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Seed Security for Sustainable Agricultural Intensification in Northern Region of Ghana

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SEED SECURITY FOR SUSTAINABLE AGRICULTURAL INTENSIFICATION IN THE NORTHERN REGION OF GHANA

A Thesis Submitted in Partial Fulfilment of the Requirement for the Degree of Master of Science in International Environmental Studies.

By Simon Masak, May 2018.

Norwegian University of Life Sciences (NMBU)

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DECLARATION

I, Simon Masak declare that this thesis is a result of my research investigations and findings. Sources of information other than my own have been acknowledged and a reference list has been appended. This work has not been previously submitted to any other university for award of any type of academic degree.

Signature……………………………………

Date…………………………………………

DEDICATION

I will like to dedicate this thesis to my family and all friends whose support and encouragement played a vital role in seeing me through the end of this study. God bless you all.

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I will first and foremost thank my supervisor, Associate Prof. Ola T. Westengen for his valuable advice and pieces of information that made me get to the completion of the study. His facilitation of linking me to contacts at Savanna Agriculture Research Institute (SARI) Nyankpala enabled me to be welcomed for the field the work.

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To all colleagues at Noragric, I appreciate all the support from you all.

God bless you all.

ABSTRACT

For smallholder farmers (SHFs) in the savanna ecological zone of Ghana seeds are crucial for livelihood security. Access to quality seeds is a fundamental contribution to the yields farmers attain from their crop production. In the face of climate change, SHFs depend on various measures to adapt their production to ensure continued sustained crop production. The use of cultivar adjustment is deemed by the Intergovernmental Panel on Climate Change (IPCC) as one of the most effective ways to adapt to changing climate. The conventional agricultural development pathway to cultivar adjustment is that new crop cultivars are developed by crop scientist for release to farmers. In the savanna ecological zone of Ghana, the Savanna Agriculture Research Institute (SARI) is mandated to develop new crop varieties to farmers.

It is however noted that, adoption of improved crop varieties by SHFs is still generally low. Above eighty percent (80%) of seeds used by farmers in sub-Saharan Africa is derived from the informal seed sector. The crops' characteristics, the financial ability of farmers, the policy or institutional mechanisms of the seed sector, the seed sector regimes and the sociocultural and economic factors largely influence adoption of improved crop varieties.

There is concern as to whether new crop varieties developed by researchers through their breeding activities meets the needs of farmers in the area. This therefore formed the basis of this research to determine if breeder perceptions of crop characteristic differ from the characteristics of farmers. This thesis therefore contributes to the understanding of adoption and its determinants in Northern Ghana. I particularly focus on whether or not the varieties developed are suitable for smallholders in the area. I assess and compare smallholder farmers' crop varietal use, needs and preferences in relation to the breeding objectives of plant breeders.

The study shows the main livelihood from the sample was farming (98%) with maize (49%), groundnuts (26%), soybeans (13%), rice (10%) and sorghum (2%) as major crops. The crop improvement and seed system development efforts involved the strengthening of private sector with oversight from the public-sector institutions.

The crop trait ranked as most important overall was high yield. There was a statistically significant relationship between the major crop cultivated and ranking of high yield as the most important crop trait. There are however interesting differences between crops and even between different varieties of the same crops. Among the three major maize varieties Sanzalsima, Wang-data and Obatampa which are all Open Pollinated Varieties (OPVs), Obatampa had high yield (44%) as main trait. Taste (15%) is most important for the groundnut variety Chiness. Government subsidy (15%) was important for the soybean variety Janguma. By way of breeding and quality criteria, breeders make efforts to use elements Participatory Plant Preeding (PPB) to inform their breeding objectives. Thus, SHFs preferences for the quality criteria for crop varieties included characteristics such as high yield, tolerance to drought stress, tolerance to pest and diseases, and taste were all on the radar of plant breeders interviewed.

Seed security was studied employing Seed System Security Assessments (SSSAs) in relation to the 5 dimensions of seed varietal suitability, quality, availability, access and stability. Improved varieties dominated in the cropping systems, but the majority of the seeds were farm-saved and thus not directly obtained from the formal seed supply system. The major challenge regarding access to seeds was lack of purchasing power. While limited number of suppliers' is the major reason for availability problems. Regarding quality problems, the major reported reason was sale of fake seeds while with seed stability, there is quite some huge gaps by way of insufficient seed production for most crops coupled with institutional bottle-necks that may be jeopardizing its resilience.

This study further points to fact that breeders, although they were knowledgeable about SHFs preferences, in some circumstance bred to meet donor dictates because funds were received from those donors, as government funds is faced with bureaucratic challenges and most times delayed from been released. It is recommended that, since SHFs in the area still depend on farmer saved seeds, efforts should be made by government to support the effective utilization of both the formal and informal seeds systems to achieve the desired goals of seed security for increased crop production and enhanced food security.

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LIST OF ACRONYMS

ADB -Africa Development Bank

AGRA -Alliance for Green Revolution in Africa

ATT -Agricultural Technology Transfer

CGRFA -Commission of Genetic Resources for Food and Agriculture

CSIR -Council for scientific and Industrial Research

DFID -Department for International Development

FAO -Food and Agriculture Organization

FASDEP -Food and Agriculture Sector Development Programme

FFSs- Farmer Field Schools

GDP -Gross Domestic Product

GHG -Greenhouse Gas

GSS -Ghana Statistical Service

ITPGRFA -International Treaty on Plant Genetic Resources for Agriculture

MoFA -Ministry of Food and Agriculture

NGOs -Non-Governmental Organizations

OLS- Ordinary Least Squares

PPB -Participatory Plant Breeding

SSSAs -Seed Systems Security Assessments

SHFs -Smallholder Framers

SARI -Savanna Agriculture Research Institute

SID- Seed Inspectorate Division

SLA -Sustainable Livelihood Approach

SLF -Sustainable Livelihood Framework

TFP -Total Factor Productivity

TRIPS - Trade Related Aspects of Intellectual Property Rights

IMF -International Monetary Fund

IPCC -International Panel on Climate Change

USAID -United States Agency for International Development

USD -United States Dollars

WTO -World Trade Organization

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

In the Northern savanna ecological zone of Ghana, smallholder farmers (hereafter SHFs) aim at increasing crop productivity to meet food requirement and attain food security. Many of the people depend on small-scale farming as source of livelihoods. With changing climate projected to have impact on agriculture, SHFs in this area therefore depend on various mechanisms to adapt. Cultivar adjustment is by the IPCC found to be among the most effective adaptation measures (IPPC AR5 2014). In this local context, one important source of new cultivars is crop varieties developed by crop breeders at the Savanna Agriculture Research Institute (SARI). SARI through the Alliance for Green Revolution in Africa (AGRA) and United States Agency for International Development (USAID) Agricultural Technology Transfer project (ATT), are promoting the development of new crop varieties for SHFs in the Northern Region. Various crop varieties of maize, rice and soybeans, cowpeas, are important varieties for the SHFs in the area and are revered as food security crops for many rural and urban households. Another part of SARI's mandate is ensuring technology transfer related to crop production and management, engage farmers trough their work in the savanna ecological zone of Ghana.

SARI in developing new crop varieties ensure that crop traits such as high yield, adaptation of the crops to the local climate, the marketability of the crop, nutritional contents of the crop and other traits are reflected in these new crop varieties developed and subsequent release to farmers. Over the past five (5) years, SARI through its work has facilitated the release of new varieties of crops. These crops include 5 Open Pollinated Varieties (OPVs) maize varieties, 5 pearl millet varieties, 4 soybean varieties and 5 cowpea varieties. The institute work to also ensure that there are sufficient, available and accessible seeds of these varieties for use by farmers. SARI has also ensured that crop production management technologies such as rotation crops (legume and cereal cropping), the efficient combination of mineral and organic fertilizers, inoculants for legume soil health improvement is taught to farmers. Others include the use of application of extract of neem as an insecticide, appropriate planting distances to attain optimum plant population, and post-harvest activities such as use of storage of grains in Purdue improved storage bags (triple PICS sacks) are also promoted for prolonged crop shelf life.

“Seed is major technology transfer vehicle and the efficiency of seed supply systems to cater for the needs of different types of farmers is an issue in agricultural policies” (Louwaars, 2002: p1). The introduction of new agricultural technologies including seeds and sustainable production methods among SHFs is aimed at increasing yields to meet food needs and nutritional demands of the growing populations (Louwaars, 2002; Pretty J. *et al*., 2011).

Sustainable agricultural intensification is a way by which farmers in sub-Saharan Africa can attain increased agricultural productivity. Sustainable agricultural intensification is achieving high yield from the same unit of land while ensuring there is less environmental consequences with continuous critical environmental services been offered and natural capital enhanced in combination of diverse production management practices (Pretty J. *et al*., 2011).

One of the pillars of sustainable intensification borders on how to increase yields through crops that are suitable to the agro ecological zones with low external input dependency. It also touches on the dependency of production methods with low environmental impact, harnessing innovative technologies through human and social capital that can generate solutions that meet the local context. Sustainable intensification also encompasses the dependency on biological and nutrient cycling processes that promote system resilience and making conscious efforts to monitor the environmental impacts of production activities (G.F. Sassenrath *et al*., 2008: Pretty J. *et al*., 2011).

It has been observed that, sustainable agricultural intensification due to fact that it harnesses agro-ecological context specific production technologies and methods with the combination of diverse practices is less vulnerable to shocks and stresses thereby effectively serving the needs of SHFs (Pretty J. *et al*., 2011).

The development of policy by government to ensure that sustainable intensification is achieved will go long way to improve the livelihood of farmers as they engaged in production because more benefits stand to be achieved both economical, socially and environmentally. The policy should target the diverse agro-ecological zones of the country as there will be different contextual situations that could be harnessed to ensure it succeeds based on natural, physical, social, financial and human capitals peculiar to each area. But it has been observed that, such policy is nonexistent for the country (G.F. Sassenrath *et al*., 2008; MoFA 2010).

This study is about the development and delivery of crop varieties a fundamental technology for sustainable intensification. Specifically, this study assesses and compares SHFs needs, preferences and use of crop varieties in relation to the breeding objectives of plant breeders at SARI through technological improvement.

The study is organized and presented into five (5) chapters. Chapter one (1) contains the introduction which looks at the background, the study justification and its significance, the objectives, theory and conceptual framework with discussion on seed system policy in Ghana.

Chapter two (2) focuses on literature review with discussion on SHFs farming challenges in Africa, function of seeds and possible conflicts, factors that influence agricultural technology adoption by SHFs, seed systems and SHFs and the role of the Green Revolution on agricultural development in sub-Saharan Africa.

Chapter three (3) presents the study methodology including the study area, study design, data sampling and analysis and the study limitation with ethical considerations.

Chapter four (4) presents the study results and discussion looking at the demographic characteristics of respondents, livelihood characterization of SHFs, SHFs most important characteristics for crops grown, the major characteristics breeders work to improve and the major challenges regarding SHFs acquiring quality seeds. Finally, chapter five (5) presents the conclusion and recommendations.

1.2 Statement of the Problem and Justification of the Study

Following land as a primary input of agriculture is seed, which are the most paramount farmer concerns when it comes to production (Louwaars, 2002). Efforts to make available and promote technological change through the development of scientific research of new agricultural methods and promoting same to farmers is seen as very critical to agricultural productivity as well

(Mapila, 2001). Yields are also seen to be closely linked first and foremost to the kind of seed material that a farmer will use coupled with other technological applications (G.F. Sassenrath *et al*., 2008; Ghana Seed Policy, 2013). Farmers who are the end users of such agricultural technologies, having the capacity to adopt and continually use new seeds and other agricultural technology available is very crucial (Mapila, 2001).

There are challenges when it comes to SHFs accessing quality seeds as planting material in sub-Saharan Africa. The input factors that are needed to produce food has been generally well studied with great deal of knowledge available for many ecological zones in Africa (Peterson and Hayami, 1973). Many studies have also been done in relation to factors that affect and determine technology adoption through the lens of econometrics. For example, the use of the logic model (Abunga *et al.*, 2012), probit model (Doss, 2000; Gerhart, 1974), two-stage probit model (Gerhart, 1974), propensity score matching (Wollini and Zeller, 2007) and the tobit model (Adesiina and Zinnah, 1993) are widely used for various technology adoptions. According to Peterson and Hayami, (1973), who however indicate that, where there are lots of gaps to be closed is in terms of the knowledge generation process, social and agroecological barriers to adopting technologies, and reasons for effective utilization of new crop varieties or otherwise. It must therefore be noted that most of the works done focused on the socio-economic analysis of adoption of seed varieties.

This study takes a new approach to study adoption of new varieties. I focus on comparing SHFs crop varietal use, needs and preferences in relation to the objectives pursued by the plant breeders at SARI.

Improved crop varieties developed by crop scientist for planting may face a possible mis-match with farmer priorities. This problem arises as developers seek to come out with new crop varieties for dissemination to farmers for use. Ceccarelli and Grando (2007) advocate for concerted efforts to ensure that breeders develop varieties to meet farmer needs to encompass the broader socioecological, economic, cultural and local environmental contextual needs, if sustainable agricultural production is to be met. According to G.F. Sassenrath *et al*., (2008: p287), "*emerging models of development and adoption rely on closer interaction between technical developers and non-technical end-users"* (G.F. Sassenrath *et al*., 2008)

Therefore, this sets the basis for necessitating this study to bridge between crop scientist as developers and farmers as users if mutual gains are to be achieved by both parties. This can help to inform breeders on issues that are important from farmers perspectives when new crop varieties are to be developed for various crop species. Whilst on the part of farmers, their needs as users will be met as seeds are an important bed rock for farmers and a valuable material that determine farmers yield and productivity (McGuire and Sperling, 2016).

1.3 Study Objectives and Research Questions

The main goal and research questions that the study seek to achieve, and answer respectively are presented below to serve as a guide to the study.

1.4 Goal of the Study

To assess and compare smallholder farmers' crop varietal use, needs and preferences in relation to the breeding objectives of plant breeders, identifying social and agroecological barriers and opportunities for increased relevance of new crop varieties.

1.5 Specific Objectives

1. To characterize livelihoods in the study area and the agricultural development efforts within crop improvement and seed system development.
2. To determine what kind of crops varieties are grow and what are the reasons for choosing these crops by farmers.
3. To evaluate how farmer perceptions/realities differ or agree with what researchers at SARI emphasize.
4. To identify barriers and leverage points for improving SHFs' access to farmer preferred varieties.

1.6 Research Questions

1. What are the major livelihood activities in the area?
2. What crop improvement and seed system development efforts are employed?
3. What characteristics of crops inform farmer preferences?
4. What are the quality criteria used by those developing and promoting crop varieties?
5. What are the quality criteria used by SHFs as utilizers of crop varieties?
6. What are the present agricultural technologies employed by SHFs?

1.7 Ghana Context

Ghana is republic country located in West Africa and was known as Gold Coast before independence from the British in 1957. It has an estimated population of nearly 26 million (Ghana Statistical Service, 2011). Majority of the population base their livelihoods on agriculture with main farm labour force at fifty two percent (52%) according to the FAO (2001). The agriculture sector contributes about one quarter to the National Gross Domestic Product (GDP), (IMF, 2012)

In relation to total agricultural productivity output, eighty percent (80%) is accounted by SHFs in the Ghanaian agricultural sector (IMF, 2012). Most farm sizes are less than two (2) hectares for about ninety percent (90%) farm households on average (Chamberlin, 2007).

Ghana has six (6) agro ecological zones that support crop production as shown in figure 1 below. Farmers in the Sudan, coastal and guinea savanna zones cultivate crops such as maize, rice, sorghum, pearl millet and various species of cowpeas as well of rearing cattle, goats, sheep and poultry. While the transitional, semi-deciduous and rain forest zones grow crops such maize, rice, cocoa, pineapples, cocoyam’s and plantains with cattle and small ruminants.

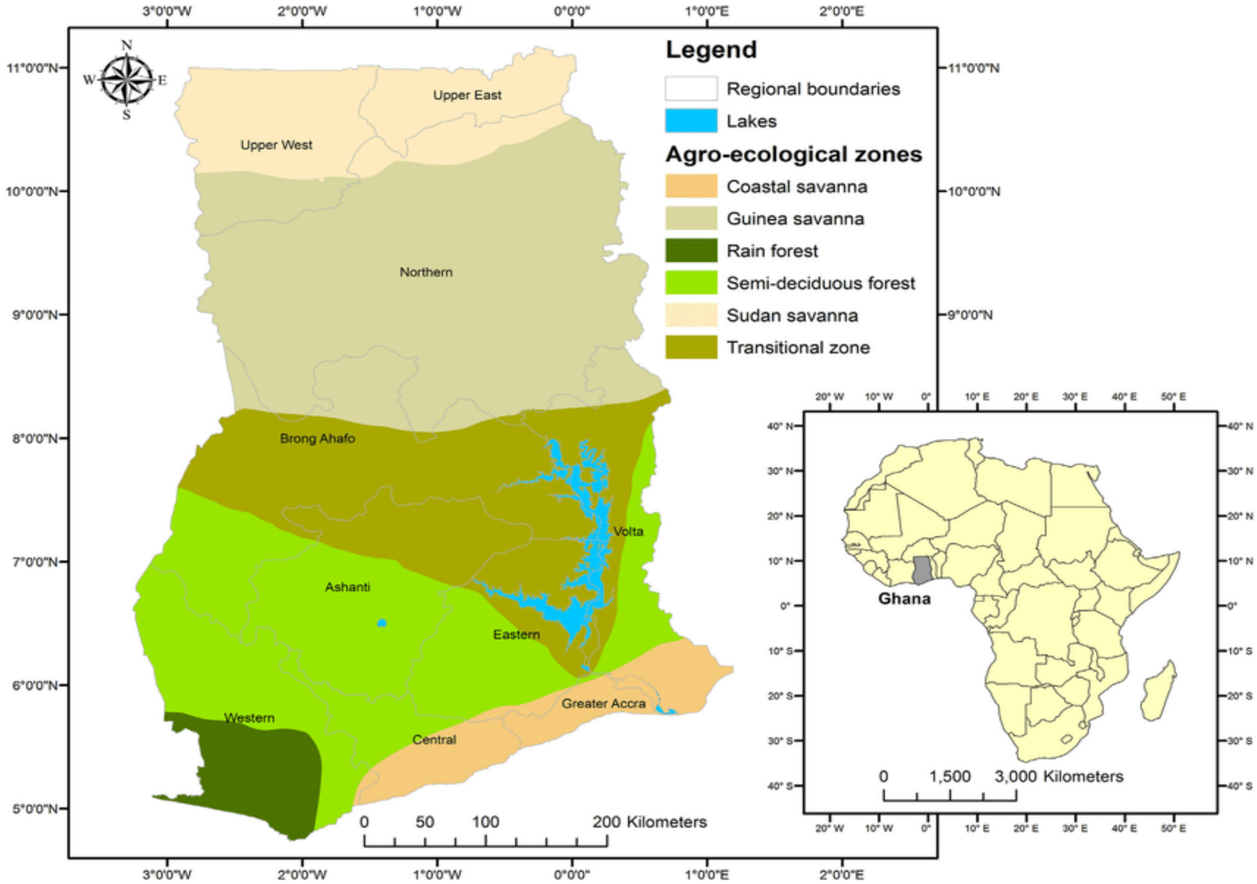


Figure 1 Showing agro-ecological zones of Ghana, Source: Rhebergen *et al*., (2016)

Through the implementation of policies such as Poverty Reduction Strategies in the 1990's and the Food and Agricultural Sector Development Policy (FASDEP II, 2010) were all part of efforts by the government to promote new technological drive through the necessary investments opportunities for boosting the agriculture sector (Ghana Seed Policy, 2013). These measures are hoped to massively fight poverty and leading to greater attainment of food security in the country.

The government is conscious of the devastating role that food insecurity can have negative impact on millions of households, and therefore embarking on these sectorial policies. The ministry of Food and Agriculture is the sector ministry that is tasked with championing the transformation of the agriculture sector in Ghana (Ghana Seed Policy, 2013). It has therefore established allied institutions such as the Council for Scientific and Industrial Research (CSIR) with its umbrella body of Savanna Agricultural Research Institute (SARI).

1.8 Crop Improvement and Seed Systems Policies in Ghana

To ensure the country become self-sufficient in seed productions and availability to farmers, the Ghana seed sector development plan began in the year 1958 with the birth of the hybrid maize seed multiplication unit. It was a unit established under the supervision of Ministry of Food and Agriculture (MoFA) with the mandate of producing solely hybrid maize. In the year 1961, the hybrid maize seed multiplication unit was changed to the seed multiplication unit with and expanded mandate for more crop development included other than the hybrid maize production (Ghana Seed Policy, 2013).

Around the sixties, the seed multiplication unit developed the contract grower schemes where these contract growers were trained and licensed to engage in certified seed production. Later in the year 1979, the seed multiplication unit was transformed into the Ghana seed company. The Ghana seed company had the mandate to produce all types of seeds apart from breeder seeds. The production of breeder seeds was only allowed by the research centers (Ghana Seed Policy, 2013). In later years, the Cotton Development Board, Fiber Development Board and the Grains and Legumes Development Boards were established as allied agencies to support the work of the Ghana seed company (Ghana Seed Policy, 2013).

The Ghana seed company a public entity in September 1989 was privatized due to Ghana entering the Economic Recovery Programme (ERP) which promoted private sector led growth, of which the seed sector was not left out. The privatization led to the private participation in the seeds industry around the 1990's. The seed industry strategy promoted by government therefore was a seed sector led by the private with public institutions having oversight responsibility of these private seed enterprises (Ghana Seed Policy, 2013).

From the late 1990's through the ERP, government continued to further drive private sector led seed development under the new Ghana seed program, which is the still the current driving force promoted by government (Ghana Seed Policy, 2013).

The current seed policy is supported by the passing of the plants and fertilizer Act, 2010 (Act 803) to facilitate improvement of the seed sector through the formal and informal seeds systems. The policy considers the important role of both formal and informal seeds systems to drive production. The informal seed system is based on traditional seed exchanges between farmer. While the formal seed system ensures development of improved seed varieties through research as illustrated in figure 2.

The seed policy holds the view that research into plant breeding is key for seed availability to farmers (Ghana Seed Policy, 2013). Therefore, SARI is mandated to contribute to push this agenda. It notes that research must focus on developing varieties with traits covering tolerant to pest and diseases, tolerant to drought, high yielding, ability to adopt to various agro-ecological areas and meeting preferences of the consuming public (Ghana Seed Policy, 2013).

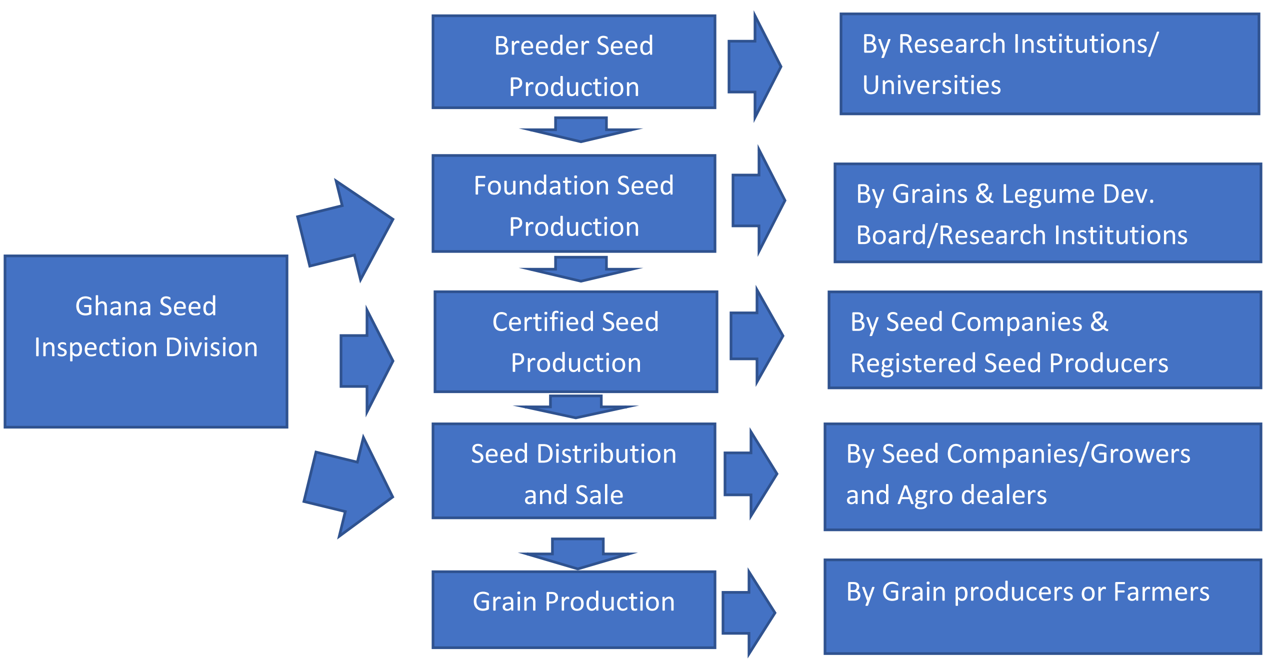


Figure 2 Flow chart of the formal Seed sector in Ghana. Source: Etwire *et al*., (2013)

The seed policy of Ghana (2013) outlines its main objective as;

‘’to support the development and establishment of a well-coordinated, comprehensive and sustainable private sector-driven seed industry through systematic and strategic approaches which will would continuously create and supply new improved varieties for use by farmers and, and further, support successful seed production, certification, marketing and seed security systems which will form the basis for food security and support the overall development of the agricultural sector’’(Ghana Seed Policy, 2013.p33).

The policy acknowledges the role of seeds as key for promotion of continuous supply of materials for plant existence and propagation. It was anticipated that the private sector will lead the process of the seed value chains through massive improvement leading to farmers accessing quality seeds for improved yields. But much of the drive anticipated has not achieved its desired goals (Ghana Seed Policy, 2013).

1.9 Theory and Conceptual Framework

The study utilizes the theory of seed security under the broad frame of Sustainable Livelihood Approach (SLA). Seed security is evaluated based on carrying out Seed System Security Assessments (SSSAs) which focuses strongly on SHFs (McGuire and Sperling, 2016).

Seed security exist in a situation when male and females in the household have the capacity to source and have access to sufficient quantity good seeds and planting materials that meets their crop varietal needs and preferences, on a sustained basis during periods of good and stressed production seasons (FAO, 2015). Seed security hinges on the 5 core pillars of seed availability, seed access, seed quality, seed varietal suitability and seed stability over time (FAO, 2015).

In relation to seed availability, it means seed supply through the various channels must be timely and at places for use by farmers. In terms of seed access, farmers must be able to acquire the needed seeds. When it comes to seed quality, it should have good germination ability, should be pure seed and without pest and disease infestations. About varietal suitability, it should be adapted to the local context and meet the specific needs and must be preferred by farmers. Whilst seed stability entails, the seed system resilience in surviving the events of shocks and stress in the local context (FAO, 2015).

While SLA broadly entails use of principles, practices and objectives emanating from sustainable livelihood framework focusing on wellbeing rather than just the linear notion of poverty (Nunan, 2015). People and communities tend to live a more fulfilled life and improving their livelihoods through enhanced wellbeing by effectively utilizing the availability of natural, social, human and physical capitals (Nunan, 2015).

According to DFID (2001) the concept of SLA forms part of the broad theory of Sustainable Livelihood Framework (SLF). SLA focuses on ability to deal with stresses and external shocks resiliently, resulting in productivity of natural resource bases prolonged with continued sustained ability to keep supporting livelihoods for a long period of time.

Scoones (1998) view SLA under the context such as agroecological, socio-cultural, historical basis, integrating capital types through pursuing certain strategies such as intensification of agriculture, aiming at achieving broad interest influenced by larger political and institutional policies and processes impacting what livelihood outcomes that a person, households, community or even a nation attains.

SLA is noted to be holistic tool that and can be broadly employed to access the livelihood potentials and or issues that that border on sustainability of systems. It therefore on this basis the study relied on these concepts to throw more light on the theme of the research.

In using these theories, I conceptualize (as illustrated in figure 3) the role of agricultural technological development and advancements serves as a crucial factor for seed security which influences how sustainable agriculture can be achieved for improved wellbeing on SHF livelihoods, in the overall economic, socio cultural and agricultural policy context of an area.

In relation to the context for study, the frame work of seed security is used to assess how crop developers align their objectives to farmer needs and how policy, for example funding from government or donors impact their work. The framework also identifies how crop varieties are adopted by SHFs based on the five-natural capital available and accessible to specific farmers in a local context. It will facilitate the eliciting issues of social, natural, financial, physical and economic factors of farmers, based on the 5 seed pillars enumerated above regarding use of crop varieties, and farmers livelihood characterization.

In conducting SSSAs, one can employ the path of focusing on predominantly a single crop analysis or regional and national analysis engaging farmers (McGuire and Sperling, 2016). In the case of this study, the former is employed.

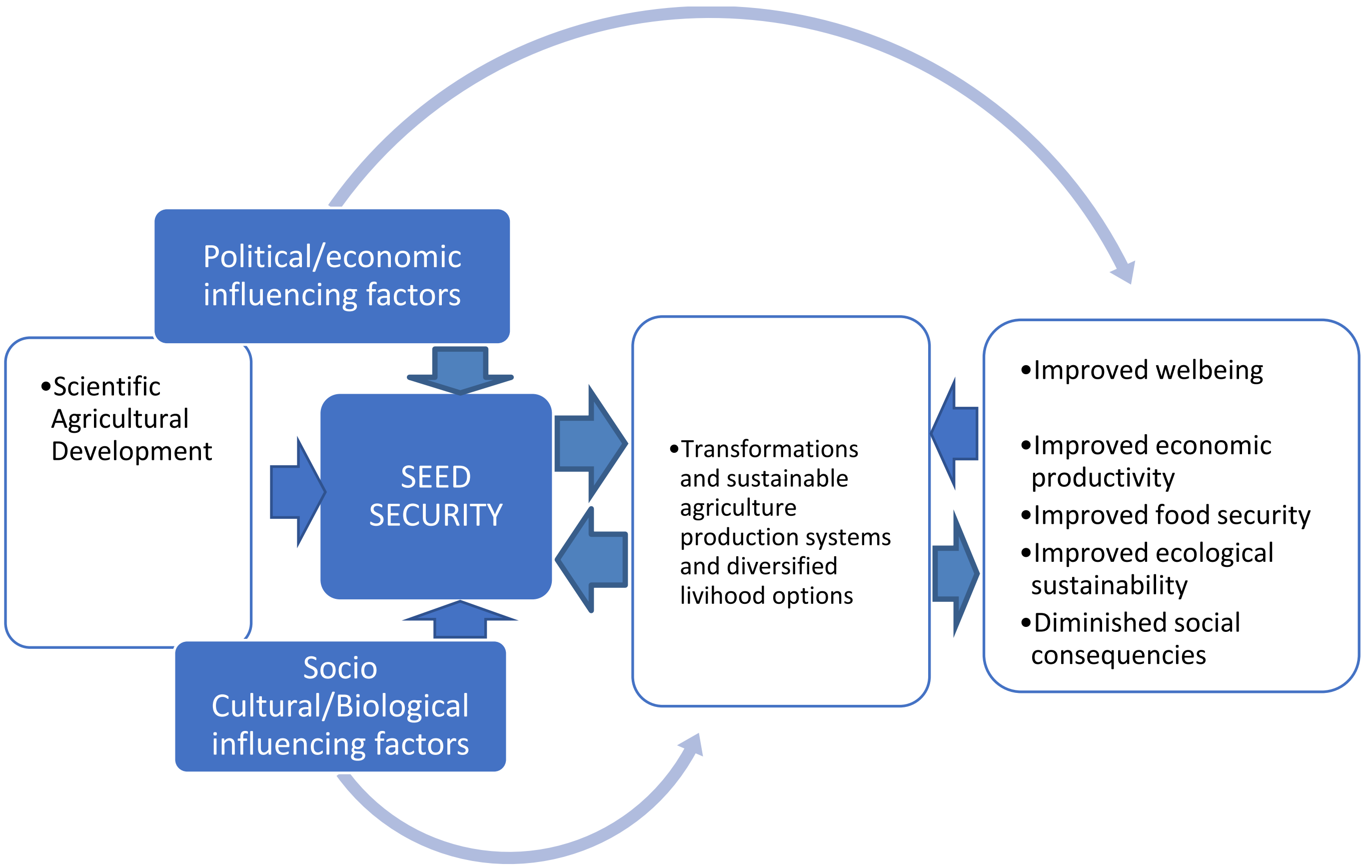


Figure 3. The conceptualization of the contribution of scientific research to seed security for sustained wellbeing.

1.10 Significance of the Study

This study sought to assess and understand the drivers of farmer preferences of crop varieties and how it is aligned with developer's priorities in Northern Ghana. The study will contribute to the knowledge process regarding seed security for sustained food production, improved sustainability and diminished social consequences or societal differences in the long run considering differentiated societal sections.

This study will also contribute to the body of knowledge regarding the adoptions of farmers to crop varieties and increase understanding based on smallholder farmer level analysis using the context of Northern Ghana as a case to further understanding of the issue.

It is further anticipated that, the knowledge generated will be useful information contributing to shape policy development and implementation in relation to Ghana's agricultural sector. The study will also serve as an important evaluation process of the current SHF seed security and agricultural practices in the area and serve as foundation for further research.

CHAPTER TWO

2.0 REVIEW OF RELEVANT LITERATURE

This section explores previous work related to role of SHF farming and challenges in sub-Saharan Africa, seed systems and SHFs in sub-Saharan Africa, seed security and possible conflicts, agricultural technology adoption and factors that influence adoption, and the impact of the Green Revolution on agriculture in sub-Saharan Africa.

2.1 Smallholder Farming, Role and Challenges in Sub-Saharan Africa

According to (FAO, 2001) seventy percent (70%) of people in Sub Sharan Africa derive their livelihood from engaging in subsistence crop production. They also contend a greater percent of these famers depend on rain fed production systems with low levels of input investments. It has also been generally established that yields are however low among subsistence small-scale farmers in sub-Saharan Africa (Wolf, 1986).

In other literature, SHFs in Sub-Saharan Africa practice small fragmented communal land cropping systems coupled with practices and use of rudimentary production equipment's without dependence on technological innovation which is viewed as a bane to driving the needed production gains (Adesiina and Baidu-Forson, 1995). They further indicate that, there is a strong view that until Sub-Saharan Africa employ modern practices that allow for farm expansion to large scale production, the masses of its population will continue to be food insecure.

According to Odulaja and Kiros (1996), weak institutional policies also play a major role for the low development gains made by SHFs. They further allude to the fact, held by many African governments that the fight against low agricultural productivity can only be attained through import of modern technology from global North. These modern technologies include high yielding crop varieties, chemical produced fertilizers, tractors with its accompanying implements and production methods.

According to Muza *et al.,* (1996) some of the reasons are low and erratic rainfall, low capital base, the problem of lack of access to high yielding varieties, lack of collateral to seek financial support to expand production and inherent technical challenges (Muza *et al.,* 1996). They conclude that, these therefore have resulted in low yields recorded for most crops compared to the potential attainable yields.

Therefore, if sustainable economic development is to be achieve for such farmers then more improvements needs to be targeted at the agrarian sector. Therefore, these perspectives form the backdrop for my in-depth look at seed development and use as part of technological development.

There are various definitions of SHFs based on specific country context (FAO, 2001; Kirsten and Van Zyl, 1998). Kirsten and Van Zyl (1998) define SHFs as farmers limited in capacity to access services required for his/her productivity to increase, often having small scale farm operations.

According to Hazell *et al.,* (2007), SHFs represent farmers engage in subsistence farming practices with much of farm labour with the aim of farming to produce greater portion for solely household consumption depending on diversified staple crops.

The World Bank's Rural Development Strategy (2003) defines SHFs as farmers engaging in farming operations with less than 2 hectares of land holding with their asset base being limited and low.

Dixon *et al.,* (2003) classify SHFs according to production system and land holding and annual output in terms of revenue generated from the production system. In relation to population of low densities, the farmers hold approximately one (1) hectare of land whilst in high densities areas, land holding increases to around ten (10) hectares of land put under production in semi-arid areas with mostly integration of with livestock that range to up to ten (10) animals.

The definition of SHFs for this study will rely on the World Bank's Rural Development Strategy (2003) and Dixon *et al.,* (2003).

2.2 Seed Systems and Smallholder Farmers in Sub-Saharan Africa

Seeds are observed to be an important material that farmers depend to serve as conduit for genetic transfer (McGuire and Sperling, 2016). They have been transferred from generations to generations as common heritage (Harlan, 1975; Louwaars, 2002). Seeds are also seen as possessing special features and can serve as a means of technology transfer with its ability to determine the productivity of farmers (McGuire and Sperling, 2016; CGRFA, 2001). At present, massive investments aimed at improving the seed sector for SHFs are carried out through scientific studies ongoing in many parts of Africa (McGuire and Sperling, 2016).

Studies have shown that, most SHFs depend on the recycling of farm-saved seeds for use in most part of Africa through the informal seed sector (McGuire and Sperling, 2016; CGRFA, 2001). Access to seeds by SHFs can be derived by from the formal seed sources or the informal seed sources (FAO, 2009; CGRFA, 2001). The informal seeds sources include farmers saved seeds, all forms of seed exchanges by farmers through their networks and local trading of seeds in markets. While the formal seed sources are scientifically improved seeds including genetically modified seeds which are traded/supplied by approved seeds dealers, agricultural research institutions and large companies dealing in seeds (FAO, 2009).

According to FAO (2009), improved seeds possesses features such as high yielding, early maturing and drought tolerant with the potential of increasing crop productivity. While Nkonya (2001) views improved seeds as having been derived from formal breeding programs.

2.3 Seed Security and Possible Conflicts

The role of seed as technological transfers and its role as potential commercial entity especially in developed countries in the latter case, presents competing interest and conflicts with these two positions (Louwaars, 2002). With the potential for commercialization, there is possibility for patent rights to be placed on improved varieties which could limit the transfer of these materials freely. This fall under the World Trade Organization (WTO) policies to liberalize the seed industry under Trade Related Aspects of Intellectual Property Rights (TRIPS). Whereas the FAO under the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) empowers sovereign rights for nations to develop national policies based on their national priority for plant genetic resources.

Another area of potential conflicts arises in relation to whether the formal seeds system or the informal seed system should be the focus of entry to drive seed system development (McGuire and Sperling, 2016). As noted, AGRA and other large donor initiatives on the one hand are advocating for formal seed sector. Whilst the push for the informal seed sector is championed by some NGOs and local driven initiatives (McGuire and Sperling, 2016).

According to Westengen and Berg (2016), seed systems development is contested in the scholarly as well as in the public debate. The push for modelling SHF seed systems to those of formal systems alone, as pertained in global North meets with resistance from activists and scholars. A possible middle way is offered by so-called “integrated seed system development” that encompasses the aspirations of both the formal and informal seed sectors (McGuire and Sperling, 2016). Westengen and Brysting (2014), further indicate that, the adaptive windows of the agricultural production livelihood base stands to be much more resilient when the formal and informal seed sectors are integrated for many developing countries.

2.4 Agricultural Technology Adoption, Factors that Influence Adoption

There is a daunting task for scientist, agricultural extension workers, governments and allied bodies with interest in agriculture sector seeking to encourage farmers to adopt innovative technologies (Feder and O’Mara, 1981). This daunting task result in much investment and is followed by mechanisms to monitor to see if gains are made of the investments leading to influencing changes to policy going forward and also through adoption studies and other farmer level studies (Feder and O’Mara, 1981).

In the work of Adesiina and Zinnah (1993), where they used the tobit model in studying swamp rice varietal adoption by farmers in Nigeria. The studies engaged one hundred and twenty-four (124) farmers growing rice in swampy humid forest to determine the factors that influence varietal technology adoption. The variables included in the studies were age, farm size, number of contact with extension agents for knowledge exchange, participation in FFSs where technologies were demonstrated, and the number of years the farmer has been engaged in swamp rice cultivation.

It was observed from the study that all variable was significant in influencing farmer adoption in the exception of age when run separately. In the case of when the variables were run together, there was no significant relationship to farmer adoption of the rice technologies. They therefore concluded that, for studying farmers technology adoption, its crucial to consider farmer perceptions.

In the case of Gerhart (1974), the two-staged probit models was used in studying the use of wheat and hybrid maize varieties and what factors affect adoption by farmers in western Kenya. Examining three hundred sixty (360) farmers cultivating wheat and hybrid maize, it was found that factors such as, level of formal education, cash crop cultivation and information of available credit have positive relationship with adoption.

Regarding different agro ecological zones, there was much evidence that it affected the use and adoption of maize varieties. It was further observed that zones with poor soils and low rainfall pattern influenced the low adoption of hybrid maize varieties. It was also established that, infrastructure (road network and input conditions) development level had great influence in technology adoption. For example, zones with poor road network resulting in difficulty in access showed low adoption coupled with limited reach by extension services (Gerhart, 1974).

According to Doss and Morris (2001), using probit model in studying improved varieties found that, variables such land holding, number of extension agents visits received, improvement in infrastructure in the sector were positively related to farmer adoption of technologies. The study also showed that, variable such as amount of house hold labour was not statistically significant to influence farmer adoption of varietal technologies.

Wollini and Zeller (2007) in studying to determine how participation in cooperatives by farmers influenced technology adoption of improved seeds, and pesticides. The study involved nine hundred and sixty-five (965) farm households. It showed that, participation in cooperatives had significant relationship with technology adoption. It was further observed that, belonging to cooperatives had a positive relationship to the adoption of pesticides and its use. They therefore in the study, point to the rational of many governments in Sub-Saharan Africa encouraging the formation and strengthening of agricultural cooperatives.

Abunga *et al.,* (2012) studied the factors that influence the adoption of modern agricultural technologies by farm households in the Upper East region of Ghana. The factors studied were grouped into economic factors, institutional factors and social factors. The variables that were studied under the economic factors included off farm activities, benefits of envisaged gain from modern technology the cost of investment in the technology and farm size. The studied observed that, the economic variables of benefits envisaged from modern technology, the cost of investment in the technology and farm size were significantly influencing farmers decisions to adopt modern technologies (Abunga *et al.,* 2012).

In relation to the social factors studied, the variables included farmer age, farmer educational level and gender. It was observed that, they all significantly positively influenced farmer decisions to adopt modern technologies in the area (Abunga *et al.,* 2012).

For the institutional factors studied, which included farmer access to extension delivery and access to general production information, the study concluded that, farmers access to extension delivery and information significantly positively influenced farmers decisions to adopt modern agricultural production technological changes in the Upper East region of Ghana by farm households (Abunga *et al.,* 2012).

In a study carried out by Doss and Morris (2001) in assessing the factors that influence adoption of improved maize technological changes in Ghana, there was significant positive relationship with regards the gender of farmers. They also found that, there was positive relationship between farmers access to credit to invest in production activities and modern technological adoption by famers.

According to Rogers (2010) adoption process by a farmer is the phases that an individual goes through from first hearing a new technology to the point of final utilization. Feder *et al*., (1985) define agriculture technology adoption as the ability of farmers to utilize disseminated knowledge and having the capacity to continue to sustain that knowledge over a long period of time knowing the potential benefit of the new technology.

Peterson and Hayami (1973) indicate that agricultural technological adoption interest grew and gained momentum based on two factors for possible explanation of its drive over the years. Firstly, the pace at which demand for food being relatively supported by agricultural production ability to meet through diversified and wide agricultural product supply to the nutrition and food demand for developed countries. Secondly, developing countries having challenges in raising agricultural production output to meet its fast-growing population. This is observed in many parts of developing countries inability to meet dietary needs, resulting in nutrient deficiencies and chronic food shortfalls. This resultant push and interest hinges on the assumption that of dependency on new agricultural technology as being the 'engine of growth' to propel the sector.

According to Abadi-Ghadim and Pannell (1999) and McNamara *et al.,* (1991), factors that influence technology adoption lie in the managerial ability of the farmer, institutional policies framework, the entire farm scale or structure and largely based on farmer characteristics. While according to Adesiina and Baidu-Forson (1995), elements by way natural resources characteristic, production systems, policy domain and the human and economic capital are the main factors.

According to Nowak (1987), technological adoption depends on access to information on the technology, farmer economic status and the ecological benefits to the whole production systems. Odulaja and Kiros (1996) and Adesiina and Baidu-Forson (1995) point to fact that, many do see farm size as a crucial factor influencing technology adoption. According to Kasenge (1998) and McNamara *et al.,* (1991), they believe there is a positive relationship with farm size and scale with adoption of agricultural technologies. Abunga *et al*., (2012) believe farm size may stand to affect the other factors that influence adoption and the vice versa. According to Yaron *et al*., (1992) they observed farm size to be negatively affected by adoption. While on the other hand, a neutral effect was observed by farm size and adoption by Mugisa-Mutetikka *et al.,* (2000).

Various technologies are made available to farmers through extension dissemination (Mapila, 2011). For example, the use of FFSs is one example developed in the 1980s to use it as a vehicle to impact technologies to farmers. FFSs concept was based on the process of learning by practicing and experiencing. It afforded those transferring the technology to use adult learning methods to convey messages to farmers. The concept of FFSs is still relevant at present and continue to be one-way crop scientist or agricultural extension workers still depend on in many parts of Africa (Rogers 1962).

2.5 The Role of the Green Revolution in Agricultural Development in Sub-Saharan Africa

It has been observed that under the Green revolution, many agricultural technologies by way of higher yielding varieties, chemical fertilizers and other technical support was introduced to improve agricultural productivity across the globe (Wolf, 1986; Evenson and Gollin, 2003). But through the assessments done by many on its aim at achieving the desired goal, there is varied and wide conclusions regarding its beneficial or otherwise to farmers (Evenson and Gollin, 2003).

There was high farmer adoption of the principles of the Green Revolution and it's believed to have revolutionized the Asian agricultural production system for crops like rice in that region (Wolf, 1986). Unfortunately, in Africa same cannot be said of the beneficial impact of the Green Revolution. At best, there is mixed feelings of the role of the Green Revolution in Africa (Wolf, 1986; Singh, 1994; Evenson and Gollin, 2003). Many writers have underscored that, the Green Revolution had little impact in making any significant changes to the African production system.

In attempting to diagnose the problem, many have said it was due to the fragmented nature of small farm sizes by farmers in Africa (Wolf, 1986). Others put the blame on the lack of political drive to create the enabling sectoral policies to fully take advantage of the Green Revolution, including equity problems (Wolf, 1986; Singh, 1994). Some also attributed it to lack of know-how by farmers to translate and continue to explore further opportunities and coupled with weak institutional framework (Ruttan, 1977). Other writers believe it was because of the dynamic interplay of the above-mentioned challenges (Singh, 1994; Ruttan, 1977). It can therefore be realized that, the impact of the Green Revolution in African marries the findings of Pretty J. *et al*.,

(2011) pointing that, the aim of solving the shortages of food for fighting hunger and rising populations produces uncertain socio-ecological consequences through the path of technological advancements.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Physical Features of Study Area

The study was carried out in two (2) districts of Savelugu-Nanton and Tolon-Kumbungu districts of the Northern Region of Ghana. These two district borders each other to the West, and both also border Tamale Metropolis the Northern Regional capital to the South. They also are boarded to the north by the West Mamprusi district, to the east by West Gonja for Tolon-Kumbungu and Karaga district for the Savelugu disrict. It is estimated to have an altitude of between 400 to 800 feet above sea level.

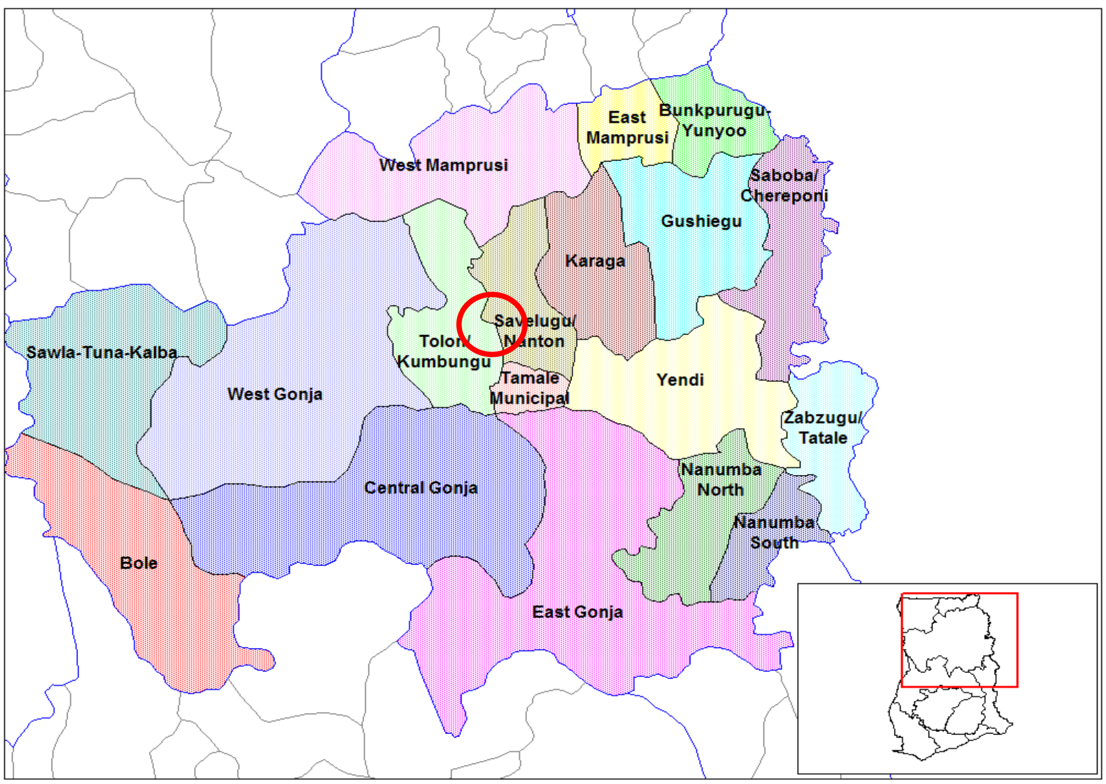


Figure 4. Map of the study area. Source. Ghana Statistical Service (2014)

3.2 Climatic Features

In relation to climate, the districts experience high T^0C with an average T^0C of 34^0C. A rainfall of 600mm annual average is observed in the area during the rainy season with a single season spanning from April to September annually (Ghana Statistical Service, 2014). The rainfall in the area is sparse and erratic in nature with heavy thunder storms accompanying rains most times.

3.3 Vegetation Type

The vegetation type dominated in the area is the Guinea Savanna woodland vegetation with grassland shrubs. The vegetation supports the cultivation of crops like maize, groundnuts, rice, cowpea, sorghum, millet and cassava. It also supports the rearing of livestock such as cattle, sheep, goats, guinea-fowls and poultry. Trees found in the area include high value economic trees such as shea tree and “dawadawa” tree. Theses tree species are highly drought resistance. Because of the long dry spells of the dry season, there is a problem of bush fires which some parts of the area experience from the activities of farmers and hunters (Ghana Statistical Service, 2014).

3.4 Methods of Sampling, Data Collection and Analysis

The study employed simple random sampling of fifty (50) farmers from each district by way eliciting primary data for the research. Multistage method of data collection was used. The districts were grouped into their various area councils with a random selection of area councils in each district. Out of which five (5) communities were further randomly selected for the interviewing of farmers in these communities. A further division of the communities into North, East, West and South with random selection of ten (10) farmers for questionnaire engagements to elicit participants responses. Fifty farmers were selected from each district giving the total of hundred (100) farmers interviewed. When it comes to breeders of crop varieties, purposive sampling of was carried out. Two (2) breeders from CSIR-SARI were interviewed.

Secondary data was also gathered through the review of relevant literature as part of the study. The quantitative data was analyzed using the statistical package "R" and excel with the results presented in graphical, table and numerical forms. The ordinary least squares (OLS) regression was used. OLS is appropriate for ordinal dependent variables. The analysis was done through the determining farmer responses with the corresponding percentages, means, averages and coefficients presented together with the transcribed qualitative data.

3.5 Study Design

To ensure the right data was captured to answer the research questions, the design illustrated in Table 1 below was used. The study employed qualitative and quantitative methods to achieve the goals and objectives of the study.

Table 1. Research design

Research questions	**Data required**	**Data collection method**	**Sample unit or categories**
What major livelihood activities are employed in the area?	The responses from farmers on livelihood activities	Structured questionnaire administered through simple random sampling of farmers Qualitative observations	100 female and male farmers
What are the quality criteria used by those developing and	The reflections from crop breeders as	Qualitative interviews with crop breeders	2 semi structured interviews

promoting crop varieties? What crop improvement and seed system development efforts are employed?	developers of improved seeds	Secondary data review	Review relevant materials
What characteristics of crops inform farmer preferences? What are the quality criteria used by SHFs as utilizers of crop varieties?	Farmer responses of what quality crop criteria are of importance to them	Structured questionnaire administered through simple random sampling of farmers. Qualitative observations	100 female and male farmers
What are the present agricultural technologies employed by SHFs and how do they impact yield?	The responses from farmers on livelihood activities	Structured questionnaire administered through simple random sampling of farmers. Qualitative observations.	100 female and male farmers

3.6 Limitations and Ethical Considerations

The main data source for the research was from local level SHF responses and breeders of crops with analysis to identify seed security among SHFs. Secondary data was also reviewed to serve as additional information, to throw more light on the study with focus on institutional analysis and policy mechanisms regarding seed technologies among SHFs regarding their preferences of crop varieties. SHFs household data and farmer level data was analyzed on seed security systems.

The interviews were carried out based on prior informed consent by respondents. The study also ensured that the rights of farmers were adhered to regarding information seeking and respondent's confidentiality adhered and assured. The study equally ensured to respect famers views and therefore, information deemed sensitive to farmers were not sought. The study further ensured that, participants during and after the study are not harmed nor injury inflicted on them by the work or through participating in the study. No farmer was forced or compelled to participate in the study. Each respondent verbally assented to a consent out of their own voluntary intent.

Farmers were interviewed in their local language resulting to their understanding of each question before responding to it. A pilot of the questionnaire was carried out to ensure that sensitive questions which were not appropriate are edited and to ensure all terminologies in the questions were well understood by respondents.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

The study employed simple random sampling of hundred (100) farmers and 2 semi structured interview of crop breeders by way eliciting primary data for the research. Multistage method of data collection was used to identify the sampled farmers. The data was analyzed using the statistical package "R" and excel and results presented in graphical, tables, numerical and qualitative forms.

4.1 Demographic Characteristics of the Respondents

The respondents were made of sixty nine percent (69%) of males and thirty one percent (31%) females. The educational level of respondents is represented by no education eighty three percent (83%), primary school eight percent (8%), junior high schools four percent (4%), senior high school three percent (3%) and diploma two percent (2%).

This shows that majority of the respondents had no formal education. Studies done by Robert *et al.*, (2004) and Mishra *et al*., (2009) indicate how there is positive relationship between technology adoption and educational level. Seventy percent (70%) of respondents were household heads while thirty percent (30%) were not. In relation to age of respondents, the minimum age was 21 with 67 been the maximum age. This indicates majority of the respondents are in the active age.

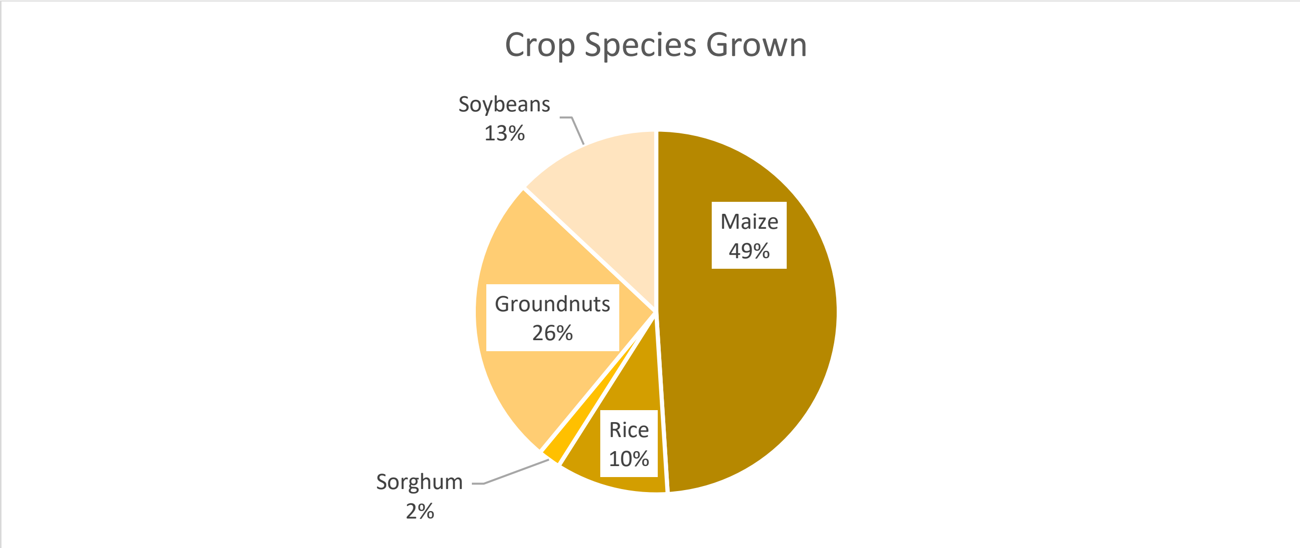
With regards to number of years engaged in farming by respondents, twenty eight percent (28%) had been engaged in farming between 1-10years while seventy two percent (72%) where above 10years. Johannes *et al.*, (2010) indicated that farmers with long term experience were better placed to depend on experiences from long practices of technology to influence their adoption as they will have observed benefits from such technologies. In relation to average number of household members, 14 members per household was identified.

4.2 Livelihood Characterization

The data from the studies show that the majority of the respondents engage in farming as their main source of livelihood at ninety eight percent (98%). It was also noted that males engage in dry season gardening in areas with dams, trading in animals and seasonal hunting. Most females engaged in picking and sale of shea nuts, petty trading, food vending and charcoal burning. This could be attributed to high number of the respondents not having formal education and therefore engage in farming as a source of livelihood. The major crops grown include maize, groundnuts, soybeans, rice and sorghum. Thus, for maize, groundnuts, soybeans, rice and sorghum, forty nine percent (49%), twenty six percent (26%), thirteen percent (13%), ten percent (10%) and two percent (2%) respectively as shown in Figure 5. Maize therefore serves as an important staple for most dishes in the area for rural and urban household consumption while soybeans is largely sold for cash.

Sub-Saharan Africa has heterogenous farming systems influenced by unique livelihood strategies, dynamics of population pressure, markets and institutional bottlenecks and peculiar agro ecological environments (Garrity *et al.*, 2012; Vanlauwe et al., 2014). According to Garrity *et al.*, (2012), sixty five percent (65%) of African rural poor derive their livelihood from about 13 major farming systems identified with farming of maize mixed with other crops among the top 5 largest systems on an annual basis.

Vanlauwe *et al*., (2014), noted that small land holdings have resulted in many farmers diversifying into rural non-farming economic activities to supplement household income. As high as about thirty five percent (35%) of rural household income in Africa is from service provision, agro processing, petty trading which are majorly non-farm economic activities (Vanlauwe *et al*., 2014),



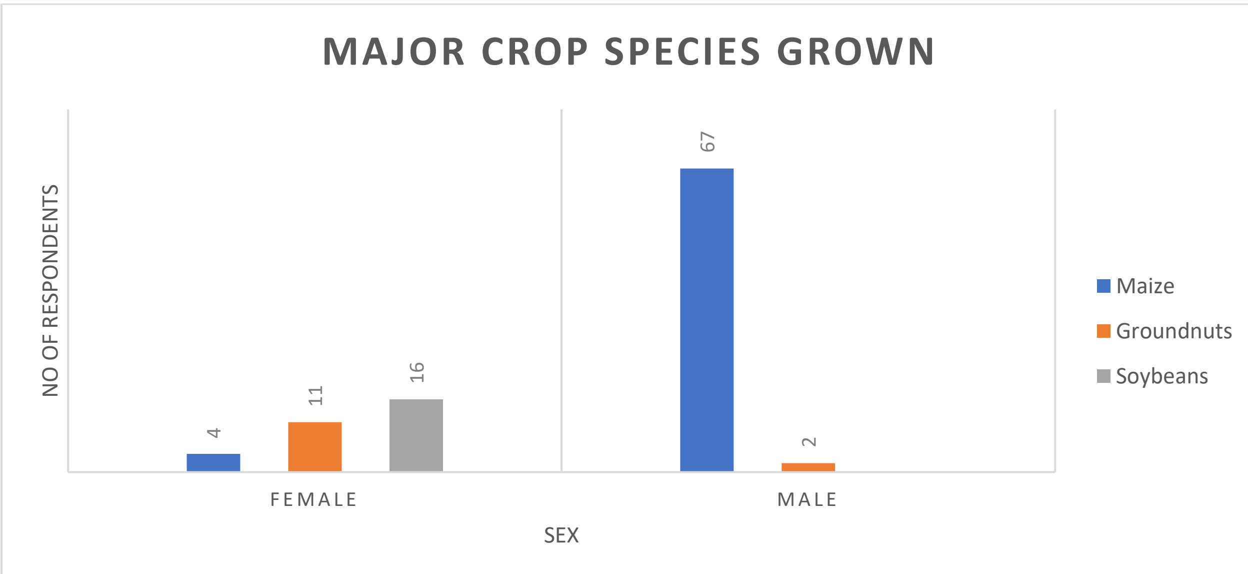
N=100

Figure 5. Diagram showing the share of farmers cultivating different crop species

From Figure 6 below, of the forty nine percent (49%) of respondents cropping maize, sixty seven percent (67%) are males, while three percent (3%) being females produce maize as a major crop. According to Evans and Young (1998), factors such access to productive land, access to credit and cattle ownership are gender differentiated in sub-Saharan Africa. It has also been noted that, women are known to be growing traditional food crops based on the conventional representation associated with gender differentiation (Evans and Young, 1998; Whithead and Kabeer, 2001). Of the twenty six percent (26%) of respondents cropping groundnuts, eleven percent (11%) being females produce it as major crop while two percent (2%) being males. All thirteen percent (13%) of respondents cropping soybeans as a major crop are females.

Many studies point to the fact that women farmers are disadvantaged and limited in accessing production resources to invest in their crop production and in new crops (Kumar, 1994; Sutherland, 1998; Evans and Young, 1998). They further state women farmers are limited in accessing inputs and labour required for crops that are marketable (Kumar, 1994; Sutherland, 1998; Evans and Young, 1998). And this can be observed in the area as maize has high input and labour requirement which makes few women cultivating maize in the area. This was noted by

Whithead and Kabeer (2001), maize cultivation in Africa for most SHFs require purchased inputs and women lack the needed capacity.



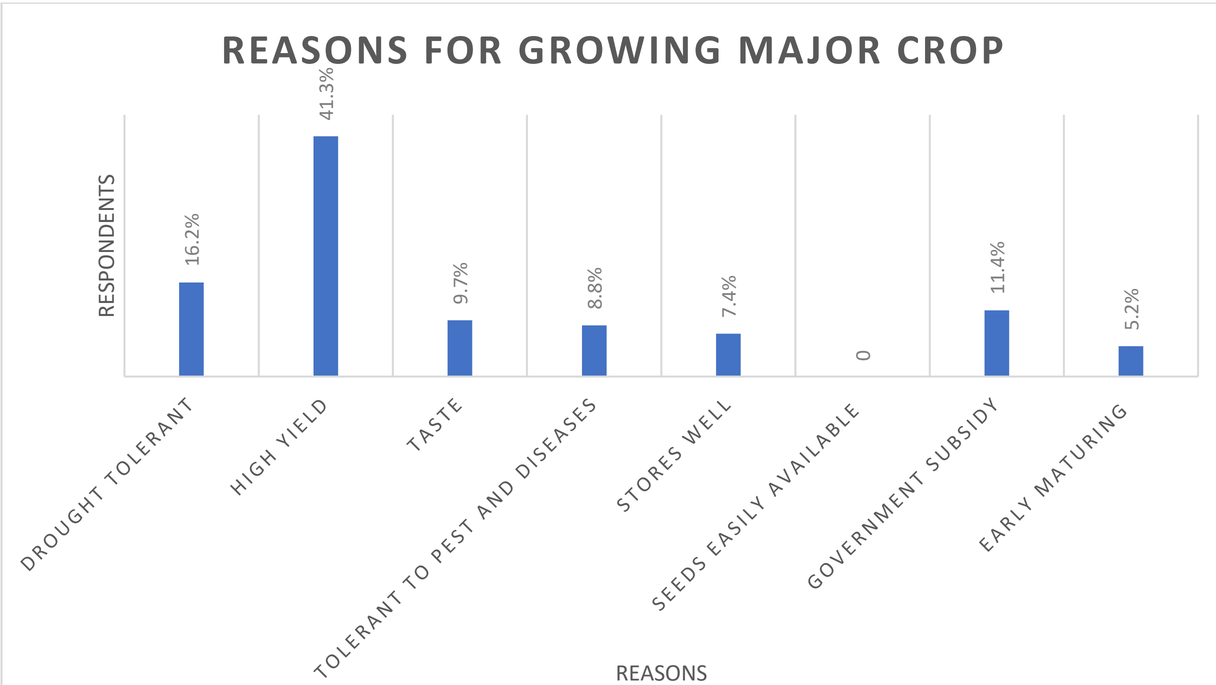
N=100

Figure 6. Diagram showing major crop species grown

4.3 What are Farmers' Most Important Characteristics of Crops Grown

This section focuses on seed security varietal suitability for SHFs in relation to the traits they prefer, characteristics important to them and adaptability in the local area. Farmers have varied reasons for choice of crop species and to large extent even varieties, for cultivation as shown in figure 7 below. The study showed that for the major crop for respondents, forty one percent (41.3%) indicated high yield as the reason for growing the major crop. But it's noticed that sixteen percent (16.2%) of the respondents also mentioned drought tolerant which indicate farmers do have priority for other crop characteristic of interest to them. This could be informed due to area observed to have one rainy season and with much long period of dry spells during the rainy season. Therefore, farmers will be conscious of how the crop will be able to withstand the dry spells.

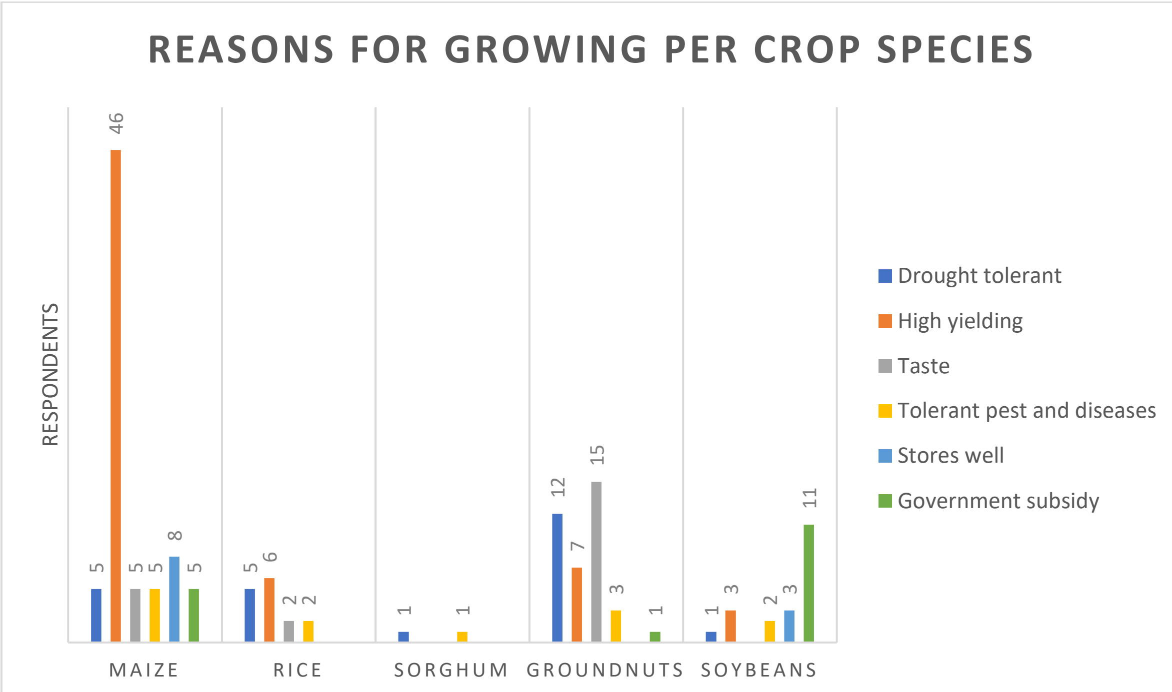
In the studies of Smale *et al*., (1995); Tura *et al.*, (2010) and Kudi *et al.*, (2011) they indicated that, the high positive yield potential observed of a crop will determine farmers use of that crop species.



N=100

Figure 7. Diagram showing reasons for growing major crop

In relation to reasons for growing crop species as shown in figure 8, it was realized that forty-six percent (46%) of the respondents indicate high yielding for maize. Maize is a major staple which is used for the “Touzafi” a local dish which serves as the main meal in the area for most households, which could drive this need. It can be realized that groundnuts having taste as the reason at fifteen percent (15%), could be attributed to fact that the crop is important for soup preparations. Soybeans having the reason as government subsidy at eleven (11%) is worth noting as seeds are gotten as support by farmers through the government subsidy programs or other NGOs support programs of making seeds available to farmers.



N=100

Figure 8. Diagram showing reasons for growing crop species

To further throw more light on farmer responses on preference, regression was done to test the relationship between major crop cultivated by SHFs and high yield as an important crop trait. I hypothesized that, high yield is most important trait for SHFs when cultivating major crop. The null hypothesis (H_0): High yield is not most important trait for SHFs when cultivating their major crop. With an alternate hypothesis (H_1): High yield is most important trait for SHFs when cultivating their major crop.

From the regression in Table 2 below, at the significance level 0.05 it can be observed that the model is statistically significant. This therefore presents evidence against H_0, which supports H_1. Therefore, there is positive influence between higher yield and major crops cultivated by SHFs from the sample. Therefore, the null hypothesis is rejected with the alternate hypothesis high yield is most important trait for SHFs when cultivating their major crop accepted. By further observing the coefficient (0.0640), when the coefficient is squared and multiplied by100, it shows the percentage contribution of the predictor variable. Therefore, the percentage contribution of the predictor variable is 36.48%. Thus, it indicates quite a high level of the high yield to the cultivation of major crop by SHFs.

Table 2. Bivariate regression analysis of major crop and higher yield as reason for cultivation

Variables **Dependent variable:** Major crop cultivated by SHFs	**Model 1** **Coef (s.e)**
Q 11. Higher yield as reason for major crop cultivated	0.6040** (0.1934)
Intercept	1.2176
N	100
R^2	0.08126
P value	0.00235

Signif. Codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ' ' 1

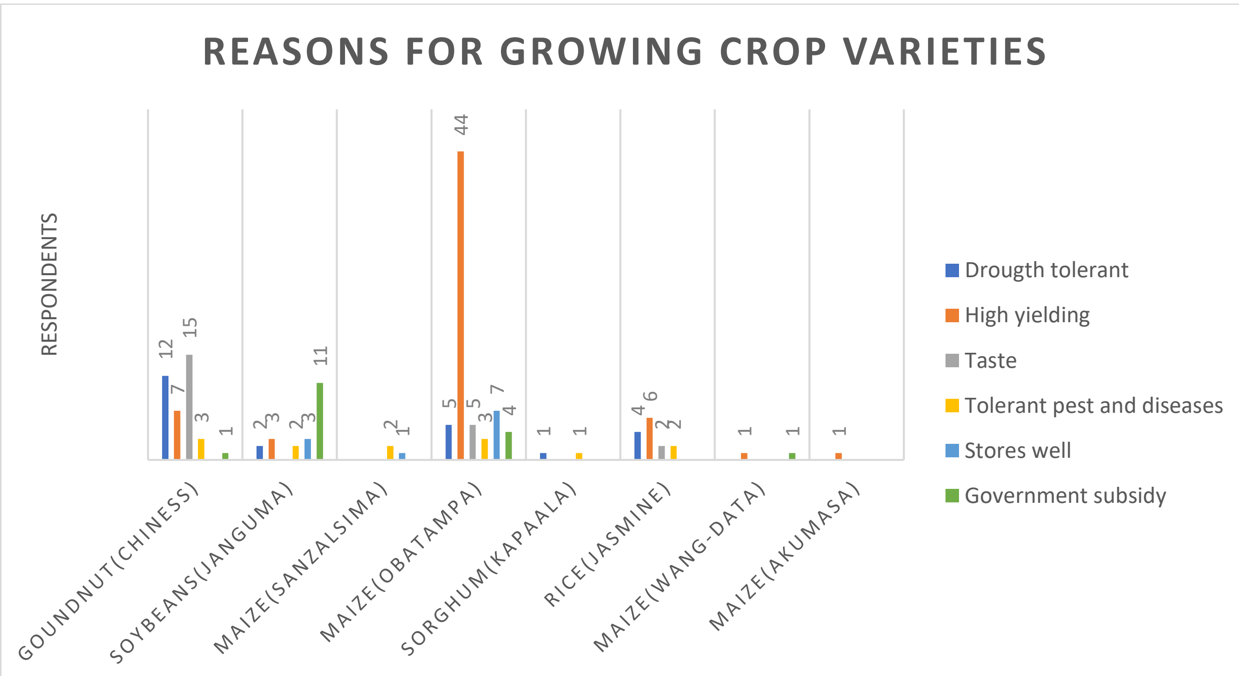
Model 1: $Y=\beta_0 + \beta_1 X_1$; $Y=1.2176+0.6040 X_1$

where Y is outcome dependent variable, β_0 *is intercept and* β_1 *is the slope,* X_1 *the explanatory independent variable*

Y= Major crop cultivated by SHFs

X_1*= Higher yield as reason for major crop cultivated*

From figure 9, it can be observed that for various crop species there are diverse reasons that account for farmers growing a variety. For the maize variety Obatampa an OPV, high yielding and drought tolerant at forty-four percent (44%) and seven percent (7%) respectively vis a vis the variety "Sanzalsima" also OPV as tolerant to drought at two percent (2). The maize variety Wang-data an OPV was mainly grown for the reason of government subsidy at one percent (1%). It should be stated that all these maize varieties are improved OPVs.



N=100

Figure 9. Diagram of reasons for growing crop varieties

4.4 Major Crop Characteristics Crop Breeders Work towards Improving at SARI

The study observed that breeders used elements Participatory Plant Breeding (PPB) before engaging in their activities. This afforded plant breeders to gather information based on the traits that are important to farmers for incorporation into breeding programmes. According to Louwaars *et al.*, (2013: p193), *"PPB using farmers' knowledge and capacities and their local varieties in* *crop improvement, offers opportunities to increases efficiency and effectiveness in breeding for diversity of farmers"* (Almekinders *et al*., 2007; Bishaw and Turner, 2007; Ceccarelli *et al.*, 2009)

As noted by a plant breeder,

"being scientist, you cannot just sit down and do your own work and get it to farmers, eventually what you do will have to be accepted".

It was noted by breeders that, farmers challenges captured during the PPB becomes the breeding objectives. Participatory breeding with linkages with farmers can not be overestimated to ensure sustained breeding activities and should be encouraged by breeders (Ceccarelli and Grando, 2007). According to, Douthwaite *et al.,* (2002) *"In a 'learning selection' model, developers interact closely with a self-selection group of interested end users and use their knowledge base to refine the initial design concept to the needs of the end user group"* (G.F. Sassenrath *et al*., (2008: p287).

The study also shows that, one of the major traits and characteristic of crops breeders work to improve is higher yield and as stated by a breeder;

"because every farmer in this area wants higher yield and that is the most important preference the farmer wants". Another breeder stated that;

"You know yields are low in this area, and therefore most farmers want to first and foremost increase their yields".

Seed policies targeted for Africa in the 1960's and 1970's was geared towards the development of high yielding varieties with investment in research critical for this move (Louwaars *et al.*, 2013). From the study it appears the situation remains the same as observed in the study area.

Other traits targeted were tolerant to the weather conditions in the area, the market preference, tolerant to pest and diseases, tolerant to drought, nutritional aspects and donor preference as well. As noted by a breeder;

"the climate here is changing and therefore farmers will also need varieties that can adopt to weather here for example, early maturing and drought tolerant species".

It was intriguing to note that breeders were also breeding to meet donor dictates as alluded by a breeder. But to what extent this really inure to farmers cannot be stated. It could be speculated that due to funding challenges as mentioned by breeders means once donors provide the funds, then breeders were bound to go by what they want regardless of it serving farmer's needs. A study by Etiwire *et al.*, (2013: p10) on analysis of the seed system in Ghana, pointed out to this, "*In fact, most varieties are developed with donor funds since government research fund allocation is mostly not forthcoming"*.

4.5 Breeders' Perceptions of Desirable Characteristics and Farmers Desirable Characteristics.

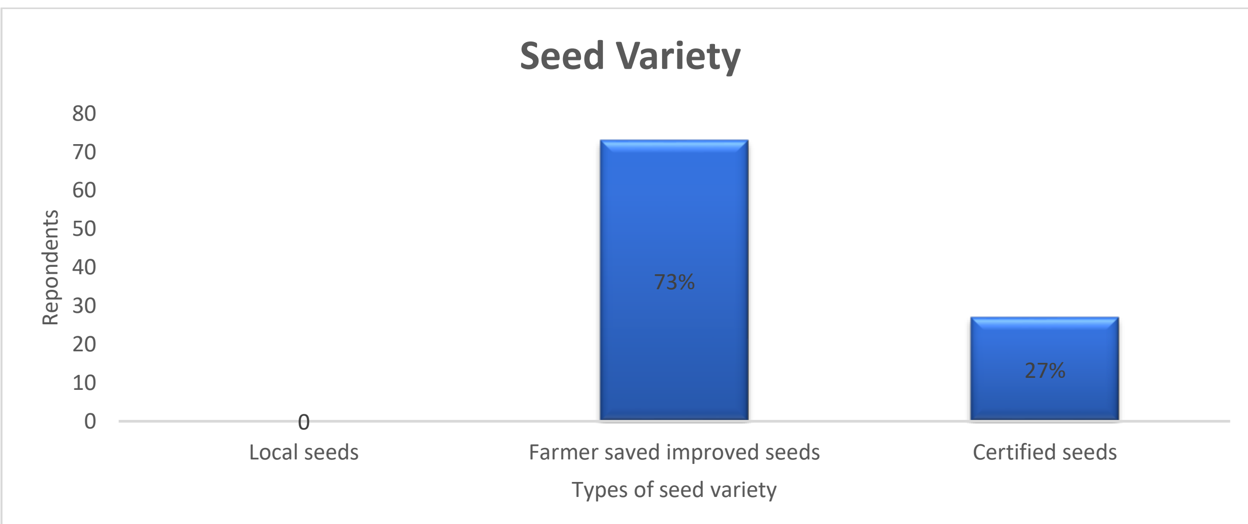
From the study there is efforts from the breeders' ends to ensure synergy of their perceptions to that of farmers characteristics. It should be noted that, these were in line with the policy goals of the seed policy of Ghana as envisaged in the policy document. Equally important worth mentioning was the fact that there appear to be alignment of the needs of farmers and the those of breeder's objectives.

All though it generally observed from the study that farmers need, and breeder's objectives are seemingly aligned. Although there is still low adoption of improved new seed crop varieties in the area. According to Pretty J. *et al*., (2011) in developing crop varieties, linkage with farmers through participatory methods were key in the process. They allude to the fact that, it is more important for orphan crops such as cassava, pigeon peas, orange fleshed sweet potatoes, tef and plantains which were neglected in past breeding activities (Pretty J. *et al*., 2011).

4.6 Seed Usage and the Determination of Major Problems/Barriers and Leverage points for SHFs Access to Quality Seeds for Seed Security

Seeds can be an important entry point for targeting productivity, nutritional improvement and agricultural resilience among many SHFs (McGuire and Sperling, 2016). Seeds in my opinion are regarded as the oracle of life and crucial for multiplication of crops and plants. Therefore, they are highly revered by farmers all around the globe and has high level of premium. Seeds transcends generations and are continually the life bone of farming to say the least. The access of seeds by farmers are not without challenges over the years.

Figure 10 below shows that from the sample, seventy three percent (73%) used farmer saved seeds while twenty seven percent (27%) used certified seeds for planting. It is observed that not more than five percent (5%) acquire quality certified seeds from approved dealers in Ghana (Ghana Seed Policy, 2013). Also, above eighty percent (80%) of farmers is observed also saves and reuse seeds from their own farms (Ghana Seed Policy, 2013). Also, Westengen and Brysting (2014) from studies pointed to the fact of most farmers in developing countries save and recycle seeds under the informal seeds system regime which has been practiced for long and still part of farmer practices. As noted also by Louwaars *et al.*, (2013), greater than eighty percent (80%) of seeds used by farmers in Africa is derived from the informal seed sector.



N=100

Figure 10. Diagram showing seed variety

From the study, it shows farmers did not use local seed varieties. This could be attributed to the fact that the study employed mainly the method of focusing on predominantly single crop analysis where these farmers are mainly maize farmers. This could therefore be further buttressed by the fact that, most of the maize varieties been used by farmers in the area are improved varieties and are only been recycled for use by farmers as the study points out.

Testing the statistical relationship between seed varietal adoption and SHFs participation in Farmer Field Schools (FFSs), it was hypothesized that more participation by SHFs in FFSs enhances certified seed adoption. The null hypothesis (H_0): More participation by SHFs in FFSs does not enhance certified seed adoption. With the alternate hypothesis (H_1): More participation in FFSs enhances certified seed adoption by SHFs.

From Table 3 below, the regression shows the relationship between seed variety adoption and SHFs participation in FFSs. The regression model 2 shows that, for every 1 unit level of increase in participation in FFSs, there is a positive increase of 0.07860 unit of seed varietal adoption. Observing the intercept of 2.17961, it shows that at no or zero participation in FFSs, SHFs use farmer saved seeds (the codes were 1 for local seed variety, 2 for farmer saved improved seed variety, 3 for certified seeds). The model shows that at the significance level of 0.05, it's statistically significant and therefore evidence to support H_1 against H_0. Therefore, H_0 will be rejected whilst H_1 is accepted. In that case, more participation in FFSs enhances certified seed adoption by SHFs.

Gerhart (1974), using the two-staged probit model for studying wheat and hybrid maize varieties and what factors affect adoption by farmers in western Kenya. Results from three hundred sixty (360) regarding age and farm size, it was negatively related and positively related respectively. In terms of farmer participation in trainings where agricultural technologies were demonstrated, there was positive relationship for farmer technology adoption.

But by observing the coefficient (0.07860), if it's squared and multiplied by100, it shows us the percentage contribution of predictor variable. Therefore, percentage contribution of the predictor (0.617%) indicate other factors will have much great influence on certified seed adoption than participation in FFS by SHFs.

Technological adoption for SHFs is influenced by differentiation in wealth and certain cultural factors (Jera and Ajayi, 2008; Kassie *et al.*, 2012). Adisa and Okunade (2005) alluded to fact that, the contribution of women is crucial in agricultural production sector in Africa and therefore efforts to facilitate their adoption of technologies should be enhanced.

Table 3. Bivariate regression analysis of seed variety and SHF participation in FFSs

Variables **Dependent variable: Seed variety**	**Model 2** **Coef (s.e)**
Q 17. Participation by SHFs in FFSs	0.07860* (0.03403)
Intercept	2.17961
N	100
R^2	0.04197
P value	0.023

Signif. Codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ' ' 1

Model 1: $Y=\beta_0 + \beta_1 X_1$; $Y=2.17961+0.07860X_1$

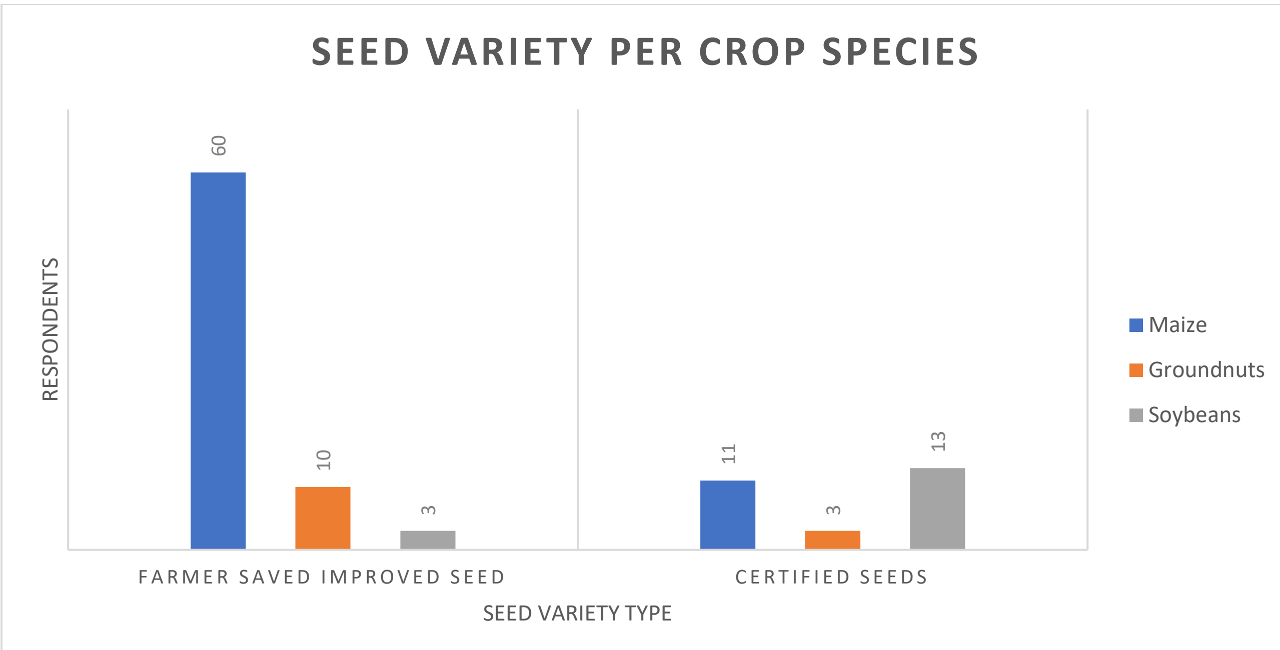
where Y is outcome dependent variable, β_0 *is intercept and* β_1 *is the slope,* X_1 *the explanatory independent variable*

Y= Seed variety

X_1*= Participation by SHFs in FFSs*

From Figure 11, the study also showed that majority of the farmers saved and recycle seeds for planting. Of the forty nine percent (49%) of respondents cropping maize, sixty (60%) used farmer saved improved seeds while eleven percent (11%) used certified seeds.

Westengen and Brysting (2014) presented findings to the fact that when it comes to maize, many farmers recycle and use improved varieties of maize for planting. This was the case observed in the study area in Ghana too. Currently most of the varieties of maize been cultivated by farmers are scientifically improved varieties. Of the twenty six percent (26%) of respondents cropping groundnuts, ten percent (10%) used farmer saved improved seeds while three percent (3%) used certified seeds. Of the thirteen percent (13%) of respondents cropping soybeans, three percent (3%) used farmer saved improved seeds while thirteen percent (13%) used certified seeds.

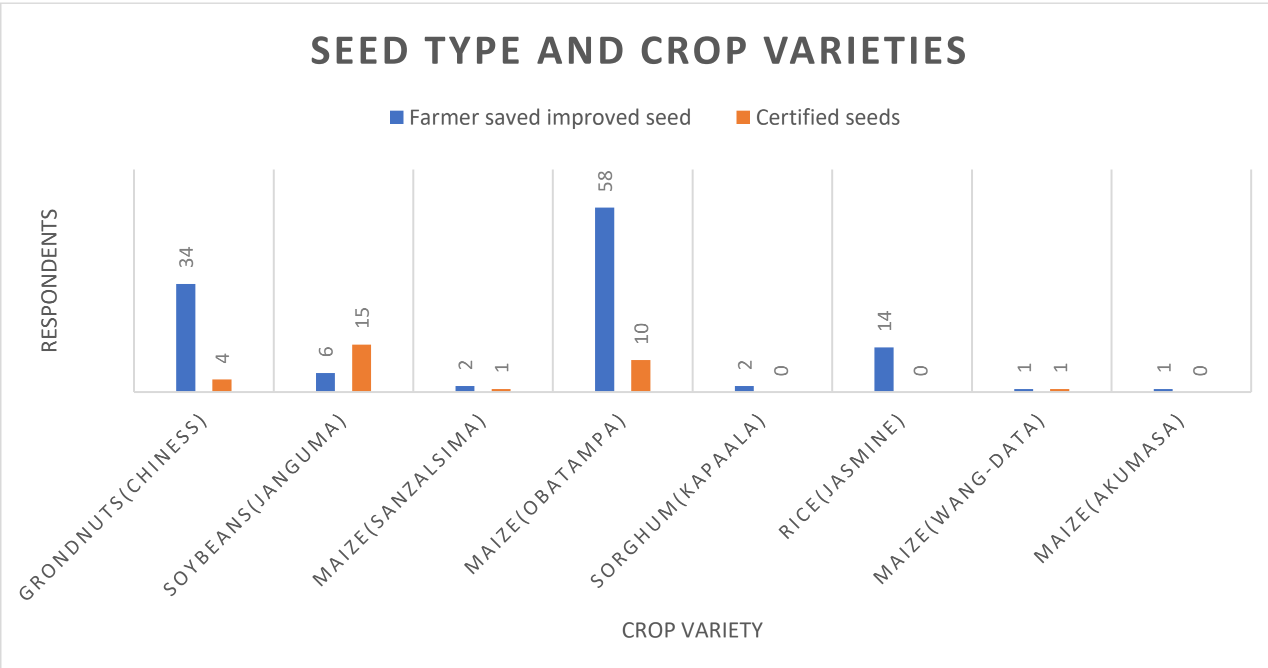


N=100

Figure 11. Diagram showing seed variety by crop species

In relation to seed variety and crop variety as shown in figure 12, for maize variety Obatampa an OPV farmers saved improved seed and certified seeds is represented as fifty-eight percent (58%) and ten percent (10%) respectively.

It was observed that for soybeans, farmer saved improved seeds was six percent (6%) while the use of certified seeds was fifteen percent (15%). It therefore shows that since soybean seeds was mainly gotten from government subsidy, the use of certified seeds was quite higher than the use of farmer saved. Farmers therefore may use more certified seeds depending on the source of seeds and the institutional arrangements put in place.

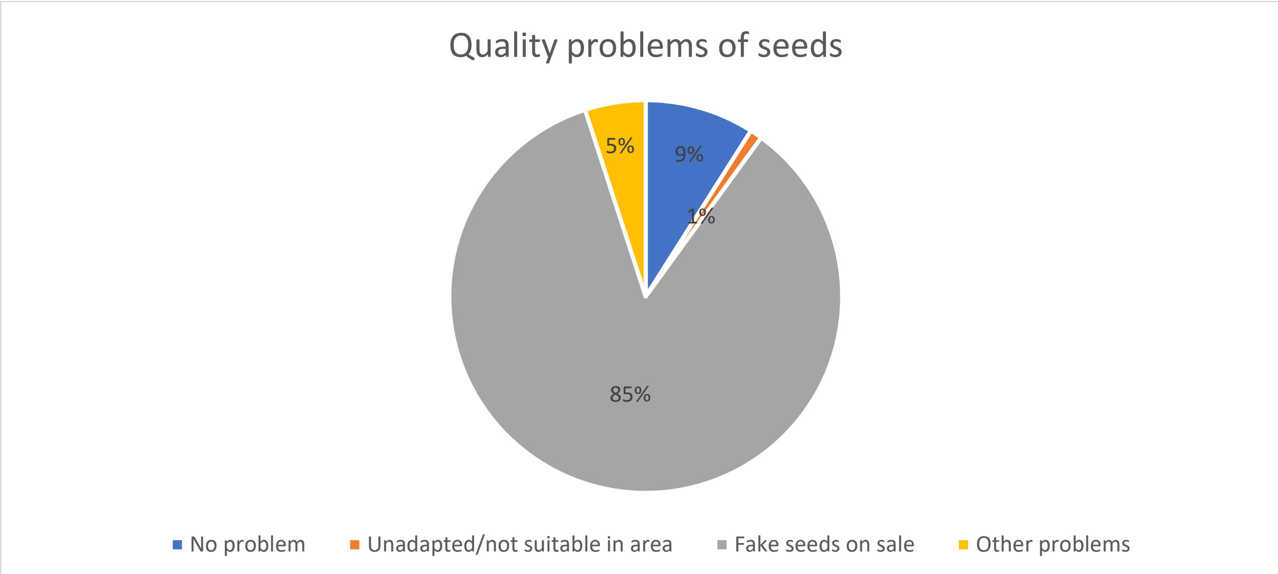


N=100

Figure 12. Diagram showing seed type by crop varieties

By way of presenting findings on seed security, identifying problems/barriers and areas for leverage for SHFs, the next section focuses on seed quality problems, availability problems, access problems and seed stability, the previous section dealt with varietal suitability in the light of farmer preferences, needs and traits important to SHFs.

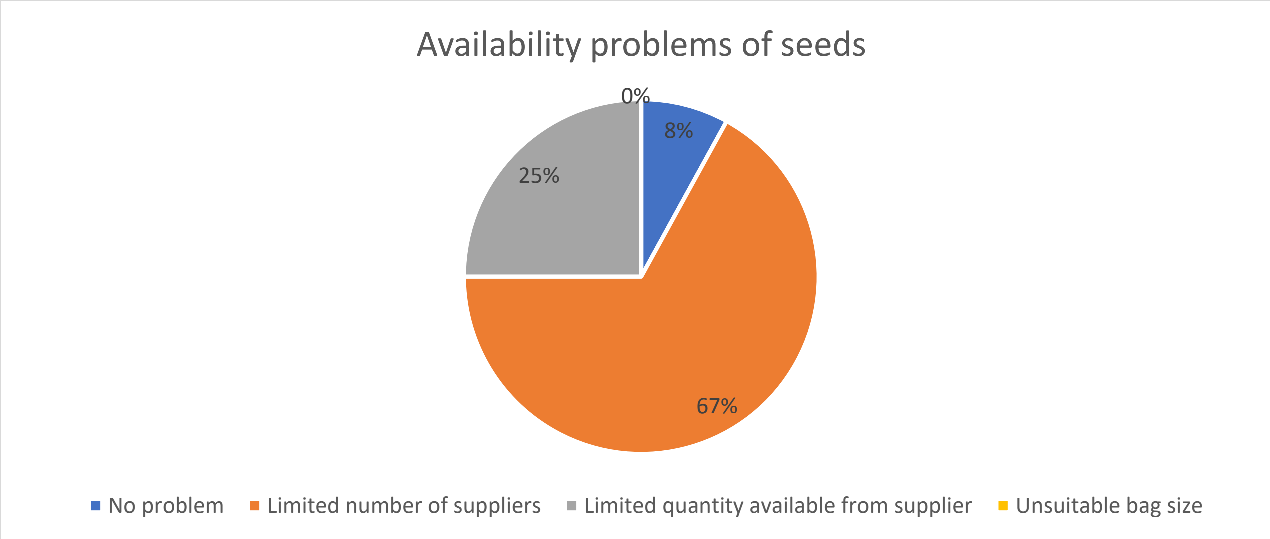
Figure 13 below shows quality problems of seed acquisition from the study. With eighty five percent (85%) of respondents indicating fake seeds on sale as major problem. It is therefore observed that, farmers in the past have been deceived by some input dealers and seeds growers in selling fake seeds to farmers. This is because of the weak monitoring systems put in place by Seed Inspectorate Division (SID) where seed growers are not effectively monitored. Some of these seed growers therefore sell grain to farmers as seed leading to poor germination. In those circumstances, farmers had to rebuy seeds to plant and this had a toll on their finances therefore, resulting in SHFs discouraged of the activities of these seed growers over the years.



N=100

Figure 13. Diagram showing quality problems of seeds

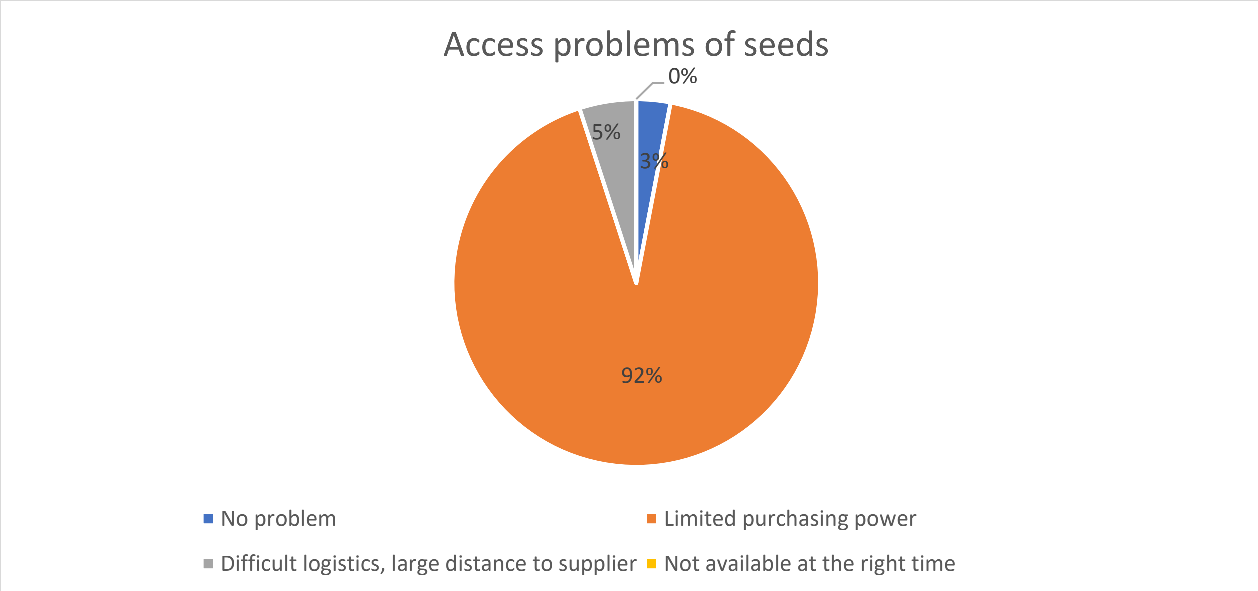
Figure 14 below shows availability problems of seeds. With sixty seven percent (67%) of respondents indicating limited number of suppliers as major problem. This therefore show the challenges that input dealers have in making seeds available to farmers. Most of seed these dealers have limited capacity to expand and therefore are not able to establish outlets in many communities to make their services accessible to farmers. They are mostly found to operate in the cities and in most instances are distanced from majority of SHFs farmers, excecated by poor road network.



N=100

Figure 14. Diagram showing availability problems of seeds

Figure 15 below shows access problems of seeds. With nine two percent (92%) of respondents indicating limited purchasing power as major problem for access to seeds. It can be observed that improved seeds because have under gone breeding is relatively costly. Therefore, most farmers indicate the lack of finance to buy these seeds. It was realized in the study that, in most cases farmers knew the benefits with improved seeds but, it was difficult to purchase improved seeds yearly every production season as high cost is a disincentive. But I do believe that, if farmers had the necessary capacity to conduct cost benefit analysis of the use of improved seeds which gives high yield verses the recycled seeds, there will have been more incentive for farmers to invest in acquiring improved seeds. For some other farmers, it's believed a major disincentive to the use of improved seeds is due to the additional agronomic practices it comes with by way of labour and inputs. They are therefore comfortable with using and recycling seeds as much additional agronomic practices might not be required. Another reason for low use of improved seeds could be dependence on particular farmer saved seed varieties due to sociocultural reasons.



N=100

Figure 15. Diagram showing access problems of seeds

Regarding seed stability, there are huge gaps when it comes to seeds. SARI has problems in relation to funds to work. There is also weak institutional processes and monitoring with SID on the activities of seeds growers and input dealers and with MoFA in engaging farmers. In 2011, the required amount by way of certified seeds was 22,500 tons for maize and 12,800 tons for rice. But the quantities that was produced were for maize only 4,600 tons which represents 20.4% while rice was 4,112 tons representing 21.7% (Ghana Seed Policy, 2013). It was observed that the situation was not different for other such soybeans, groundnuts, cowpeas and sorghum if even not worse. The production was at 0.93% for sorghum, 0.83% for cowpeas, 0.05% for groundnuts and 11% for soybeans (Ghana Seed Policy, 2013). This picture therefore, I believe does not seem to portray a much resilient seed stability and security for most SHFs in Ghana and may well be vulnerable.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

In conclusion, the needs of farmers in the selection of seeds for planting is influenced by peculiar circumstances in the area. The study showed that by way of livelihood characterization, ninety eight percent (98%) of respondents had farming as their main source of livelihood. The major crops cultivated were maize, groundnuts, soybeans, rice and sorghum representing forty nine percent (49%), twenty six percent (26%), thirteen percent (13%), ten percent (10%) and two percent (2%) respectively.

In relation to the kinds of crop varieties and the reasons for growing them, the study revealed forty one percent (41.3%) indicated high yield as the reason for growing the major crop. Whilst sixteen percent (16.2%) of the respondents also mentioned drought tolerant as an important reason. Majority of the farmers in the area save and reuse their own seeds from their farms than buying improved seeds or certified seeds. But farmers were inclined to accept and use certified if it was received from support from government subsidy programs or from other NGO support.

In evaluating if farmer perceptions/realities differ or agree with researchers at SARI, the study showed breeders ensured synergy of their perceptions to that of farmers characteristics by making conscious effort through PPB to incorporate farmers needs to their breeding objectives. Breeders were also breeding to meet donor dictates due to funding challenges from government and this raises issues as to whether those met farmers' needs. Bivariate regression showed statistical significance for major crop cultivated by SHFs and high yield. In the case of seed varietal adoption and participation in FFSs it was statistically significant for the sample as well.

Related to other seed security dimensions of quality, access and availability were, for quality problems eighty five percent (85%) of respondents indicating fake seeds on sale as major problem observed. On access problems, ninety two percent (92%) of respondents indicated limited purchasing power as major problem. Whilst on availability problems, sixty seven percent (67%) of respondents noted limited number of suppliers. On seed stability, there is huge gap for seeds and the seed sector or seed system security may be vulnerable for most SHFs in Ghana.

One critical observation I consider key to the enhancement of seed security sustainability for SHF in the area, is for local community seed initiatives such as community seed banking as indigenous way of seed storage serves as an important source of seeds for majority of farmers. These local seed storage and exchange mechanisms has been part of their socio-cultural way of life by preserving certain seeds which may possess peculiar characteristics, or which formal breeding may dilute or break those traits these farmers value. Such traits may also be very important at ensuring those seeds to have survived generations upon generations with these farmers. Another issue worth noting is, some forms of indigenous seed processing and preservation methods that SHFs have practiced over the years is critical area that further research is needed to focus. This knowledge will be important to contribute to seed system resilience especially for SHFs in sub-Saharan Africa.

By way of reflection, the study enabled me to appreciate the many challenges that seed system security presents especially for SHFs in sub-Saharan Africa. Some of the challenges observed to the slow development of the seed sector include; low investment in the sector, poor seed processing and poor quality assurance, inadequate extension to farmer ratio (1:1500) contributing to ineffective dissemination, limitation in needed quality human resource in the sectors in general, the actors in the value chain lacking requisite skills and investment coupled with lack of equipment, logistics and motivation for plant breeders are the bane of the seed sector in Ghana (Ghana Seed Policy, 2013). An issue that was also intriguing was the fact that, I did appreciate the funding challenges these breeders at SARI face that retards their work and will therefore need government intervention for sustained breeding activities.

Further reflection on the issues emanating and presented from the study, I therefore join the call for concerted efforts to ensure parallel effective running of both formal and informal seed sectors to ensure sustained seed security for agricultural development in the country. I believe much gains stand to be gained currently in Ghana based on present sociocultural and economic status of most farmers especially SHFs. I will like to state categorically my position that, the seed system security efforts will be suicidal and not achieving desired results if one sector is projected more than the other. To have the parallel seed sector running is our surest bet for the country.

It may be deduced from the study by way of environmental and poverty or food security implications of agriculture as main livelihood strategy that, farmers will need to seek to diversify livelihoods to continue to meet their food security needs. The government should engage stakeholders to develop a sustainable intensification blue print for SHFs to take advantage of it. This will also go a long way to specify the role that donors like AGRA, other large donor initiatives and private sector companies can play to improve seed system security for SHFs without possible conflicts of large private seed companies or donor priorities.

By way of sustainability of agronomic practices in the study area, some respondents indicated the problem of erosion or loss of soil fertility. The ineffective use of tractors as a major land tillage method could be contributing to soil erosion as this exposes the top soil. Government should empower MoFA to establish tractor service centers to train operators on effective or sustainable land tillage methods. This is important because if seed does not get a good soil bed, then germination and crop development will be challenged for the young plants.

Another problem is the fact that, most of these farmers do not know the nutrients lacking in their fields, so they don't buy the fertilizers that could be effective in improving these soils. This is because of the lack of nutrient testing which is still a big challenge for SHFs. The common practice of applying the same fertilizers across board year after year is a major challenge which need to be rectified. This calls for education on the importance on soil nutrient testing and for government to also ensure that research stations are equipped, and the cost of soil nutrient testing made affordable to ameliorate this challenge.

Some recommendations include;

- I suggested MoFA should liaise with the government to hold a national policy dialogue on seed security to ensure key players are brought together to deliberate on the future of sustainable seed systems for the country to align various priorities with national seed policy so as ensure its effective implementation.
- The government should make conscious efforts to resource SARI by way of funds for the effective discharge their mandate.
- There should be support for seed growers to expand to ensure there is enough quality seeds with support equal support with processing equipment, as many of the seed growers lack the necessary machinery resulting in difficult to deliver quality seeds.

- The community based local seed banks should be supported with technical capacity to ensure their effective seed delivery.
- SID should be equipped to effectively discharged their mandate of serving as watch dog for seed growers to ensure they work within the right environment to produce quality seeds for farmers and therefore clamp down on growers who do not work to meet certification standards.

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7.0 APPENDICES

7.1 Appendix 1: Questionnaire on the socio-ecological impact of new agricultural technologies among smallholder in Norther Region of Ghana.

This question is for academic purposes and will be used as such and your confidentiality is highly protected. Do you agree for the interview to proceed? Yes ☐ No ☐

Section A. Respondents characteristic and household information

1. Respondents age……………….
2. Sex Male ☐ Female ☐
3. Are you a household head? A. Yes: ☐ b. No ☐
4. Educational level of respondent? A. None ☐ b. Primary school ☐ c. Junior high school ☐ d. O`Level's ☐ e. Senior high school ☐ f. Diploma ☐ g. University degree ☐ h. Master's degree ☐

5. No. of household members? ……………….

6. What is the main occupation of household head…………………………………………………………..

Section B. Crop production and varietal preference

7. How many years have you been engaging in farming? A. 1-3yrs ☐ b: 3-5yrs ☐ c. 5-10yrs ☐ d. above 10yrs ☐
8. Which of these crops do you consider as your major crop past 5 cropping seasons? a. Maize ☐ b. Rice ☐ c. Pearl Millet ☐ d. Sorghum ☐ e. Groundnuts ☐ f. Cowpeas ☐ i. Soybean ☐ j. other…………………………………………………..
9. For the major crop produced last cropping season, which seed varieties did you use? a. Local variety ☐ b. Farmer saved improved variety ☐ c. Certified seeds ☐

11 Is higher yield in improved varieties a main reason for choosing this crop? A. Strongly agree ☐ b. Agree ☐ c. Somewhat agree ☐ d. Disagree ☐ e. Strongly disagree ☐

NB. After section B. Capture crops grown by completing the table in section F starting with major crop grown by farmer.

12 List other characteristics and attributes that you considered for each crops grown other than the options listed in CODE F2 in section F (Crop production/seed system)?...
....
....

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

Section C. Agricultural technology use and sources of access to knowledge

13 Which of these agricultural land tillage methods do you employ on your farm most production seasons the past 5 years? a. Zero tillage ☐ b. Use of hoe ☐ c: Use of bullocks ☐ d. Use of tractor ☐

14 Which of these fertilizers did you use in the last cropping season and mostly use on your farm? a. None ☐ b. Organic ☐ c. Chemical ☐ d. Organic and chemical ☐

15 Did you use pesticides on your farm last cropping season? a. Yes ☐ b. No ☐

16 Which of the following sources do you mostly learn agricultural technology from? A. Other farmers ☐ b. Extension officers ☐ c. Crop Scientist and Researchers ☐ d. Radio/TV ☐ e. Farmer Field schools ☐ .f. other sources ☐

17 How many times have you participated in farmer field schools where modern high yielding varieties demonstrated and coming into contact with crop scientist/extension agents in the last 5 production seasons? a. None ☐ b. 1 time ☐ c. 3 times ☐ d. 4 times ☐ e. 5 and above times ☐

18 Did you receive any agricultural extension officer/crop scientist on your farm in the last production year a. Yes ☐ b. No ☐

19 How close is a crop scientist/researcher to your community? A.0-1km ☐ b. 1-2km ☐ c. 2-3km ☐ d.3-5km ☐ e. Above 5 km ☐

20 How close is an agricultural extension officer to your community? A. 0-1km ☐ b. 1-2km ☐ c. 2-3km ☐ d.3-5km ☐ e. Above 5 km ☐

Section D. Agricultural assets and livelihoods

21 What is the household total farming land size for production? A. 1-2ha ☐ b. 3-4ha ☐ c: 5-6ha ☐ d. 7-8ha ☐ e. 9-10ha ☐ g. above 10ha ☐

22 What was the total area put under cultivation the last cropping season? a. 1-2ha ☐ b. 3-4ha ☐ c. 5-6ha ☐ d. 7-8ha ☐ e. 9-10ha ☐ f. Above 10ha ☐

10. What is number of active household labour engaged in farming?………………

23 Where do you mostly store your agricultural produce? A. Home storage in room ☐ b. Storage ban ☐ c. Community ware house ☐

24 Is storage for your agricultural produce a challenge? A. Yes ☐ b. No ☐

25 In which of these outlets do you sell your agricultural products? a. Traders in local market ☐ b. Farm gate ☐ c. Large aggregates in urban market ☐ d. Marketing company ☐

26 Do you have food available for the household all year round? A. Yes ☐ b. No ☐

27 Does your household own a tractor? a. Yes ☐ b. No ☐

28 Does your household own bullock and plough? A. Yes ☐ b. No ☐

29 Is marketing a challenge for your agricultural products? a. Always ☐ b. Sometimes ☐ c. Never ☐

30 Do you belong to farmer-based organization? A. Yes ☐ b. No ☐

31 Do you belong to village savings and loan scheme/credit scheme? A. Yes ☐ b. No ☐
32 Which of these category by way of cattle ownership do you belong? A. None ☐ b. 1-2 ☐ c. 3-4 ☐ d. 4-5 ☐ e. above 5 ☐
33 Which of these category by way small ruminants (goats & sheep) ownership do you belong? A. None ☐ b. 1-4 ☐ c. 5-10 ☐ d. 10-20 ☐ e. above 20 ☐

Section E. Level of knowledge of agro ecological changes

34 Have you observed any agro ecological changes over the past 5 production seasons in the area? A. Yes ☐ b. No ☐ c. Not sure ☐
35 If Yes, name any ………………………………………………………………………………………… ………………………………………………………………………………………… …………………………………………………………………………………
36 How will you describe the level of yields you have observed over the past 5 production seanos? A. Marginal increases ☐ b. High Increases ☐ c. Marginal decrease ☐ d. High decreases ☐ e. Not sure ☐

Thank you very much for your time in answering this questionnaire

Section F: Crop production / Seed System

F/1 37. What are the crops grown on your farm and in which season (Fill the table)

Crops (species)	**Variety name**	**Type of variety**			**Cropping system (Code F1)**	**Reason for growing the variety *CODE F2***	**Source of seed *CODE F3***	**Cost of seeds**	**Year fresh seed obtained lastly**	**Maturity period *CODE F4***	**Quality problems CODE F5**	**Availability problems CODE F6**	**Access problems CODE F7**
		Local	Farm Saved Improved	Certified									

7.2 Appendix 2: Interview guide for Crop Scientist

- What triggers the development new crop varieties
- What criteria are used in developing new crop varieties
- What criteria is used in promoting new crop variety
- In your opinion are social considerations and requirements guiding new varietal development and release
- Are there any agroecological considerations and requirements guiding the development and release of new crop varieties
- In your opinion what factors promote farmers adoption of new crop varieties
- In your opinion what barriers limit farmers adoption of new released crop varieties

7.3 Appendix 3: Variable code

Question	**Variable codes**
Q8. Which of these crops do you consider as your major crop past 5 cropping seasons?	a. Maize=1 b. Rice=2 c. Pearl Millet=2 d. Sorghum=4 e. Groundnuts=5 f. Cowpeas=6 i. Soybean=7
Q9. For the major crop produced last cropping season, which seed varieties did you use?	a. Traditional variety=1 b. Farmer saved improved variety=2 c. Certified seeds=3
Q 11. Is higher yield in improved varieties a main reason for choosing this crop?	a. Strongly agree=1 b. Agree=2 c. Somewhat agree=3 d. Disagree =4 e. Strongly disagree=5
Q. 17 How many times have you participated in farmer field schools where modern high yielding varieties demonstrated and coming into contact with crop scientist/extension agents in the last 5 production seasons?	a. None=0 b. 1 time=1 c. 3 times=2 d. 4 times=4 e. 5 and above times=5

7.4 Appendix 4: Regression Model 1 and 2

```
> RegModel.1 <- lm(Major_Crop~Higher.yield_reason.for.cultivation, data=Dataset2)

> summary(RegModel.1)

Call:
lm(formula = Major_Crop ~ Higher.yield_reason.for.cultivation,
    data = Dataset2)

Residuals:
    Min      1Q  Median      3Q     Max
-2.6337 -1.4256 -0.8216  1.5173  5.1784

Coefficients:
                                    Estimate Std. Error t value Pr(>|t|)
(Intercept)                           1.2176     0.4645   2.621  0.01016 *
Higher.yield_reason.for.cultivation   0.6040     0.1934   3.123  0.00235 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 2.29 on 98 degrees of freedom
Multiple R-squared:  0.09054,	Adjusted R-squared:  0.08126
F-statistic: 9.756 on 1 and 98 DF,  p-value: 0.002351
```

```
> RegModel.2 <- lm(Seed_Variety~Participation_FarmerField.schools, data=Dataset2)

> summary(RegModel.2)

Call:
lm(formula = Seed_Variety ~ Participation_FarmerField.schools,
    data = Dataset2)

Residuals:
    Min      1Q  Median      3Q     Max
-0.4940 -0.2582 -0.1796  0.5060  0.8204

Coefficients:
                                  Estimate Std. Error t value Pr(>|t|)
(Intercept)                        2.17961    0.05864   37.17   <2e-16 ***
Participation_FarmerField.schools  0.07860    0.03403    2.31    0.023 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.4367 on 98 degrees of freedom
Multiple R-squared:  0.05164,	Adjusted R-squared:  0.04197
F-statistic: 5.337 on 1 and 98 DF,  p-value: 0.02298
```

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