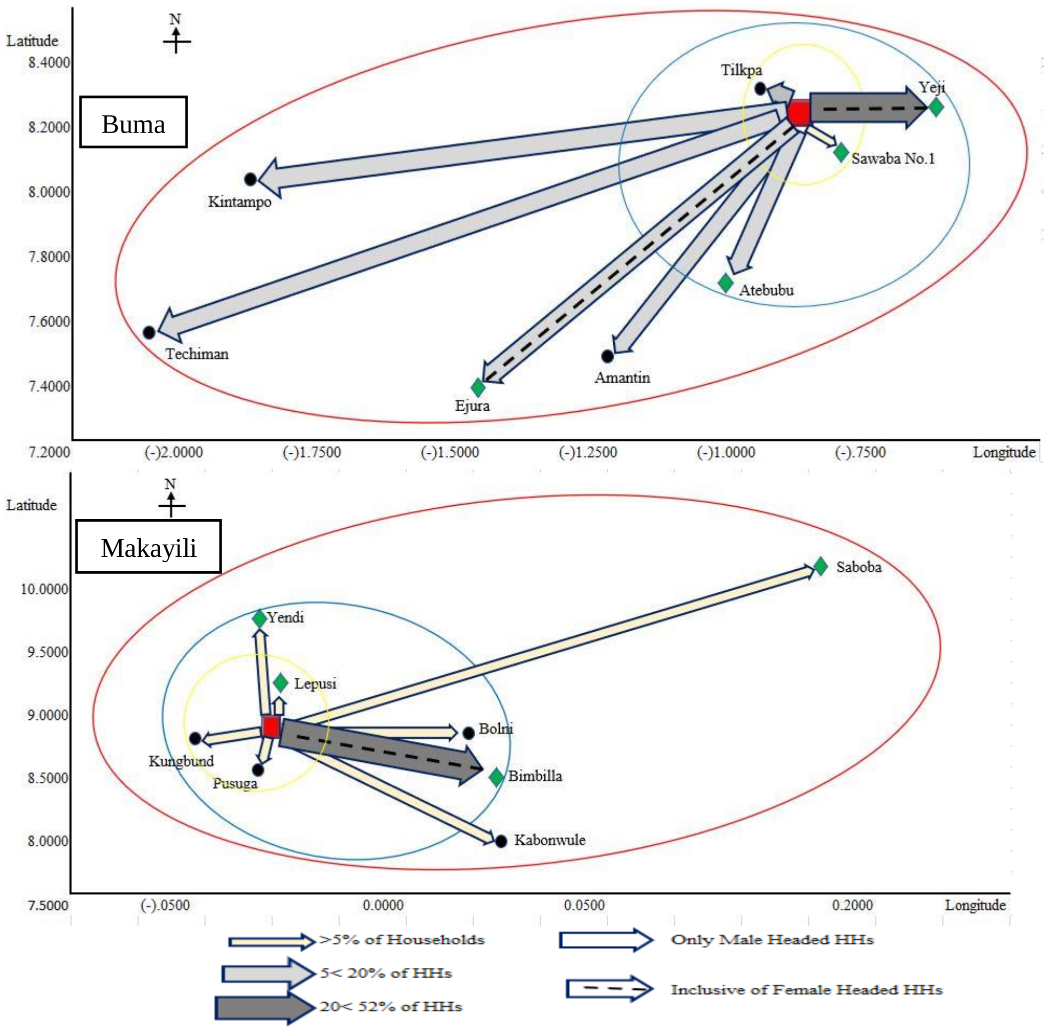

Figure 4.2: The Spatial Interactions and Geographical Extent of Seed Sources in the Two Villages for 2018 and 2019 Cropping Seasons.
Data Source: Compiled from Fieldwork, July-August 2019.

The interviewed households emphasized that acquiring seeds from distant neighboring communities was essential to achieving seed security even if their own saved seeds were not lost. For example, one 56-year old respondent stated:

> *"I acquire new seeds every planting season because if I keep planting only my own saved seed over a long period, it loses its quality and quantity of yield. As such, I prefer acquiring seeds from faraway villages with different soil types from this community"* [**Judah, Male, 38 years of farming experience, Buma]**.

This view was shared by most of the households (52%) in Buma and 10% of those in Makayili. The view of the farmers shows that extra-village spatial interaction is not only necessary for achieving seed security but also essential for conserving species and agrobiodiversity loss through continuous cropping. This finding collaborates with Zimmerer (2003) and Bellon et al.'s (2011) findings that exchange of seeds between the hill and valley farming villages in the Andean region was necessary for maintaining the agrobiodiversity of their crops.

Figure 4.2 depicts the relationship between the gender of household head and distance traveled to acquire seeds. This result is consistent with Zimmerer's (2003) work in the Andes but contradicts the findings of Wencélius et al., (2016) in northern Cameroon. It appeared that the result contradicts because Wencélius et al., (2016) selection of respondents was based on household wealth, which predicated the ability to acquire seeds from distance communities. However, in this study, the female-headed households gave two main reasons for their relatively limited spatial interaction in seeds acquisitions. On the one hand, about 83.3% stated that seeds of the crops (e.g., groundnut, maize, beans, and cassava) they cultivate are readily available within and near the villages, and they do not need to travel a long distance to acquire the seeds. On the other hand, 60% indicated that the lack of means of transportation impedes their ability to travel a long distance to acquire seeds.

Figure 4.2 also illustrates the sites for extra-village seed acquisition. The towns Yeji and Bimbilla serve as the central extra-village sources for seed acquisition by farmers in Buma and Makayili, respectively. The two central towns shared vital characteristics that make them suitable destination of seed sources for over 52% of the households in the two villages. First, Yeji and Bimbilla both serve as municipal capitals where improved seeds can be acquired from the agriculture unit and commercial seeds dealers. The two towns have local markets where grains of all varieties from other neighboring villages are sold and bought. Most importantly, they are located relatively closer to the villages within a radius of fewer than 60 km. Lastly, these central seed sources are also connected to the study villages by year-round motorable roads with public buses to facilitate mobility.

4.5.3 Construction of In-house Seed Barns

Another notable coping strategy for seed insecurity is the construction of in-house seed barns. Figure 4.3 shows seed barns in the two study villages. The green barns represent storage facilities for yam seeds, while the yellow ones are for storing grain seeds. Thus, households that could afford have resorted to constructing seed barns near their houses to safely store their seeds to prevent seeds loss and destruction by conflicts, cattle, and frequent bushfires.

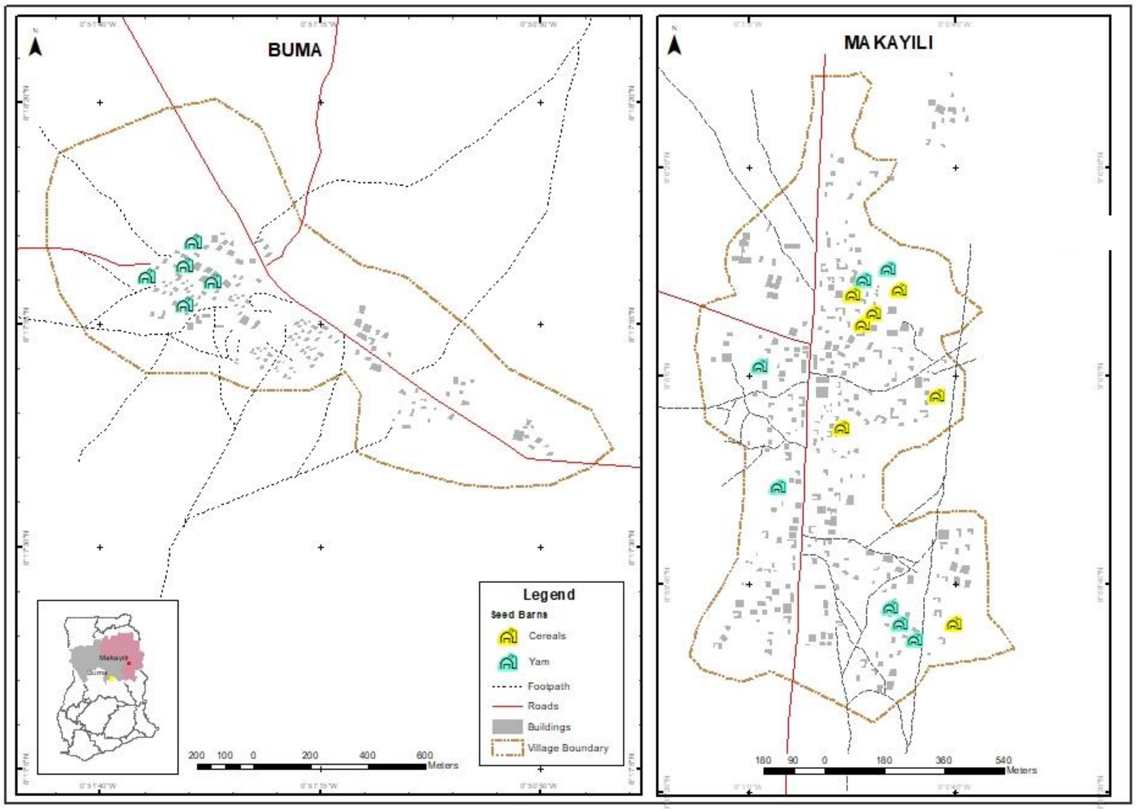

Figure 4.3: The Construction of In-house Seed Barns as an Adaptive Strategy.
Data Source: Compiled from Fieldwork, July-August 2019.

However, this implies that seeds must be transported from farms to be stored after harvest and back to farms for planting during the farming seasons. As a result, most of the respondents complained that this particular adaptive action was costly and labor-intensive and could only be undertaken by worthy farmers. These conditions explain why only a few barns are present in the villages, as shown in Figure 4.3. Nevertheless, constructing in-house seed barns is more prioritized among households in Makayili than those in Buma. This is mainly because of the recurring conflicts in Makayili that tend to affect seeds kept in storage.

CHAPTER FIVE

DISCUSSIONS AND CONCLUSION

5.1 Synthesis of Results and Relations to Existing Literature

This study contributes to the literature on climate change and seed security. The univariate analysis indicates that while some of the variables were statistically significant in shaping farmers' perception of seed security and climate change, others were not significant. The variables that were significant included village location, mobile phone ownership, number of household members engaged in agriculture, accessibility to credit, crop diversity, access to tractor plowing services, and total annual income. The multivariate analysis suggests that experiences and perceptions of climate change influence perceptions of vulnerability to seed insecurity. This finding reaffirms evidence from other related literature suggesting that experiences and perceptions about climate change influence agricultural decisions—such as making seed choices now and in the future (see Waldman et al., 2017; Jain et al., 2015; Sekhar et al., 2015).

Results of Model-1 indicated that mobile phone ownership, access to credit and savings, and access to tractor plowing services are the significant predictors of vulnerability to seed insecurity. These results point to the crucial role of information, wealth, and social networks in ensuring seed security. Similarly, Almekinders et al. (2019); Pons et al. (2017); Fisher et al. (2015); Waldman et al. (2017); and Croft et al. (2018) have pointed out that farmer seed choices are determined by the availability of information on seed performance, and the transfer of that information. Assan et al. (2018); Wencélius et al. (2016); Gaffney et al. (2016); Urrea-hernandez et al. (2016); Tripp & Mensah-bonsu (2013); and Coomes et al. (2015) found that household's wealth and access to credit were linked to the acquisition of good quality seeds, as these allow purchasing and disseminating new varieties. Also, Violon et al. (2016) and Kawa et al. (2013) have indicated that farmer seeds transfers follow social relations around family membership, status, wealth, and trust, even in the absence of market-mediated seeds exchange.

Model-2 shows that among the social characteristics of households, only village location, educational attainment, age, and migrant status of household heads significantly predicted vulnerability to seed insecurity. Likewise, Croft et al. (2018); Bellon et al. (2011); and Zimmerer (2003) showed that the geographical location of farmers has an influence on both access to seeds and its circulation. Ekhuya et al. (2018) and Fisher et al. (2015) found that more educated household heads were also more likely to adopt improved seeds. Fisher et al. (2015) show that compared with younger heads, older household heads were more likely to adopt new seed varieties, which may be indicative of the unwillingness of older farmers to get rid of native seeds.

Model-3 in the regression showed that when only household characteristics are considered, mobile phone ownership and access to tractor plowing service were the significant determinants of vulnerability to seed insecurity. This is indicative that mobile phone ownership, as an indicator of wealth, could serve as a useful predictor of vulnerability to seed insecurity among farmers. In other related studies, Poudel et al.

(2015) and McGuire & Sperling (2015) indicated that the traditional seeds sharing among farmers is changing toward more seed purchasing, and points to the increasing importance of wealth in accessing desired seeds.

The in-depth interviews revealed that farmers have been experiencing seed insecurity over the past three decades. Furthermore, these experiences are shaped by different factors, both climatic and non-climatic. The farmers admitted that whereas some of these factors have long been historically present in the study area, others are very recent. Those factors that appeared to be more recent were mainly climatic in nature. Overall, the findings showed that the intersection of climatic and non-climatic factors is making it challenging to ensure seed security. Climate variabilities do not appear as the sole concern in ensuring seed security. Farmers' immediate concerns also reflected several issues that are non-climatic in nature, including the government's subsidies on seeds and fertilizers, ethnic conflicts, and farmer-herder conflicts.

The study findings further revealed that households are responding to seed insecurity with some adaptive strategies. Foremost among these strategies include government support such as the provision of seed aid. Farmers also resort to the geographical expansion of their seed networks during times of stress. However, the distance covered in these extra-community networks was found to be significantly different between the two villages ($p = 0.012$). Further analysis indicates a more outward spatial interaction among households in Buma than in Makayili. Interviews with the farmers show that extra-village spatial interactions are not only necessary for achieving seed security, but also essential for conserving species and agrobiodiversity loss through continue cropping (see also, Bellon et al. 2011; Zimmerer, 2003). The results also showed that female-headed households' seed acquisitions were more predominant within the study villages and in nearby communities. These women-headed households were less willing to procure seeds beyond a distance of 60 km. Another coping strategy adopted by farmers was the construction of in-house seed barns. Many wealthy households have constructed barns to safely store seeds and prevent loss and destruction by livestock, bushfires, and social conflicts.

The approach and findings of this thesis have relevance for human-environment research in political ecology. Earlier and critical studies in this sub-field have explored how neoliberal policies (e.g., Wattnem, 2016; Shiva et al., 1999; Nyantakyi-Frimpong, and Bezner Kerr, 2017), government seed interventions (Sperling et al., 2008), micro-level and gendered politics (McGuire & Sperling, 2013; Nyantakyi-Frimpong & Bezner-Kerr, 2015; Sperling, 2008) impact smallholder farming systems. This study further contributes to this scholarly work demonstrating how historical ethnic conflicts, government subsidized seed programs, and neoliberal economic policies contribute to farmers' seed security. It also illustrates how the combined effects of climate change and conflicts influence seed storage dynamics. As the results demonstrate, it is not only climate change that might constrain and shape smallholder seed security. So too are local- and macro-political economic proccesses in both historical and contemporary times. Novel in this study is the use of seed security assessment framework and consideration of all the seed systems (i.e., both formal and informal seed systems) available to the farmers.

5.2 Policy Implications and Conclusion

Government and non-governmental institutions responsible for supplying improved seeds should pay attention to getting seeds closer to farmers. As the study results indicate, female-headed households were less likely to travel far to access seeds. Getting seeds closer to farmers would ensure equitable access to improved planting materials and effective redistribution of desired seeds. It is also recommended for policy interventions to increase equitable access to quality seeds among farmers through credit provision to poor households rather than the general approach of using subsidies. The credit provisioning approach would ensure that specific farmers (needy households) are targeted and seeds made available to them during planting season while they pay immediately after harvest without or with minimal interest. This approach is not expected to create indebtedness among farmers because the quantities of seeds required for planting form only a small fraction of their farm produce (McGuire & Sperling, 2011). The need for access to improved seeds on credit during the planting season is necessitated by the fact that current climate variabilities have resulted in a situation where the lean period is gradually coinciding with the planting season, as the true-planting rains have shifted from March to June.

There is the need to harnessing the potentials of disseminating information on climate and seed through mobile phones, especially with translated information in local languages. Evidence shows that increased access to information on climate change and seeds is key to enhancing improved seed adoption rates among farmers (Almekinders et al., 2019; Fisher et al., 2015). For instance, Fisher et al. (2015) found that households that received information on improved varieties of seed were more likely to adopt them.

Likewise, Waldman et al. (2017) indicated that farmers' adoption of improved seeds is often affected by the availability of information on seed performance. Therefore, mobile phones could be used to disseminate seed-related information to local farmers. Also, of particular importance is the ability of farmers to establish new seed network partners over distance and maintain those relationships through simple phone calls.

There is also a need to ensure the timely provision and access to tractor plowing services to farmers. Based on the vital role social networks play in accessing plowing service and seeds (Kansanga, 2017; Violon et al., 2016), it is argued that prioritizing farmers' social networks and the resources inherent in those social capitals would be crucial. Government policy interventions to supply tractor plowing service should be designed to harness these existing social networks in smallholder farming systems. Besides, there is a need to promote the private sector's involvement in providing tractor plowing services. This recommendation can be achieved by providing tax incentives and reducing import duties on tractor importation. It would ensure that tractors are adequately available to provide timely plowing services to the farmers.

Finally, there is a need to support local government agricultural institutions to help farmers whose seed security has been affected by floods, bushfires, insect infestation, and other socio-ecological stressors. Proper targeting in such programs would ensure that government assistance is delivered to the neediest farmers experiencing seed insecurity. As well, government institutions need to be equipped with the required resources and capacity to effectively provide early warning services to farmers to help them safeguard their seeds against destructions by floods and bushfires. These agencies need to ensure frequent education and sensitization of the farmers on the proper application of agrochemicals and timely creation of fire belts to protect seeds from bushfire destruction.

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Appendix A: Household Survey Questionnaire

Name of community: ....

Name of enumerator: ....

DATE..
TIME...

Research Objective 1: Smallholder farmers' experiences of seed insecurity and how these experiences differ by socio-economic characteristics

1. Age of respondent: ……………………………… (years)

2. Gender (Sex): Male ☐ Female ☐

3. Relationship: Household head ( ) Spouse ( ) Child ( ) Other living in HH ( )

4. Education Attainment: None ( ) Nonformal ( ) Primary school ( ) Secondary ( ) Tertiary ( )

5. Mobile Ownership: Yes ( ) No ( )

6. Gender of the household Head: Male ( ) Female ( )

7. Residential status of the household: Owner ( ) Tenant ( ) Free Occupant ( ) Others…………..

8. For how long have you continually lived in this Community?....................... (Years)

9. How many people live in this household?

Total	<5 years	5- 17 years	18- 35 years	36- 60 years	>60 years

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

11. Do you rear livestock? Yes ( ) No ( )

12. If yes which type of livestock do you keep? And how many do you have?

Type	**Number**	**Type**	**Number**
Cattle	…………	Sheep	……………
Fowls	……………	Pigs	…………..
Guinea Fowls	………….	Others (specify)…………………………………..	
Goats	…………...		

13. What were your **Main** sources of income last season?

Source	**Amount**	**Source**	**Amount**
Crop produce	…………	Livestock sale	………….
On-farm daily labor	…………	Livestock products	………….

Hunting & gathering ………… Remittances ………….
Non-on-farm daily labor …………. Petty trade ………….
Sale of charcoal/fuel wood …………. Salary ………….
Others (specify)…………………….

14. Who decides on which crop is sold and how the money is used? Men ( ) Women ( ) Both ( )

15. Are you able to save some cash from the income you earned? Yes ( ) No ( )

16. Are you able to access credit from any source? Yes ( ) No ( )

17. For how many days (0-7) of the last 7 days have you eaten the following food groups?

Food group	**Days (0-7)**	**Food group**	**Days (0-7)**
Cereals	………………	Milk/ milk products	……………….
Roots and tuber	…………….	Fruits	………….
Pulses / legumes	…………….	Sugar / sweet	………….
Vegetables	……….…….	Oil / ghee / fat	………….
Meat / fish / eggs	………………		

Objective 2: understand the temporal nature of seed insecurity experiences

18. What crops did you plant last season?

Cereals

Sorghum ( ) Maize ( ) Rice ( ) Millet ( ) bulrush

Oilseed/Legumes

Groundnut ( ) Beans ( ) Cowpea ( ) Bambara Beans ( ) Soya ( )

Tubers/Root

Cassava ( ) Sweet potato ( ) Potato ( ) Cocoyam ( ) Yams ( )

Vegetables

Banana ( ) Tomatoes ( ) Pepper ( ) Okra ( ) others (specify)………..

19. Of the above crops, which were the three most important you cultivated last season?

Crop production parameters	**Crop A**	**Crop B**	**Crop C**
a) Name (or code) of the three most important crops			
b) What is the Main use of the crop? 1= food; 2= income; 3= social (e.g. funerals)			
c) What land area did you plant during the last season? (unit in acre)			
d) Farming method: 1= Slash and burnt; 2= Zero/minimum tillage; 3= use of hand tools; 4=Animal traction; 5= Tractor			
e) Quantity of seed used (number of bowls for cereals and # of sets for tuber/root)			
f) How was the crop grown 1=rain-fed or 2= irrigated?			
g) What was the cropping practice? 1=mixed crop; 2=sole crop			
h) What kind of fertilizer did you apply? 1= organic, 2= inorganic			

Crop production parameters	Crop A	Crop B	Crop C
j) If organic, what type of manure? 1=compost; 2=animal; 3=others ………..			
k) Quantity harvested (number of bags for cereals and # of tubers/roots for tuber/root)			
l) How do you rate the harvest? 1=Excellent; 2=Good; 3=Fair; 4=Poor 5=Very Poor			

20. Of the above main crops, which ones will you plant during this upcoming season?

Crop production parameters	Crop A	Crop B	Crop C
a) Name (or code) of the three most important crops			
b) What is the land area planted or expected to be planted? (unit in acre)			
c) Quantity of seed expected to be planted? (number of bowls for cereals and # of sets for tuber/root)			
d) Would you change your Main crop(s): 1=Yes 2=No			
e) Main reason for change in main crop(s) if any (See codes below)			
f) Would you change land area to be planted: 1= Yes; 2=No			
g) Main reason for change of area if yes (see codes below)			

Codes for Main reason for change

1 = Increased climate risks; (e.g. lack of rainfall, low rainfall, shorten rainy season, high temperature/heat)

2 = Lack of land;	8 = Increase in seed prices;
3 = Access to more land;	9 = Decrease in seed prices;
4 = Lack of labor force;	10 = Decrease of produce price;
5 = Access to more labor force;	11 = Guaranteed selling price or secure market;
6 =Lack of desired seeds;	12 = Household needs
7 =Better access to seeds;	13= Land conflict

Objective 3: critically evaluate farmers' strategies used to improve seed insecurity

21. Overall, if you consider the following seed sources, will there be enough seed available for

i. Crop A during the upcoming or this season? (Upcoming- March July, 2020/ this season- March July, 2019) Yes ( ) No ( )

ii. Crop B during the upcoming or this season? (Upcoming- March July, 2020/ this season- March July, 2019) Yes ( ) No ( )

iii. Crop C during the upcoming or this season? (Upcoming- March July, 2020/ this season- March July, 2019) Yes ( ) No ( )

22. What was/were your source(s) of seed for the important

i. Crop A? In the lasts planting season

1. Own seed ( ) 2. Local Market ( ) 3. Social Network ( ) 4. Agro-input- Dealer ( ) 5. Seed aid ( )

ii. Crop B? In the lasts planting season

1. Own seed ( ) 2. Local Market ( ) 3. Social Network ( ) 4. Agro-input- Dealer ( ) 5. Seed aid ( )

iii. Crop C? In the lasts planting season

1. Own seed ( ) 2. Local Market ( ) 3. Social Network ( ) 4. Agro-input- Dealer ( ) 5. Seed aid ( )

23. If you obtained seeds from the local market, where did/will you buy your seed from? Market 1:………………………… Market 2:……………………………

24. Varietal suitability, availability, accessibility, and quality of major crop seeds from the source(s) indicated above.

Crop production parameters	**Source(s) of seed for last planting season**														
	Own			**L. Market**			**S. Network**			**A.I. Dealers**			**Seed aid**		
	A	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
a) Name of the Major variety															
b) Was the seed clean? 1= clean (no impurities, no damage); 2= fairly clean (some impurities, no damage); 3=not clean (Some impurities & damage)															
c) Was there enough seed from this source? 1=Yes; 2=No															
d) How did/will you desire sees from these sources 1= very desirable 2= desirable 3= Neutral 4= Not desirable 5= At All															

25. Availability and accessibility of major crop seeds from the source(s) indicated above.

Crop production parameters	**Source(s) of seed for last planting season**														
	Own			**L. Market**			**S. Network**			**A.I. Dealers**			**Seed aid**		
	A	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
a) Name of the Major variety															
b) Would the variety for next season be same as last season? 1= Yes; 2=No															
c) If No, Main reason for change of variety (see codes below)															
d) What type of variety were they? 1= local; 2=improved															
e) Is there enough seed from this source? 1=Yes; 2=No															
f) What quantity of seed did/will you plant from this source? (# of bowls or sets)															

Crop production parameters	Source(s) of seed for last planting season														
	Own			L. Market			S. Network			A.I. Dealers			Seed aid		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
g) Would you change the quantity of seed from this source? 1=Yes; 2=No															
h) Reason for change in the quantity of seed (see code below)															
i) At what time are seeds available? 1=Before the planting season; 2= at start of the season; 3=mid-season; 4= towards the end of season															
j) Where do you obtain seeds from? 1= in this village; 2= neighboring village; 3= faraway places.															
k) How did/will you acquire the seed? 1= Cash; 2= On credit; 3= bartered; 4=free (gift)															
l) If you buy seeds, how is the current price or term of trade for seed? 1=affordable; 2= high; 3=very high															
m) Indicate name of organization who provided seed aid, if any															

Codes for the Main reason for change

1 = Lack of seed from same source;	7=Received free seed;
2 = More seeds available from this source;	8=Increase in seed prices;
3 = Lack of resistance to pest;	9=Decrease in seed prices;
4 = Good resistance to pests;	10= Lack of resistance to diseases;
5= Good performance of seeds under climate stress;	11=Good resistance to diseases;
6= Bad performance of seeds under climate stress;	12= Lost seeds during storage

26. Are you venerable to seed insecurity as a result of increasing climate risks
(1) Not vulnerable to Seed Insecurity (2) Not Sure (3) Vulnerable to Seed Insecurity

27. Are you vulnerable to seed insecurity as a result of conflicts (tension with your neighbors) (1) Not vulnerable to Seed Insecurity (2) Not Sure (3) Vulnerable to Seed Insecurity

Appendix B: In-depth Interviews Guide

Seed insecurity Drivers

1. Which of the following serves as determinants of seed availability in this community?

Themes	Factors	Agree	Disagree
Climatic Factors	Floods		
	High Temperature		
	Drought		
	Dry Spell		
	Shortened Rainy Season		
Ecological Factors	Soil Fertility		
	Land Degradation		
	Pest Infestation		
	Bushfires		
Socio-Economic Factors	Seed Prices		
	Tractor Service		
	Household needs		
	Agro-chemicals		
Politics	Fulani Herdsmen		
	Conflicts		
	Subsidies		

Human-Environment and Seed Drivers Timelines

2. Of the above factors, which period did it becomes relevant per your experience?

		Rawlings' Time (1983-2000)		**Kufuor's Time (2001-2008)**		**Mills' Time (2009-2012)**	**Mahama' Time (2013-2016)**	**Nana's Time (2017-2019)**
		1983-1993	**94-2000**	**01-03**	**04-08**			
Climatic Factors	Floods							
	High Temperature							
	Drought							
	Dry Spell							
	Shortened Rainy Season							
Ecological Factors	Soil Fertility							
	Land Degradation							
	Pest Infestation							

	Bushfires							
Socio-Economic Factors	Seed Prices							
	Tractor Service							
	Household needs							
	Agro-chemicals							
Politics	Fulani Herdsmen							
	Conflicts							
	Subsidies							

3. Even though the government has subsidized fertilizer, 44.99% of you indicated you did not apply fertilizer in your maize farm. Kindly explain why this is the case?

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……………………………………………………………………………………………
……………………………………………………………………………………………

4. Despite that 20.1% of you with a local variety of crops wish to acquire improved variety, yet over 80.19% of this proportion wish to acquire such seeds from the social network. But improved variety is supply by DADU and Agro-input dealers. Kindly explain why this is the case?

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……………………………………………………………………………………………

5. Why does female headed households tend to be more oriented inward and within village in seed acquisition

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

Appendix C: Focus Group Discussion Guide

Name of Community: ....

Number of participants: ……………………………

1. How has the community changed its practices in the way it grows crops, in your lifetimes in response to climate stress or and conflicts?

2. Which challenges remain as far as crop production is concerned in this community? (concerning climate stress and or conflicts)

3. Specifically, how has the community changed the way it uses crops in response to climate stress or and conflicts and the associated challenges?

4. Has the above observation affected seed security in the community?

5. Which are the most important crops you grow for food and sell?

Crop	Food	Sell
1.		
2.		
3.		

6. For the whole community, which crops do you grow on more land, and which did you grow on less land, in the last 5 years?

7. Which Crops have increased the land area you cultivated in the last five years?

Crop	Reasons for the increased land area
1.	
2.	
3.	

8. Which Crops have decreased land area you cultivated in the last five years?

Crop	Reasons for the decreased land area
1.	
2.	
3.	

9. Which Crop varieties have disappeared over the last five years?

Crop	Reasons for the disappearance
1.	
2.	
3.	

10. Which Crop varieties have been newly adopted in this community over the last five years?

Crop	Reasons for the disappearance
1.	
2.	
3.	

11. For your most important crop (1, 2, 3), could you show me where you get seeds from? And rank them or order them in their importance.
Hint: Own seed ( ) Local Market ( ) Social Network ( ) Agro-input- Dealer ( ) Seed aid ( )

1st Crop

2nd Crop

3rd Crop

12. From the sources mapped above, what is the quality (germination and purity) of the seed?
Hint: 1= Bad; 2= Average; 3=Good

1st Crop

2nd Crop

3rd Crop

13. What are the advantages (pros) and disadvantages (cons) of the different seed sources you are using for this crop?

Seed source	Pros	Cons
Own seed		
Local Market		
Social Network		
Agro-input- Dealer		
Seed aid		

14. Please explain why that factor is ranked first (This could be done simultaneously with the pairwise ranking process)
15. Overall, do you think there is/are seed problem in this community?
Yes (1) No (0)

16. If Yes/No, why?

17. What could be the main solution for seed problem in this community?